

Handbook of
Sustainability
and Sustainable Development



Allyssa Lee

First Edition, 2012

ISBN 978-81-323-1565-0

© All rights reserved.

Published by:

Learning Press

4735/22 Prakashdeep Bldg,

Ansari Road, Darya Ganj,

Delhi - 110002

Email: info@wtbooks.com

Table of Contents

Chapter 1 - Introduction to Sustainability

Chapter 2 - History of Sustainability

Chapter 3 - Sustainability Measurement

Chapter 4 - Carrying Capacity

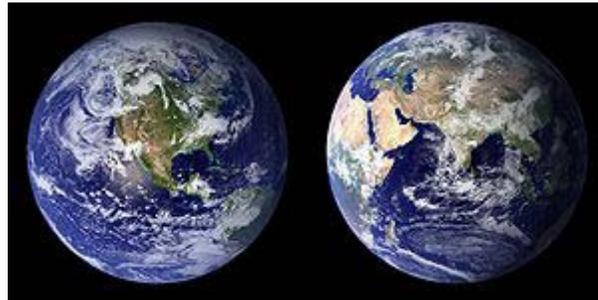
Chapter 5 - Sustainability and Environmental Management

Chapter 6 - Sustainable Energy

Chapter 7 - Sustainable Development

Chapter- 1

Introduction to Sustainability



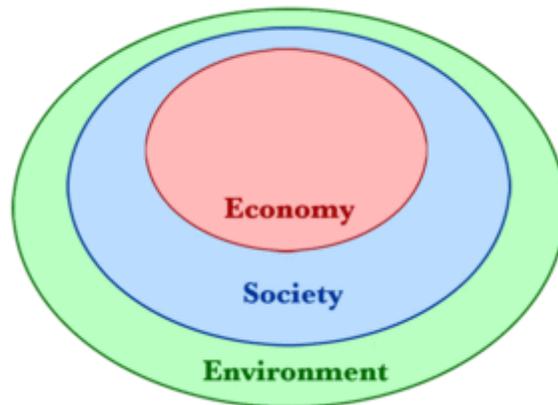
Achieving sustainability will enable the Earth to continue supporting human life as we know it. "Blue Marble" NASA composite images: 2001 (left), 2002 (right).

Sustainability is the capacity to endure. In ecology, the word describes how biological systems remain diverse and productive over time. Long-lived and healthy wetlands and forests are examples of sustainable biological systems. For humans, sustainability is the potential for long-term maintenance of well being, which has environmental, economic, and social dimensions.

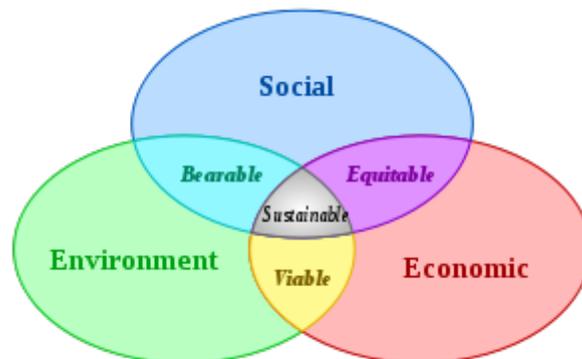
Healthy ecosystems and environments provide vital goods and services to humans and other organisms. There are two major ways of reducing negative human impact and enhancing ecosystem services. One approach is environmental management; this approach is based largely on information gained from earth science, environmental science, and conservation biology. Another approach is management of consumption of resources, which is based largely on information gained from economics.

Sustainability interfaces with economics through the social and ecological consequences of economic activity. Moving towards sustainability is also a social challenge that entails, among other factors, international and national law, urban planning and transport, local and individual lifestyles and ethical consumerism. Ways of living more sustainably can take many forms from reorganising living conditions (e.g., ecovillages, eco-municipalities and sustainable cities), reappraising economic sectors (permaculture, green building, sustainable agriculture), or work practices (sustainable architecture), using science to develop new technologies (green technologies, renewable energy, or new and affordable cost-effective practices) to make adjustments that conserve resources.

Definition



A diagram indicating the relationship between the three pillars of sustainability suggesting that both economy and society are constrained by environmental limits



Scheme of sustainable development: at the confluence of three constituent parts.

The word sustainability is derived from the Latin *sustinere* (*tenere*, to hold; *sus*, up). Dictionaries provide more than ten meanings for *sustain*, the main ones being to “maintain”, “support”, or “endure”. However, since the 1980s *sustainability* has been used more in the sense of human sustainability on planet Earth and this has resulted in the most widely quoted definition of sustainability and sustainable development, that of the Brundtland Commission of the United Nations on March 20, 1987: “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

At the 2005 World Summit it was noted that this requires the reconciliation of environmental, social and economic demands - the “three pillars” of sustainability. This view has been expressed as an illustration using three overlapping ellipses indicating that

the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing.

The UN definition is not universally accepted and has undergone various interpretations. What sustainability is, what its goals should be, and how these goals are to be achieved are all open to interpretation. For many environmentalists the idea of sustainable development is an oxymoron as development seems to entail environmental degradation. Ecological economist Herman Daly has asked, "what use is a sawmill without a forest?" From this perspective, the economy is a subsystem of human society, which is itself a subsystem of the biosphere, and a gain in one sector is a loss from another. This can be illustrated as three concentric circles.

A universally accepted definition of sustainability remains elusive because it is expected to achieve many things. On the one hand it needs to be factual and scientific, a clear statement of a specific "destination". The simple definition "sustainability is improving the quality of human life while living within the carrying capacity of supporting ecosystems", though vague, conveys the idea of sustainability having quantifiable limits. But sustainability is also a call to action, a task in progress or "journey" and therefore a political process, so some definitions set out common goals and values. The Earth Charter speaks of "a sustainable global society founded on respect for nature, universal human rights, economic justice, and a culture of peace."

To add complication the word *sustainability* is applied not only to human sustainability on Earth, but to many situations and contexts over many scales of space and time, from small local ones to the global balance of production and consumption. It can also refer to a future intention: "sustainable agriculture" is not necessarily a current situation but a goal for the future, a prediction. For all these reasons sustainability is perceived, at one extreme, as nothing more than a feel-good buzzword with little meaning or substance but, at the other, as an important but unfocused concept like "liberty" or "justice". It has also been described as a "dialogue of values that defies consensual definition".

Some researchers and institutions have pointed out that these three dimensions are not enough to reflect the complexity of contemporary society and suggest that culture could be included in this development model.

History

The history of sustainability traces human-dominated ecological systems from the earliest civilizations to the present. This history is characterized by the increased regional success of a particular society, followed by crises that were either resolved, producing sustainability, or not, leading to decline.

In early human history, the use of fire and desire for specific foods may have altered the natural composition of plant and animal communities. Between 8,000 and 10,000 years ago, Agrarian communities emerged which depended largely on their environment and the creation of a "structure of permanence."

The Western industrial revolution of the 17th to 19th centuries tapped into the vast growth potential of the energy in fossil fuels. Coal was used to power ever more efficient engines and later to generate electricity. Modern sanitation systems and advances in medicine protected large populations from disease. In the mid-20th century, a gathering environmental movement pointed out that there were environmental costs associated with the many material benefits that were now being enjoyed. In the late 20th century, environmental problems became global in scale. The 1973 and 1979 energy crises demonstrated the extent to which the global community had become dependent on non-renewable energy resources.

In the 21st century, there is increasing global awareness of the threat posed by the human-induced enhanced greenhouse effect, produced largely by forest clearing and the burning of fossil fuels.

Principles and concepts

The philosophical and analytic framework of sustainability draws on and connects with many different disciplines and fields; in recent years an area that has come to be called sustainability science has emerged. Sustainability science is not yet an autonomous field or discipline of its own, and has tended to be problem-driven and oriented towards guiding decision-making.

Scale and context

Sustainability is studied and managed over many scales (levels or frames of reference) of time and space and in many contexts of environmental, social and economic organization. The focus ranges from the total carrying capacity (sustainability) of planet Earth to the sustainability of economic sectors, ecosystems, countries, municipalities, neighbourhoods, home gardens, individual lives, individual goods and services, occupations, lifestyles, behaviour patterns and so on. In short, it can entail the full compass of biological and human activity or any part of it. As Daniel Botkin, author and environmentalist, has stated: "We see a landscape that is always in flux, changing over many scales of time and space."

Consumption — population, technology, resources

A major driver of human impact on Earth systems is the destruction of biophysical resources, and especially, the Earth's ecosystems. The total environmental impact of a community or of humankind as a whole depends both on population and impact per person, which in turn depends in complex ways on what resources are being used, whether or not those resources are renewable, and the scale of the human activity relative to the carrying capacity of the ecosystems involved. Careful resource management can be applied at many scales, from economic sectors like agriculture, manufacturing and industry, to work organizations, the consumption patterns of households and individuals and to the resource demands of individual goods and services.

One of the initial attempts to express human impact mathematically was developed in the 1970s and is called the I PAT formula. This formulation attempts to explain human consumption in terms of three components: population numbers, levels of consumption (which it terms "affluence", although the usage is different), and impact per unit of resource use (which is termed "technology", because this impact depends on the technology used). The equation is expressed:

$$I = P \times A \times T$$

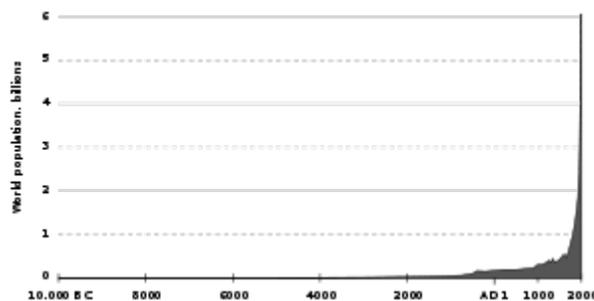
Where: I = Environmental impact, P = Population, A = Affluence, T = Technology

Measurement

Sustainability measurement is a term that denotes the measurements used as the quantitative basis for the informed management of sustainability. The metrics used for the measurement of sustainability (involving the sustainability of environmental, social and economic domains, both individually and in various combinations) are evolving: they include indicators, benchmarks, audits, indexes and accounting, as well as assessment, appraisal and other reporting systems. They are applied over a wide range of spatial and temporal scales.

Some of the best known and most widely used sustainability measures include corporate sustainability reporting, Triple Bottom Line accounting, World Sustainability Society and estimates of the quality of sustainability governance for individual countries using the Environmental Sustainability Index and Environmental Performance Index.

Population



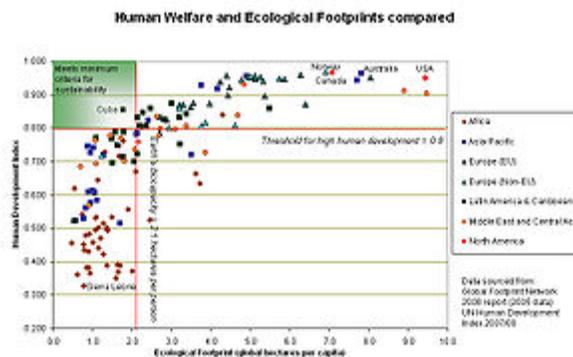
Graph showing human population growth from 10,000 BC – AD 2000, illustrating current exponential growth

According to the 2008 Revision of the official United Nations population estimates and projections, the world population is projected to reach 7 billion early in 2012, up from the current 6.9 billion (May 2009), to exceed 9 billion people by 2050. Most of the increase will be in developing countries whose population is projected to rise from 5.6 billion in 2009 to 7.9 billion in 2050. This increase will be distributed among the population aged

15–59 (1.2 billion) and 60 or over (1.1 billion) because the number of children under age 15 in developing countries is predicted to decrease. In contrast, the population of the more developed regions is expected to undergo only slight increase from 1.23 billion to 1.28 billion, and this would have declined to 1.15 billion but for a projected net migration from developing to developed countries, which is expected to average 2.4 million persons annually from 2009 to 2050. Long-term estimates of global population suggest a peak at around 2070 of nine to ten billion people, and then a slow decrease to 8.4 billion by 2100.

Emerging economies like those of China and India aspire to the living standards of the Western world as does the non-industrialized world in general. It is the combination of population increase in the developing world and unsustainable consumption levels in the developed world that poses a stark challenge to sustainability.

Carrying capacity



Ecological footprint for different nations compared to their Human Development Index (HDI)

More and more data are indicating that humans are not living within the carrying capacity of the planet. The Ecological footprint measures human consumption in terms of the biologically productive land needed to provide the resources, and absorb the wastes of the average global citizen. In 2008 it required 2.7 global hectares per person, 30% more than the natural biological capacity of 2.1 global hectares (assuming no provision for other organisms). The resulting ecological deficit must be met from unsustainable *extra* sources and these are obtained in three ways: embedded in the goods and services of world trade; taken from the past (e.g. fossil fuels); or borrowed from the future as unsustainable resource usage (e.g. by over exploiting forests and fisheries).

The figure (right) compares the sustainability of countries by contrasting their Ecological Footprint with their UN Human Development Index (a measure of standard of living). The graph shows what is necessary for countries to maintain an acceptable standard of living for their citizens while, at the same time, maintaining sustainable resource use. The general trend is for higher standards of living to become less sustainable. As always, population growth has a marked influence on levels of consumption and the efficiency of resource use. The sustainability goal is to raise the global standard of living without increasing the use of resources beyond globally sustainable levels; that is, to not exceed

"one planet" consumption. Information generated by reports at the national, regional and city scales confirm the global trend towards societies that are becoming less sustainable over time.

Global human impact on biodiversity

At a fundamental level energy flow and biogeochemical cycling set an upper limit on the number and mass of organisms in any ecosystem. Human impacts on the Earth are demonstrated in a general way through detrimental changes in the global biogeochemical cycles of chemicals that are critical to life, most notably those of water, oxygen, carbon, nitrogen and phosphorus.

The *Millennium Ecosystem Assessment* is an international synthesis by over 1000 of the world's leading biological scientists that analyses the state of the Earth's ecosystems and provides summaries and guidelines for decision-makers. It concludes that human activity is having a significant and escalating impact on the biodiversity of world ecosystems, reducing both their resilience and biocapacity. The report refers to natural systems as humanity's "life-support system", providing essential "ecosystem services". The assessment measures 24 ecosystem services concluding that only four have shown improvement over the last 50 years, 15 are in serious decline, and five are in a precarious condition.

Environmental dimension

Healthy ecosystems provide vital goods and services to humans and other organisms. There are two major ways of reducing negative human impact and enhancing ecosystem services and the first of these is environmental management. This direct approach is based largely on information gained from earth science, environmental science and conservation biology. However, this is management at the end of a long series of indirect causal factors that are initiated by human consumption, so a second approach is through demand management of human resource use.

Management of human consumption of resources is an indirect approach based largely on information gained from economics. Herman Daly has suggested three broad criteria for ecological sustainability: renewable resources should provide a sustainable yield (the rate of harvest should not exceed the rate of regeneration); for non-renewable resources there should be equivalent development of renewable substitutes; waste generation should not exceed the assimilative capacity of the environment.

Environmental management

At the global scale and in the broadest sense environmental management involves the oceans, freshwater systems, land and atmosphere, but following the sustainability principle of scale it can be equally applied to any ecosystem from a tropical rainforest to a home garden.

Atmosphere

In March 2009 at a meeting of the Copenhagen Climate Council, 2,500 climate experts from 80 countries issued a keynote statement that there is now "no excuse" for failing to act on global warming and that without strong carbon reduction targets "abrupt or irreversible" shifts in climate may occur that "will be very difficult for contemporary societies to cope with". Management of the global atmosphere now involves assessment of all aspects of the carbon cycle to identify opportunities to address human-induced climate change and this has become a major focus of scientific research because of the potential catastrophic effects on biodiversity and human communities.

Other human impacts on the atmosphere include the air pollution in cities, the pollutants including toxic chemicals like nitrogen oxides, sulfur oxides, volatile organic compounds and particulate matter that produce photochemical smog and acid rain, and the chlorofluorocarbons that degrade the ozone layer. Anthropogenic particulates such as sulfate aerosols in the atmosphere reduce the direct irradiance and reflectance (albedo) of the Earth's surface. Known as global dimming, the decrease is estimated to have been about 4% between 1960 and 1990 although the trend has subsequently reversed. Global dimming may have disturbed the global water cycle by reducing evaporation and rainfall in some areas. It also creates a cooling effect and this may have partially masked the effect of greenhouse gases on global warming.

Freshwater and Oceans

Water covers 71% of the Earth's surface. Of this, 97.5% is the salty water of the oceans and only 2.5% freshwater, most of which is locked up in the Antarctic ice sheet. The remaining freshwater is found in glaciers, lakes, rivers, wetlands, the soil, aquifers and atmosphere. Due to the water cycle, fresh water supply is continually replenished by precipitation, however there is still a limited amount necessitating management of this resource. Awareness of the global importance of preserving water for ecosystem services has only recently emerged as, during the 20th century, more than half the world's wetlands have been lost along with their valuable environmental services. Increasing urbanization pollutes clean water supplies and much of the world still does not have access to clean, safe water. Greater emphasis is now being placed on the improved management of blue (harvestable) and green (soil water available for plant use) water, and this applies at all scales of water management.

Ocean circulation patterns have a strong influence on climate and weather and, in turn, the food supply of both humans and other organisms. Scientists have warned of the possibility, under the influence of climate change, of a sudden alteration in circulation patterns of ocean currents that could drastically alter the climate in some regions of the globe. Ten per cent of the world's population – about 600 million people – live in low-lying areas vulnerable to sea level rise.

Land use



A rice paddy. Rice, wheat, corn and potatoes make up more than half the world's food supply.

Loss of biodiversity stems largely from the habitat loss and fragmentation produced by the human appropriation of land for development, forestry and agriculture as natural capital is progressively converted to man-made capital. Land use change is fundamental to the operations of the biosphere because alterations in the relative proportions of land dedicated to urbanisation, agriculture, forest, woodland, grassland and pasture have a marked effect on the global water, carbon and nitrogen biogeochemical cycles and this can impact negatively on both natural and human systems. At the local human scale, major sustainability benefits accrue from sustainable parks and gardens and green cities.

Since the Neolithic Revolution about 47% of the world's forests have been lost to human use. Present-day forests occupy about a quarter of the world's ice-free land with about half of these occurring in the tropics. In temperate and boreal regions forest area is gradually increasing (with the exception of Siberia), but deforestation in the tropics is of major concern.

Food is essential to life. Feeding more than six billion human bodies takes a heavy toll on the Earth's resources. This begins with the appropriation of about 38% of the Earth's land surface and about 20% of its net primary productivity. Added to this are the resource-hungry activities of industrial agribusiness – everything from the crop need for irrigation water, synthetic fertilizers and pesticides to the resource costs of food packaging, transport (now a major part of global trade) and retail. Environmental problems associated with industrial agriculture and agribusiness are now being addressed through such movements as sustainable agriculture, organic farming and more sustainable business practices.

Management of human consumption

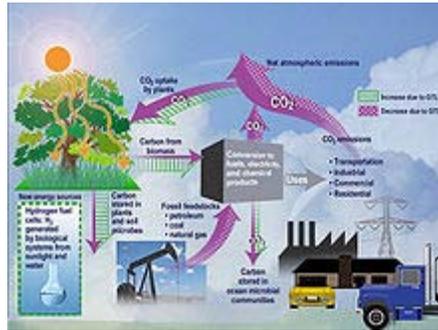


Helix of sustainability – the carbon cycle of manufacturing

The underlying driver of direct human impacts on the environment is human consumption. This impact is reduced by not only consuming less but by also making the full cycle of production, use and disposal more sustainable. Consumption of goods and services can be analysed and managed at all scales through the chain of consumption, starting with the effects of individual lifestyle choices and spending patterns, through to the resource demands of specific goods and services, the impacts of economic sectors, through national economies to the global economy. Analysis of consumption patterns relates resource use to the environmental, social and economic impacts at the scale or context under investigation. The ideas of embodied resource use (the total resources needed to produce a product or service), resource intensity, and resource productivity are important tools for understanding the impacts of consumption. Key resource categories relating to human needs are food, energy, materials and water.

In 2010, the International Resource Panel, hosted by the United Nations Environment Programme (UNEP), published the first global scientific assessment on the impacts of consumption and production and identified priority actions for developed and developing countries. The study found that the most critical impacts are related to ecosystem health, human health and resource depletion. From a production perspective, it found that fossil-fuel combusting processes, agriculture and fisheries have the most important impacts. Meanwhile, from a final consumption perspective, it found that household consumption related to mobility, shelter, food and energy-using products cause the majority of life-cycle impacts of consumption.

Energy



Flow of CO₂ in an ecosystem

The Sun's energy, stored by plants (primary producers) during photosynthesis, passes through the food chain to other organisms to ultimately power all living processes. Since the industrial revolution the concentrated energy of the Sun stored in fossilized plants as fossil fuels has been a major driver of technology which, in turn, has been the source of both economic and political power. In 2007 climate scientists of the IPCC concluded that there was at least a 90% probability that atmospheric increase in CO₂ was human-induced, mostly as a result of fossil fuel emissions but, to a lesser extent from changes in land use. Stabilizing the world's climate will require high-income countries to reduce their emissions by 60–90% over 2006 levels by 2050 which should hold CO₂ levels at 450–650 ppm from current levels of about 380 ppm. Above this level, temperatures could rise by more than 2°C to produce “catastrophic” climate change. Reduction of current CO₂ levels must be achieved against a background of global population increase and developing countries aspiring to energy-intensive high consumption Western lifestyles.

Reducing greenhouse emissions, is being tackled at all scales, ranging from tracking the passage of carbon through the carbon cycle to the commercialization of renewable energy, developing less carbon-hungry technology and transport systems and attempts by individuals to lead carbon neutral lifestyles by monitoring the fossil fuel use embodied in all the goods and services they use.

Water

Water security and food security are inextricably linked. In the decade 1951–60 human water withdrawals were four times greater than the previous decade. This rapid increase resulted from scientific and technological developments impacting through the economy – especially the increase in irrigated land, growth in industrial and power sectors, and intensive dam construction on all continents. This altered the water cycle of rivers and lakes, affected their water quality and had a significant impact on the global water cycle. Currently towards 35% of human water use is unsustainable, drawing on diminishing aquifers and reducing the flows of major rivers: this percentage is likely to increase if climate change impacts become more severe, populations increase, aquifers become progressively depleted and supplies become polluted and unsanitary. From 1961 to 2001

water demand doubled - agricultural use increased by 75%, industrial use by more than 200%, and domestic use more than 400%. In the 1990s it was estimated that humans were using 40–50% of the globally available freshwater in the approximate proportion of 70% for agriculture, 22% for industry, and 8% for domestic purposes with total use progressively increasing.

Water efficiency is being improved on a global scale by increased demand management, improved infrastructure, improved water productivity of agriculture, minimising the water intensity (embodied water) of goods and services, addressing shortages in the non-industrialised world, concentrating food production in areas of high productivity, and planning for climate change. At the local level, people are becoming more self-sufficient by harvesting rainwater and reducing use of mains water.

Food



Feijoada - A typical black bean food dish from Brazil

The American Public Health Association (APHA) defines a "sustainable food system" as "one that provides healthy food to meet current food needs while maintaining healthy ecosystems that can also provide food for generations to come with minimal negative impact to the environment. A sustainable food system also encourages local production and distribution infrastructures and makes nutritious food available, accessible, and affordable to all. Further, it is humane and just, protecting farmers and other workers, consumers, and communities." Concerns about the environmental impacts of agribusiness and the stark contrast between the obesity problems of the Western world and the poverty and food insecurity of the developing world have generated a strong movement towards healthy, sustainable eating as a major component of overall ethical consumerism. The environmental effects of different dietary patterns depend on many factors, including the proportion of animal and plant foods consumed and the method of food production. The World Health Organization has published a *Global Strategy on Diet, Physical Activity and Health* report which was endorsed by the May 2004 World Health Assembly. It recommends the Mediterranean diet which is associated with health and longevity and is low in meat, rich in fruits and vegetables, low in added sugar and limited salt, and low in saturated fatty acids; the traditional source of fat in the Mediterranean is olive oil, rich in monounsaturated fat. The healthy rice-based Japanese diet is also high in carbohydrates and low in fat. Both diets are low in meat and saturated fats and high in legumes and

other vegetables; they are associated with a low incidence of ailments and low environmental impact.

At the global level the environmental impact of agribusiness is being addressed through sustainable agriculture and organic farming. At the local level there are various movements working towards local food production, more productive use of urban wastelands and domestic gardens including permaculture, urban horticulture, local food, slow food, sustainable gardening, and organic gardening.

Sustainable seafood is seafood from either fished or farmed sources that can maintain or increase production in the future without jeopardizing the ecosystems from which it was acquired. The sustainable seafood movement has gained momentum as more people become aware about both overfishing and environmentally-destructive fishing methods.

Materials, toxic substances, waste



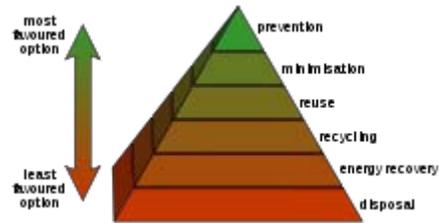
An electric wire reel reused as a center table in a Rio de Janeiro decoration fair. The reuse of materials is a very sustainable practice that is rapidly growing among designers in Brazil.

As global population and affluence has increased, so has the use of various materials increased in volume, diversity and distance transported. Included here are raw materials, minerals, synthetic chemicals (including hazardous substances), manufactured products, food, living organisms and waste.

Sustainable use of materials has targeted the idea of dematerialization, converting the linear path of materials (extraction, use, disposal in landfill) to a circular material flow that reuses materials as much as possible, much like the cycling and reuse of waste in nature. This approach is supported by product stewardship and the increasing use of material flow analysis at all levels, especially individual countries and the global economy.

Synthetic chemical production has escalated following the stimulus it received during the second World War. Chemical production includes everything from herbicides, pesticides and fertilizers to domestic chemicals and hazardous substances. Apart from the build-up of greenhouse gas emissions in the atmosphere, chemicals of particular concern include:

heavy metals, nuclear waste, chlorofluorocarbons, persistent organic pollutants and all harmful chemicals capable of bioaccumulation. Although most synthetic chemicals are harmless there needs to be rigorous testing of new chemicals, in all countries, for adverse environmental and health effects. International legislation has been established to deal with the global distribution and management of dangerous goods.



The waste hierarchy

Every economic activity produces material that can be classified as waste. To reduce waste industry, business and government are now mimicking nature by turning the waste produced by industrial metabolism into resource. Dematerialization is being encouraged through the ideas of industrial ecology, ecodesign and ecolabelling. In addition to the well-established “reduce, reuse and recycle” shoppers are using their purchasing power for ethical consumerism.

Economic dimension



The *Great Fish Market*, painted by Jan Brueghel the Elder

On one account, sustainability "concerns the specification of a set of actions to be taken by present persons that will not diminish the prospects of future persons to enjoy levels of consumption, wealth, utility, or welfare comparable to those enjoyed by present persons." Sustainability interfaces with economics through the social and ecological consequences of economic activity. Sustainability economics represents: "... a broad interpretation of ecological economics where environmental and ecological variables and issues are basic but part of a multidimensional perspective. Social, cultural, health-related and monetary/financial aspects have to be integrated into the analysis." However, the concept of sustainability is much broader than the concepts of sustained yield of welfare, resources, or profit margins. At present, the average per capita consumption of people in the developing world is sustainable but population numbers are increasing and

individuals are aspiring to high-consumption Western lifestyles. The developed world population is only increasing slightly but consumption levels are unsustainable. The challenge for sustainability is to curb and manage Western consumption while raising the standard of living of the developing world without increasing its resource use and environmental impact. This must be done by using strategies and technology that break the link between, on the one hand, economic growth and on the other, environmental damage and resource depletion.

In addressing this issue several key areas have been targeted for economic analysis and reform: the environmental effects of unconstrained economic growth; the consequences of nature being treated as an economic externality; and the possibility of an economics that takes greater account of the social and environmental consequences of market behaviour.

Decoupling environmental degradation and economic growth



International Recycle Symbol

Historically there has been a close correlation between economic growth and environmental degradation: as communities grow, so the environment declines. This trend is clearly demonstrated on graphs of human population numbers, economic growth, and environmental indicators. Unsustainable economic growth has been starkly compared to the malignant growth of a cancer because it eats away at the Earth's ecosystem services which are its life-support system. There is concern that, unless resource use is checked, modern global civilization will follow the path of ancient civilizations that collapsed through overexploitation of their resource base. While conventional economics is concerned largely with economic growth and the efficient allocation of resources, ecological economics has the explicit goal of sustainable scale (rather than continual growth), fair distribution and efficient allocation, in that order. The World Business Council for Sustainable Development states that "business cannot succeed in societies that fail".

In economic and environmental fields, the term decoupling is becoming increasingly used in the context of economic production and environmental quality. When used in this way, it refers to the ability of an economy to grow without incurring corresponding increases in environmental pressure. An economy that is able to sustain GDP growth without having a negative impact on the environment is said to be decoupled. Exactly how, if, or to what extent this can be achieved is a subject of much debate. In 2011 the International Resource Panel, hosted by the United Nations Environment Programme (UNEP), warned

that by 2050 the human race could be devouring 140 billion tons of minerals, ores, fossil fuels and biomass per year – three times its current rate of consumption – unless nations can make serious attempts at decoupling. The report noted that citizens of developed countries consume an average of 16 tons of those four key resources per capita per annum (ranging up to 40 or more tons per person in some developed countries). By comparison, the average person in India today consumes four tons per year. Sustainability studies analyse ways to reduce resource intensity (the amount of resource (e.g. water, energy, or materials) needed for the production, consumption and disposal of a unit of good or service) whether this be achieved from improved economic management, product design, or new technology. Ecological economics includes the study of societal metabolism, the throughput of resources that enter and exit the economic system in relation to environmental quality.

Nature as an economic externality



Deforestation of native rain forest in Rio de Janeiro City for extraction of clay for civil engineering (2009 picture)

The economic importance of nature is indicated by the use of the expression ecosystem services to highlight the market relevance of an increasingly scarce natural world that can no longer be regarded as both unlimited and free. In general, as a commodity or service becomes more scarce the price increases and this acts as a restraint that encourages frugality, technical innovation and alternative products. However, this only applies when the product or service falls within the market system. As ecosystem services are generally treated as economic externalities they are unpriced and therefore overused and degraded, a situation sometimes referred to as the Tragedy of the Commons.

One approach to this dilemma has been the attempt to "internalise" these "externalities" by using market strategies like ecotaxes and incentives, tradeable permits for carbon, and the encouragement of payment for ecosystem services. Community currencies associated with Local Exchange Trading Systems (LETS), a gift economy and Time Banking have also been promoted as a way of supporting local economies and the environment. Green economics is another market-based attempt to address issues of equity and the

environment. The global recession and a range of associated government policies are likely to bring the biggest annual fall in the world's carbon dioxide emissions in 40 years.

Economic opportunity

Treating the environment as an externality may generate short-term profit at the expense of sustainability. Sustainable business practices, on the other hand, integrate ecological concerns with social and economic ones (i.e., the triple bottom line). Growth that depletes ecosystem services is sometimes termed "uneconomic growth" as it leads to a decline in quality of life. Minimising such growth can provide opportunities for local businesses. For example, industrial waste can be treated as an "economic resource in the wrong place". The benefits of waste reduction include savings from disposal costs, fewer environmental penalties, and reduced liability insurance. This may lead to increased market share due to an improved public image. Energy efficiency can also increase profits by reducing costs.

The idea of sustainability as a business opportunity has led to the formation of organizations such as the Sustainability Consortium of the Society for Organizational Learning, the Sustainable Business Institute, and the World Council for Sustainable Development. Research focusing on progressive corporate leaders who have embedded sustainability into commercial strategy has yielded a leadership competency model for sustainability. The expansion of sustainable business opportunities can contribute to job creation through the introduction of green-collar workers.

Social dimension

Sustainability issues are generally expressed in scientific and environmental terms, but implementing change is a social challenge that entails, among other things, international and national law, urban planning and transport, local and individual lifestyles and ethical consumerism. "The relationship between human rights and human development, corporate power and environmental justice, global poverty and citizen action, suggest that responsible global citizenship is an inescapable element of what may at first glance seem to be simply matters of personal consumer and moral choice."

Peace, security, social justice

Social disruptions like war, crime and corruption divert resources from areas of greatest human need, damage the capacity of societies to plan for the future, and generally threaten human well-being and the environment. Broad-based strategies for more sustainable social systems include: improved education and the political empowerment of women, especially in developing countries; greater regard for social justice, notably equity between rich and poor both within and between countries; and intergenerational equity. Depletion of natural resources including fresh water increases the likelihood of "resource wars". This aspect of sustainability has been referred to as environmental security and creates a clear need for global environmental agreements to manage

resources such as aquifers and rivers which span political boundaries, and to protect shared global systems including oceans and the atmosphere.

Sustainability and Poverty

A major hurdle to achieve sustainability is the alleviation of poverty. It has been widely acknowledged that poverty is one source of environmental degradation. Such acknowledgment has been made by the Brundtland Commission report *Our Common Future* and the Millennium Development Goals. According to the Brundtland report, “poverty is a major cause and effect of global environmental problems. It is therefore futile to attempt to deal with environmental problems without a broader perspective that encompasses the factors underlying world poverty and international inequality.” Individuals living in poverty then to rely heavily on their local ecosystem as a source for basic needs (such as nutrition and medicine) and general well-being. As population growth continues to increase, increasing pressure is being placed on the local ecosystem to provide these basic essentials. According to the UN Population Fund, high fertility and poverty have been strongly correlated, and the world’s poorest countries also have the highest fertility and population growth rates.

Human relationship to nature

According to Murray Bookchin, the idea that humans must dominate nature is common in hierarchical societies. Bookchin contends that capitalism and market relationships, if unchecked, have the capacity to reduce the planet to a mere resource to be exploited. Nature is thus treated as a commodity: “The plundering of the human spirit by the market place is paralleled by the plundering of the earth by capital.” Still more basically, Bookchin argued that most of the activities that consume energy and destroy the environment are senseless because they contribute little to quality of life and well being. The function of work is to legitimize, even create, hierarchy. For this reason understanding the transformation of organic into hierarchical societies is crucial to finding a way forward.

Social ecology, founded by Bookchin, is based on the conviction that nearly all of humanity's present ecological problems originate in, indeed are mere symptoms of, dysfunctional social arrangements. Whereas most authors proceed as if our ecological problems can be fixed by implementing recommendations which stem from physical, biological, economic etc., studies, Bookchin's claim is that these problems can only be resolved by understanding the underlying social processes and intervening in those processes by applying the concepts and methods of the social sciences.

Deep ecology establishes principles for the well-being of all life on Earth and the richness and diversity of life forms. This requires a substantial decrease in human population and consumption along with the reduction of human interference with the nonhuman world. To achieve this, deep ecologists advocate policies for basic economic, technological, and ideological structures that will improve the *quality of life* rather than the *standard of*

living. Those who subscribe to these principles are obliged to make the necessary change happen.

Human settlements

Sustainability principles

1. Reduce dependence upon fossil fuels, underground metals, and minerals
2. Reduce dependence upon synthetic chemicals and other unnatural substances
3. Reduce encroachment upon nature
4. Meet human needs fairly & efficiently

One approach to sustainable living, exemplified by small-scale urban transition towns and rural ecovillages, seeks to create self-reliant communities based on principles of simple living, which maximise self-sufficiency particularly in food production. These principles, on a broader scale, underpin the concept of a bioregional economy. Other approaches, loosely based around new urbanism, are successfully reducing environmental impacts by altering the built environment to create and preserve sustainable cities which support sustainable transport. Residents in compact urban neighbourhoods drive fewer miles, and have significantly lower environmental impacts across a range of measures, compared with those living in sprawling suburbs.

Ultimately, the degree of human progress towards sustainability will depend on large scale social movements which influence both community choices and the built environment. Eco-municipalities may be one such movement. Eco-municipalities take a systems approach, based on sustainability principles. The eco-municipality movement is participatory, involving community members in a bottom-up approach. In Sweden, more than 70 cities and towns—25 per cent of all municipalities in the country—have adopted a common set of "Sustainability Principles" and implemented these systematically throughout their municipal operations. There are now twelve eco-municipalities in the United States and the American Planning Association has adopted sustainability objectives based on the same principles.

There is a wealth of advice available to individuals wishing to reduce their personal impact on the environment through small, inexpensive and easily achievable steps. But the transition required to reduce global human consumption to within sustainable limits involves much larger changes, at all levels and contexts of society. The United Nations has recognised the central role of education, and have declared a decade of education for sustainable development, 2005–2014, which aims to "challenge us all to adopt new behaviours and practices to secure our future". The Worldwide Fund for Nature proposes a strategy for sustainability that goes beyond education to tackle underlying individualistic and materialistic societal values head-on and strengthen people's connections with the natural world.

Chapter- 2

History of Sustainability

The **history of sustainability** traces human-dominated ecological systems from the earliest civilizations to the present. This history is characterized by the increased regional success of a particular society, followed by crises that were either resolved, producing sustainability, or not, leading to decline.

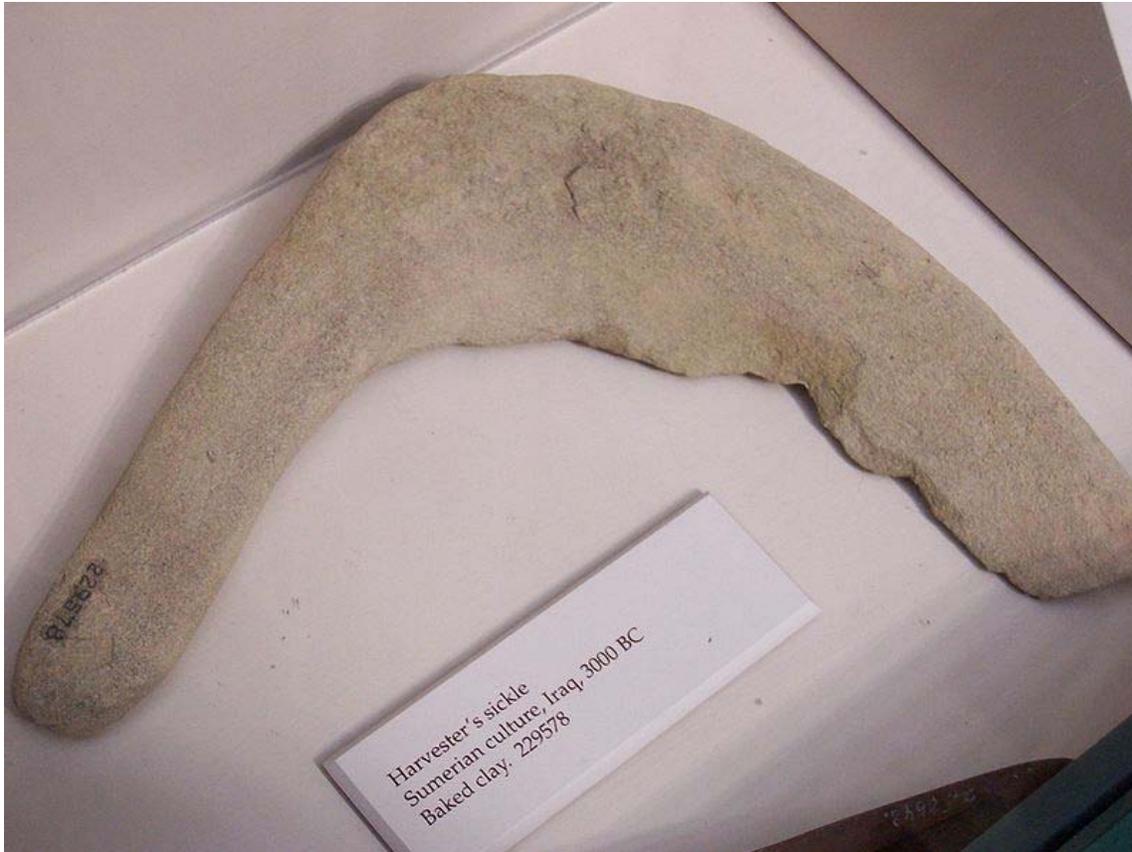
In early human history, the use of fire and desire for specific foods may have altered the natural composition of plant and animal communities. Between 8,000 and 10,000 years ago, Agrarian communities emerged which depended largely on their environment and the creation of a "structure of permanence."

The Western industrial revolution of the 17th to 19th centuries tapped into the vast growth potential of the energy in fossil fuels. Coal was used to power ever more efficient engines and later to generate electricity. Modern sanitation systems and advances in medicine protected large populations from disease. In the mid-20th century, a gathering environmental movement pointed out that there were environmental costs associated with the many material benefits that were now being enjoyed. In the late 20th century, environmental problems became global in scale. The 1973 and 1979 energy crises demonstrated the extent to which the global community had become dependent on non-renewable energy resources.

In the 21st century, there is increasing global awareness of the threat posed by the human-induced enhanced greenhouse effect, produced largely by forest clearing and the burning of fossil fuels.

Early civilizations

In early human history, although the energy and other resource demands of nomadic hunter-gatherers was small, the use of fire and desire for specific foods may have altered the natural composition of plant and animal communities. Between 8,000 and 10,000 years ago, agriculture emerged in various regions of the world. Agrarian communities depended largely on their environment and the creation of a "structure of permanence." Societies outgrowing their local food supply or depleting critical resources either moved on or faced collapse.

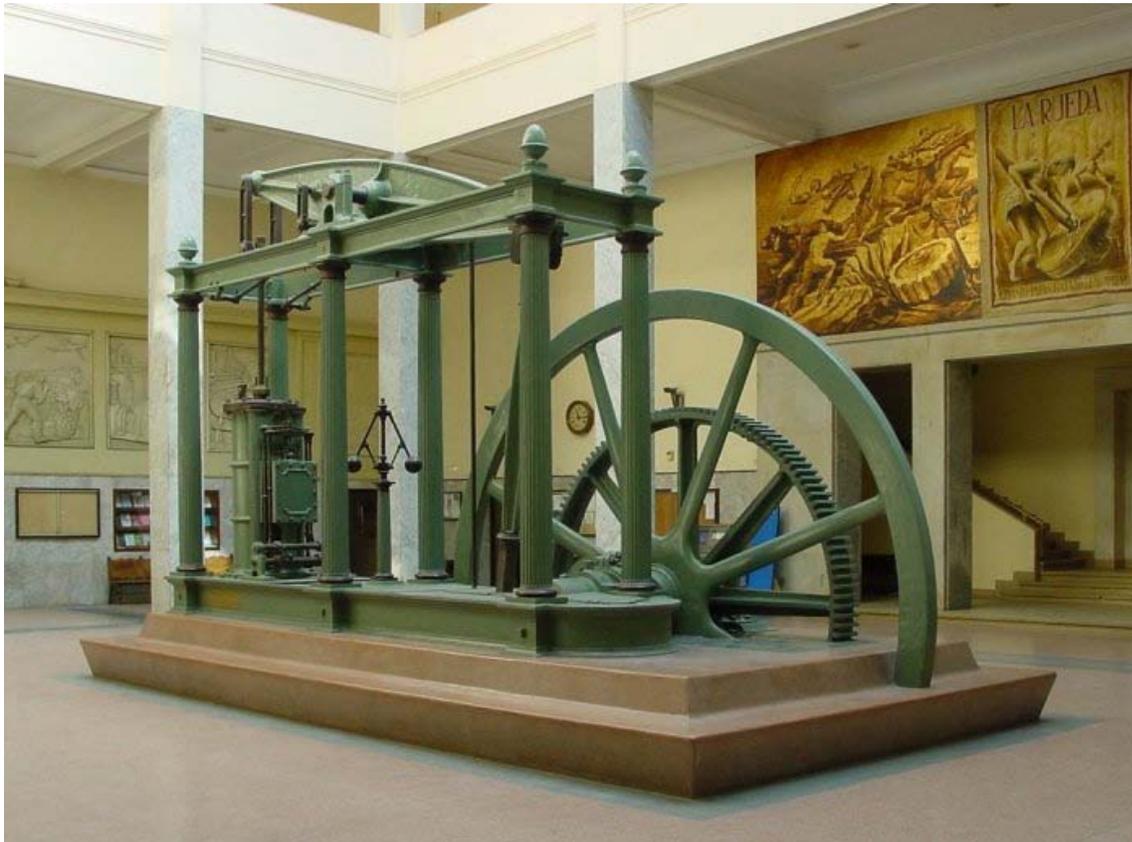


Sumerian harvester's sickle, 3000 BC, made from baked clay

Archeological evidence suggests that the first civilizations arose in Sumer, in southern Mesopotamia (now Iraq) and Egypt, both dating from around 3000 BCE. By 1000 BCE, civilizations were also established in India, China, Mexico, Peru and in parts of Europe. Sumer illustrates issues central to the sustainability of human civilization. Sumerian cities practised intensive, year-round agriculture from ca. 5300 BCE. The surplus of storable food created by this economy allowed the population to settle in one place instead of migrating in search of wild foods and grazing land. It also allowed for a much greater population density. The development of agriculture in Mesopotamia required many labourers to build and maintain its irrigation system. This, in turn, led to political hierarchy, bureaucracy, and religious sanction, along with standing armies to protect the emergent civilization. Intensified agriculture allowed for population increase, but also led to deforestation in upstream areas with resultant flooding and over-irrigation, which raised soil salinity. While there was a shift from the cultivation of wheat to the more salt-tolerant barley, yields still diminished. Eventually, decreasing agricultural production and other factors led to the decline of the civilization. From 2100 BC to 1700 BC, it is estimated that the population was reduced by nearly sixty percent. Civilizations similarly thought to have eventually fallen because of poor management of resources include the Mayans, Anasazi and Easter Islanders, among many others. In contrast, stable communities of shifting cultivators and horticulturists existed in New Guinea and South America, and large agrarian communities in China, India and elsewhere have farmed in

the same localities for centuries. Some Polynesian cultures have maintained stable communities for between 1,000 and 3,000 years on small islands with minimal resources using rahui and kaitiakitanga to control human pressure on the environment. In Sri Lanka nature reserves established during the reign of king Devanampiyatissa and dating back to 307 BC were devoted to sustainability and harmonious living with the nature.

Emergence of industrial societies



A Watt steam engine, the steam engine fuelled primarily by coal that propelled the Industrial Revolution in Britain and the world

Technological advances over several millennia gave humans increasing control over the environment. But it was the Western industrial revolution of the 17th to 19th centuries that tapped into the vast growth potential of the energy in fossil fuels. Coal was used to power ever more efficient engines and later to generate electricity. Modern sanitation systems and advances in medicine protected large populations from disease. Such conditions led to a human population explosion and unprecedented industrial, technological and scientific growth that has continued to this day, marking the commencement of a period of global human influence known as the Anthropocene. From 1650 to 1850 the global population doubled from around 500 million to 1 billion people.

Concerns about the environmental and social impacts of industry were expressed by some Enlightenment political economists and through the Romantic movement of the 1800s. Overpopulation was discussed in an essay by Thomas Malthus, while John Stuart Mill foresaw the desirability of a "stationary state" economy, thus anticipating concerns of the modern discipline of ecological economics. In the late 19th century Eugenius Warming was the first botanist to study physiological relations between plants and their environment, heralding the scientific discipline of ecology.

Early 20th century

By the 20th century, the industrial revolution had led to an exponential increase in the human consumption of resources. The increase in health, wealth and population was perceived as a simple path of progress. However, in the 1930s economists began developing models of non-renewable resource management and the sustainability of welfare in an economy that uses non-renewable resources (Hartwick's rule).

Ecology had now gained general acceptance as a scientific discipline, and many concepts vital to sustainability were being explored. These included: the interconnectedness of all living systems in a single living planetary system, the biosphere; the importance of natural cycles (of water, nutrients and other chemicals, materials, waste); and the passage of energy through trophic levels of living systems.

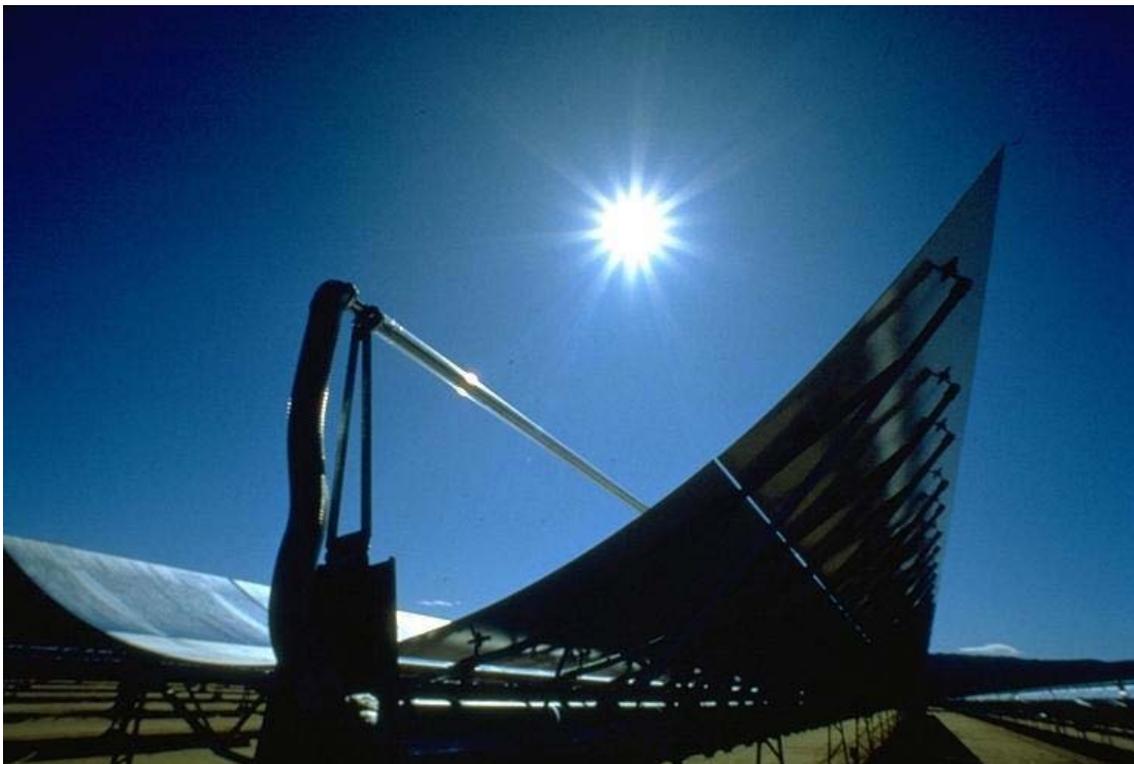
Mid 20th century: environmentalism

Following the deprivations of the great depression and World War II the developed world entered a new period of escalating growth, a post-1950s "great acceleration ... a surge in the human enterprise that has emphatically stamped humanity as a global geophysical force." A gathering environmental movement pointed out that there were environmental costs associated with the many material benefits that were now being enjoyed. Innovations in technology (including plastics, synthetic chemicals, nuclear energy) and the increasing use of fossil fuels, were transforming society. Modern industrial agriculture—the "Green Revolution" — was based on the development of synthetic fertilizers, herbicides and pesticides which had devastating consequences for rural wildlife, as documented by American marine biologist, naturalist and environmentalist Rachel Carson in *Silent Spring* (1962).

In 1956, American geoscientist M. King Hubbert's peak oil theory predicted an inevitable peak of oil production, first in the United States (between 1965 and 1970), then in successive regions of the world - with a global peak expected thereafter. In the 1970s environmentalism's concern with pollution, the population explosion, consumerism and the depletion of finite resources found expression in *Small Is Beautiful*, by British economist E. F. Schumacher in 1973, and *The Limits to Growth* published by the global think tank, the Club of Rome, in 1975.

Late 20th century

Environmental problems were now becoming global in scale. The 1973 and 1979 energy crises demonstrated the extent to which the global community had become dependent on a nonrenewable resource; President Carter in his State of the Union Address called on Americans to "Conserve energy. Eliminate waste. Make 1980 indeed a year of energy conservation." While the developed world was considering the problems of unchecked development the developing countries, faced with continued poverty and deprivation, regarded development as essential to raise the living standards of their peoples. In 1980 the International Union for Conservation of Nature had published its influential *World Conservation Strategy*, followed in 1982 by its *World Charter for Nature*, which drew attention to the decline of the world's ecosystems.



Hi-tec renewable energy. A solar concentrator, North America

In 1987 the United Nation's World Commission on Environment and Development (the Brundtland Commission), in its report *Our Common Future* suggested that development was acceptable, but it must be sustainable development that would meet the needs of the poor while not increasing environmental problems. Humanity's demand on the planet has more than doubled over the past 45 years as a result of population growth and increasing individual consumption. In 1961 almost all countries in the world had more than enough capacity to meet their own demand; by 2005 the situation had changed radically with many countries able to meet their needs only by importing resources from other nations. A move toward sustainable living by increasing public awareness and adoption of

recycling, and renewable energies emerged. The development of renewable sources of energy in the 1970s and 80's, primarily in wind turbines and photovoltaics and increased use of hydroelectricity, presented some of the first sustainable alternatives to fossil fuel and nuclear energy generation, the first large-scale solar and wind power plants appearing during the 1980s and 90's. Also at this time many local and state governments in developed countries began to implement small-scale sustainability policies.

21st century: global awareness

Through the work of climate scientists in the IPCC there is increasing global awareness of the threat posed by the human-induced enhanced greenhouse effect, produced largely by forest clearing and the burning of fossil fuels. In March 2009 the Copenhagen Climate Council, an international team of leading climate scientists, issued a strongly worded statement: "The climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts."

Ecological economics now seeks to bridge the gap between ecology and traditional neoclassical economics: it provides an inclusive and ethical economic model for society. A plethora of new concepts to help implement and measure sustainability are becoming more widely accepted including: the Car-free movement, Smart Growth (more sustainable urban environments), Life Cycle Assessment (the Cradle to Cradle analysis of resource use and environmental impact over the life cycle of a product or process), Ecological Footprint Analysis, green building, dematerialization (increased recycling of materials), decarbonisation (removing dependence on fossil fuels) and much more.

The work of Bina Agarwal and Vandana Shiva amongst many others, has brought some of the cultural wisdom of traditional, sustainable agrarian societies into the academic discourse on sustainability, and also blended that with modern scientific principles. In 2009 the Environmental Protection Agency of the United States determined that greenhouse gases "endanger public health and welfare" of the American people by contributing to climate change and causing more heat waves, droughts and flooding, and threatening food and water supplies. Rapidly advancing technologies now provide the means to achieve a transition of economies, energy generation, water and waste management, and food production towards sustainable practices using methods of systems ecology and industrial ecology.

Chapter- 3

Sustainability Measurement

Sustainability measurement is a term that denotes the measurements used as the quantitative basis for the informed management of sustainability. The metrics used for the measurement of sustainability (involving the sustainability of environmental, social and economic domains, both individually and in various combinations) are still evolving: they include indicators, benchmarks, audits, indexes and accounting, as well as assessment, appraisal and other reporting systems. They are applied over a wide range of spatial and temporal scales.

Some of the best known and most widely used sustainability measures include corporate sustainability reporting, Triple Bottom Line accounting, and estimates of the quality of sustainability governance for individual countries using the Environmental Sustainability Index and Environmental Performance Index.

Sustainability indicators and their function

The principal objective of sustainability indicators is to inform public policy-making as part of the process of sustainability governance. Sustainability indicators can provide information on any aspect of the interplay between the environment and socio-economic activities. Building strategic indicator sets generally deals with just a few simple questions: what is happening? (descriptive indicators), does it matter and are we reaching targets? (performance indicators), are we improving? (efficiency indicators), are measures working? (policy effectiveness indicators), and are we generally better off? (total welfare indicators). One popular general framework used by The European Environment Agency uses a slight modification of the Organisation for Economic Cooperation and Development DPSIR system. This breaks up environmental impact into five stages. Social and economic developments (consumption and production) (*D*)rive or initiate environmental (*P*)ressures which, in turn, produces a change in the (*S*)tate of the environment which leads to (*I*)mpacts of various kinds. Societal (*R*)esponses (policy guided by sustainability indicators) can be introduced at any stage of this sequence of events.

Metrics at the global scale

United Nations Indicators

The United Nations has developed extensive sustainability measurement tools in relation to sustainable development as well as a *System of Integrated Environmental and Economic Accounting*.

Benchmarks, indicators, indexes, auditing etc.

In the last couple of decades there has arisen a crowded toolbox of quantitative methods used to assess sustainability — including measures of resource use like life cycle assessment, measures of consumption like the ecological footprint and measurements of quality of environmental governance like the Environmental Performance Index. The following is a list of quantitative "tools" used by sustainability scientists - the different categories are for convenience only as defining criteria will intergrade. It would be too difficult to list all those methods available at different levels of organisation so those listed here are at for the global level only.

- **benchmarks**

A benchmark is a point of reference for a measurement. Once a benchmark is established it is possible to assess trends and measure progress. Baseline global data on a range of sustainability parameters is available at list of global sustainability statistics 2010 Biodiversity Indicators Partnership

- **indexes**

A sustainability index is an aggregate sustainability indicator that combines multiple sources of data. There is a *Consultative Group on Sustainable Development Indices*

Air Quality Index	GDP per capita	Happy Planet Index
Child Development Index	Gini coefficient	Human Development Index
Corruption Perceptions Index	Gender Parity Index	Legatum Prosperity Index
Democracy Index	Gender-related Development Index	Index of Sustainable Economic Welfare
Environmental Performance Index	Gender Empowerment Measure	Life Expectancy Index
Emergy Sustainability	Gross national happiness	Sustainable Governance Indicators. The Status

Index	Genuine Progress Indicator	Index ranks 30 OECD countries in terms of sustainable reform performance
Education Index	(formerly Index of Sustainable Economic Welfare)	Sustainable Society Index
Environmental Sustainability Index	Gross National Product	Water Poverty Index
Environmental Vulnerability Index		

- **metrics**

Many environmental problems ultimately relate to the human effect on those global biogeochemical cycles that are critical to life. Over the last decade monitoring these cycles has become a more urgent target for research:

- water cycle
- carbon cycle
- phosphorus cycle
- nitrogen cycle
- sulphur cycle
- oxygen cycle

- **auditing**

Sustainability auditing and reporting are used to evaluate the sustainability performance of a company, organization, or other entity using various performance indicators.

Popular auditing procedures available at the global level include:

- ISO 14000
- ISO 14031
- Natural Step
- Triple Bottom Line Accounting
- input-output analysis can be used for any level of organization with a financial budget. It relates environmental impact to expenditure by calculating the resource intensity of goods and services.

- **development and NGO project auditing**

"Litmus test" type indicators are also used in the development and NGO community to test conformity and compliance with the guidelines of sustainable human development and the international Rio Declaration of 1992.

- Sustainable development indicator for NGOs and Other Organizations

- **reporting**

- Global Reporting Initiative Global Reporting Initiative modelling and monitoring procedures. Many of these have only just been developed.
- State of the Environment reporting provides general background information on the environment and is progressively including more indicators.
- European sustainability

- **accounting**

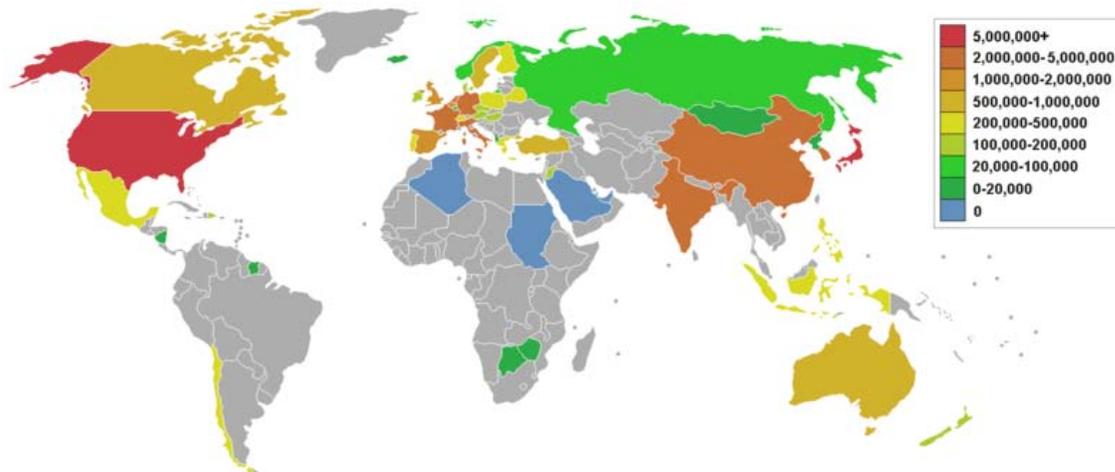
Some accounting methods attempt to include environmental costs rather than treating them as externalities

- Green accounting
- Sustainable Value
- Sustainability economics

Resource metrics

Part of this process can relate to resource use such as energy accounting or to economic metrics or price system values as compared to non-market economics potential, for understanding resource use. An important task for resource theory (energy economics) is to develop methods to optimize resource conversion processes. These systems are described and analyzed by means of the methods of mathematics and the natural sciences. Human factors, however, have dominated the development of our perspective of the relationship between nature and society since at least the Industrial Revolution, and in particular have influenced how we describe and measure the economic impacts of changes in resource quality. A balanced view of these issues requires an understanding of the physical framework in which all human ideas, institutions, and aspirations must operate.

Economics, oil and energy



Oil imports by country

Energy return on energy investment

When oil production first began in the mid-nineteenth century, the largest oil fields recovered fifty barrels of oil for every barrel used in the extraction, transportation and refining. This ratio is often referred to as the Energy Return on Energy Investment (EROI or EROEI). Currently, between one and five barrels of oil are recovered for each barrel-equivalent of energy used in the recovery process. As the EROEI drops to one, or equivalently the Net energy gain falls to zero, the oil production is no longer a net energy source. This happens long before the resource is physically exhausted.

Note that it is important to understand the distinction between a barrel of oil, which is a measure of oil, and a barrel of oil equivalent (BOE), which is a measure of energy. Many sources of energy, such as fission, solar, wind, and coal, are not subject to the same near-term supply restrictions that oil is. Accordingly, even an oil source with an EROEI of 0.5 can be usefully exploited if the energy required to produce that oil comes from a cheap and plentiful energy source. Availability of cheap, but hard to transport, natural gas in some oil fields has led to using natural gas to fuel enhanced oil recovery. Similarly, natural gas in huge amounts is used to power most Athabasca Tar Sands plants. Cheap natural gas has also led to Ethanol fuel produced with a net EROEI of less than 1, although figures in this area are controversial because methods to measure EROEI are in debate.

Growth-based economic models

Insofar as economic growth is driven by oil consumption growth, post-peak societies must adapt. M. King Hubbert believed:

“ Our principal constraints are cultural. During the last two centuries we have known nothing but exponential growth and in parallel we have evolved what amounts to an exponential-growth culture, a culture so heavily dependent upon the continuance of exponential growth for its stability that it is incapable of reckoning with problems of nongrowth. ”

Some economists describe the problem as uneconomic growth or a false economy. At the political right, Fred Ikle has warned about "conservatives addicted to the Utopia of Perpetual Growth". Brief oil interruptions in 1973 and 1979 markedly slowed - but did not stop - the growth of world GDP.

Between 1950 and 1984, as the Green Revolution transformed agriculture around the globe, world grain production increased by 250%. The energy for the Green Revolution was provided by fossil fuels in the form of fertilizers (natural gas), pesticides (oil), and hydrocarbon fueled irrigation.

David Pimentel, professor of ecology and agriculture at Cornell University, and Mario Giampietro, senior researcher at the National Research Institute on Food and Nutrition

(INRAN), place in their study *Food, Land, Population and the U.S. Economy* the maximum U.S. population for a sustainable economy at 200 million. To achieve a sustainable economy world population will have to be reduced by two-thirds, says the study. Without population reduction, this study predicts an agricultural crisis beginning in 2020, becoming critical c. 2050. The peaking of global oil along with the decline in regional natural gas production may precipitate this agricultural crisis sooner than generally expected. Dale Allen Pfeiffer claims that coming decades could see spiraling food prices without relief and massive starvation on a global level such as never experienced before.

Hubbert peaks

Although Hubbert peak theory receives most attention in relation to peak oil production, it has also been applied to other natural resources.

Natural gas

Doug Reynolds predicted in 2005 that the North American peak would occur in 2007. Bentley (p. 189) predicted a world "decline in conventional gas production from about 2020".

Coal

Peak coal is significantly further out than peak oil, but we can observe the example of anthracite in the USA, a high grade coal whose production peaked in the 1920s. Anthracite was studied by Hubbert, and matches a curve closely. Pennsylvania's coal production also matches Hubbert's curve closely, but this does not mean that coal in Pennsylvania is exhausted—far from it. If production in Pennsylvania returned at its all time high, there are reserves for 190 years. Hubbert had recoverable coal reserves worldwide at 2500×10^9 metric tons and peaking around 2150 (depending on usage).

More recent estimates suggest an earlier peak. *Coal: Resources and Future Production* (PDF 630KB), published on April 5, 2007 by the Energy Watch Group (EWG), which reports to the German Parliament, found that global coal production could peak in as few as 15 years. Reporting on this Richard Heinberg also notes that the date of peak annual energetic extraction from coal will likely come earlier than the date of peak in quantity of coal (tons per year) extracted as the most energy-dense types of coal have been mined most extensively. A second study, *The Future of Coal* by B. Kavalov and S. D. Peteves of the Institute for Energy (IFE), prepared for European Commission Joint Research Centre, reaches similar conclusions and states that "coal might not be so abundant, widely available and reliable as an energy source in the future".

Work by David Rutledge of Caltech predicts that the total of world coal production will amount to only about 450 gigatonnes. This implies that coal is running out faster than usually assumed.

Finally, insofar as global peak oil and peak in natural gas are expected anywhere from imminently to within decades at most, any increase in coal production (mining) per annum to compensate for declines in oil or NG production, would necessarily translate to an earlier date of peak as compared with peak coal under a scenario in which annual production remains constant.

Fissionable materials

In a paper in 1956, after a review of US fissionable reserves, Hubbert notes of nuclear power:

“ There is promise, however, provided mankind can solve its international problems and not destroy itself with nuclear weapons, and provided world population (which is now expanding at such a rate as to double in less than a century) can somehow be brought under control, that we may at last have found an energy supply adequate for our needs for at least the next few centuries of the "foreseeable future." ”

Technologies such as the thorium fuel cycle, reprocessing and fast breeders can, in theory, considerably extend the life of uranium reserves. Roscoe Bartlett claims

“ Our current throwaway nuclear cycle uses up the world reserve of low-cost uranium in about 20 years. ”

Caltech physics professor David Goodstein has stated that

“ ... you would have to build 10,000 of the largest power plants that are feasible by engineering standards in order to replace the 10 terawatts of fossil fuel we're burning today ... that's a staggering amount and if you did that, the known reserves of uranium would last for 10 to 20 years at that burn rate. So, it's at best a bridging technology ... You can use the rest of the uranium to breed plutonium 239 then we'd have at least 100 times as much fuel to use. But that means you're making plutonium, which is an extremely dangerous thing to do in the dangerous world that we live in. ”

Metals

Hubbert applied his theory to "rock containing an abnormally high concentration of a given metal" and reasoned that the peak production for metals such as copper, tin, lead, zinc and others would occur in the time frame of decades and iron in the time frame of two centuries like coal. The price of copper rose 500% between 2003 and 2007 was by some attributed to peak copper. Copper prices later fell, along with many other commodities and stock prices, as demand shrank from fear of a global recession. Lithium availability is a concern for a fleet of Li-ion battery using cars but a paper published in

1996 estimated that world reserves are adequate for at least 50 years. A similar prediction for platinum use in fuel cells notes that the metal could be easily recycled.

Phosphorus

Phosphorus supplies are essential to farming and depletion of reserves is estimated at somewhere from 60 to 130 years. Individual countries supplies vary widely; without a recycling initiative America's supply is estimated around 30 years. Phosphorus supplies affect total agricultural output which in turn limits alternative fuels such as biodiesel and ethanol.

Peak water

Hubbert's original analysis did not apply to renewable resources. However over-exploitation often results in a Hubbert peak nonetheless. A modified Hubbert curve applies to any resource that can be harvested faster than it can be replaced.

For example, a reserve such as the Ogallala Aquifer can be mined at a rate that far exceeds replenishment. This turns much of the world's underground water and lakes into finite resources with peak usage debates similar to oil. These debates usually center around agriculture and suburban water usage but generation of electricity from nuclear energy or coal and tar sands mining mentioned above is also water resource intensive. The term fossil water is sometimes used to describe aquifers whose water is not being recharged.

Renewable resources

- **Fisheries:** At least one researcher has attempted to perform Hubbert linearization (Hubbert curve) on the whaling industry, as well as charting the transparently dependent price of caviar on sturgeon depletion. Another example is the cod of the North Sea. The comparison of the cases of fisheries and of mineral extraction tells us that the human pressure on the environment is causing a wide range of resources to go through a depletion cycle which follows a Hubbert curve.

Chapter- 4

Carrying Capacity

The **carrying capacity** of a biological species in an environment is the population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. For the human population, more complex variables such as sanitation and medical care are sometimes considered as part of the necessary establishment.

As population density increases, birth rate often decreases and death rate typically increases. The difference between the birth rate and the death rate is the "natural increase". The carrying capacity could support a positive natural increase, or could require a negative natural increase. Thus, the carrying capacity is the number of individuals an environment can support without significant negative impacts to the given organism and its environment. Below carrying capacity, populations typically increase, while above, they typically decrease. A factor that keeps population size at equilibrium is known as a regulating factor. Population size decreases above carrying capacity due to a range of factors depending on the species concerned, but can include insufficient space, food supply, or sunlight. The carrying capacity of an environment may vary for different species and may change over time due to a variety of factors, including: food availability, water supply, environmental conditions and living space.

The origins of the term carrying capacity are uncertain with researchers variously stating that it was used "in the context of international shipping" or that it was first used during 19th Century laboratory experiments with micro-organisms. A recent review finds the first use of the term in an 1845 report by the US Secretary of State to the Senate (Sayre, 2007).

Carrying Values

It is possible for a species to exceed its carrying capacity temporarily. Population could then crash. Population variance occurs as part of the natural selection process but may occur more dramatically in some instances. Due to a variety of factors, one determinant of carrying capacity may lag behind another. For example, a waste product of a species may build up to toxic levels slower than the food supply is exhausted. The result is a fluctuation in the population around the equilibrium point which is statistically significant. These fluctuations are increases or decreases in the population until either the

population returns to the original equilibrium point, or a new equilibrium is established. These fluctuations may be more devastating for an ecosystem than are gradual population corrections, because, if they produce drastic decreases or increases, those may affect other species in the ecosystem and they may begin to move with statistical significance around their own equilibrium points. The fear is of a domino-like effect, where the final consequences are unknown and may lead to collapses of species or even whole ecosystems.

Examples

One of the world's best-studied predator-prey relationships is the moose and wolf population of Isle Royale National Park in Lake Superior. Without the wolves, the moose would overgraze the island's vegetation. Without the moose, the wolves would die. The first scientists who studied the issue thought that the wolves would eventually overpopulate and kill all the moose calves, then die from famine. This has not occurred as inbreeding, disease and environmental factors have limited the wolf population naturally.

Easter Island has been cited as an example of a human population crash. When fewer than 100 humans first arrived, the island was covered with trees with a large variety of food types. In 1722, the island was visited by Jacob Roggeveen, who estimated a population of 2000 to 3000 inhabitants with very few trees, "a rich soil, good climate" and "all the county was under cultivation". Half a century later, it was described as "a poor land" and "largely uncultivated". The ecological collapse which followed has been variously attributed to overpopulation, slave traders, European diseases (including a smallpox epidemic which killed so many so quickly, the dead were left unburied and a tuberculosis epidemic which wiped out a quarter of the population), social upheaval and invasive species (such as the Polynesian rats which may have wiped out the ground nesting birds and eaten the palm tree seeds). Whatever the combination of factors, only 111 inhabitants were left on the island in 1877. For whatever reasons (whether Moai worship, survival, status or sheer ignorance), the question of how many humans the island could realistically support never seems to have been answered. This example, and others, are discussed at length in Jared Diamond's *Collapse* and subsequent literature.

The Chincoteague Pony Swim is a human-assisted example.

Both herds are managed differently. The National Park Service owns and manages the Maryland herd while the Chincoteague Volunteer Fire Company owns and manages the Virginia herd. The Virginia herd, referred to as the "Chincoteague" ponies, is allowed to graze on Chincoteague National Wildlife Refuge, through a special use permit issued by the U.S. Fish and Wildlife Service. The size of both herds is restricted to approximately 150 adult animals each in order to protect the other natural resources of the wildlife refuge.

A further example is the Island of Tarawa, where the finite amount of space is evident, especially since landfills cannot be dug to dispose of solid waste, due to constraints in the subsurface rock and lack of topographic elevations. With colonial influence and an

abundance of food (relative to life before the year 1850), the population has expanded to the extent that overpopulation is transparently present.

Mathematics

The Lotka-Volterra equations are simple mathematical model of population dynamics which show how in a closed system, like that of the wolves and moose on Isle Royale, limited prey will cause the predator population to decline rapidly. An extended example can be used where multiple species are competing for the same resources, or single species feed on multiple prey.

Humans

In the words of one researcher: "Over the past three decades, many scholars have offered detailed critiques of carrying capacity—particularly its formal application—by pointing out that the term does not successfully capture the multi-layered processes of the human-environment link, and that it often has a blame-the-victim framework. These scholars most often cite the fluidity and non-equilibrium nature of this relationship, and the role of external forces in influencing environmental change, as key problems with the term."

In other words, the relationship of humans to their environment may be more complex than is the relationship of other species to theirs. Humans can alter the type and degree of their impact on their environment by, for instance, increasing the productivity of land through more intensive farming techniques, leaving a defined local area, or scaling back their consumption; of course, humans may also irreversibly decrease the productivity of the environment or increase consumption.

Supporters of the concept argue that humans, like every species, have a finite carrying capacity. Animal population size, living standards, and resource depletion vary, but the concept of carrying capacity still applies. The World3 model of Donella Meadows deals with carrying capacity at its core.

Carrying capacity, at its most basic level, is about organisms and food supply, where "X" amount of humans need "Y" amount of food to survive. If the humans neither gain or lose weight in the long run, the calculation is fairly accurate. If the quantity of food is invariably equal to the "Y" amount, carrying capacity has been reached. Humans, with the need to enhance their reproductive success, understand that food supply can vary and also that other factors in the environment can alter humans' need for food. A house, for example, might mean that one does not need to eat as much to stay warm as one otherwise would. Over time, monetary transactions have replaced barter and local production, and consequently modified local human carrying capacity. However, purchases also impact regions thousands of miles away. For example, carbon dioxide from an automobile travels to the upper atmosphere. This led Paul R. Ehrlich to develop the IPAT equation

$$I = P * A * T$$

where:

I is the impact on the environment resulting from consumption

P is the population number

A is the consumption per capita (affluence)

T is the technology factor

This is another way of stating the carrying capacity equation for humans which substitutes impact for resource depletion, adding the technology term to cover different living standards. As can be seen from the equation, money affects carrying capacity - but it is too general a term for accurate carrying capacity calculation.

One way to estimate human demand compared to ecosystem's carrying capacity is "Ecological Footprint" accounting. Rather than speculating about future possibilities and limitations imposed by carrying capacity constraints, Ecological Footprint accounting provides empirical, non-speculative assessments of the past. It compares historically regeneration rates (biocapacity) against historical human demand (Ecological Footprint) in the same year. One result shows that humanity's demand for 1999 exceeded the planet's biocapacity for 1999 by over 20 percent. This overshoot can be maintained for some time since stocks can be liquidated (e.g., overfishing, deforestation) and sinks can be filled up (e.g., carbon accumulation in the atmosphere). Countries can have Footprints that are higher than their biocapacity for three reasons: they can a) net-import, b) net-emit CO₂ to other countries, and c) overshoot their own ecosystems. But for the world as a whole only overshoot is available, since there is no trade with other planets.

Carrying capacity debates focusing on the possibility or impossibility of future technological break-throughs for substituting resources raise the question of whether or not it is possible to define a measure of carrying capacity or sustainability which does not already contain implicit assumptions about solutions to the problems of resource over-exploitation and environmental degradation.

Possible reduction of Earth's carrying capacity in the 21st century

Agricultural capability on Earth expanded in the last quarter of the 20th century. But now there are many projections of a continuation of the decline in world agricultural capability (and hence carrying capacity) which began in the 1990s. Most conspicuously, China's food production is forecast to decline by 37% by the last half of the 21st century, placing a strain on the entire carrying capacity of the world, as China's population could expand to about 1.5 billion people by the year 2050. This reduction in China's agricultural capability (as in other world regions) is largely due to the world water crisis and especially due to mining groundwater beyond sustainable yield, which has been happening in China since the mid-20th century.

In tourism

The process of defining Tourism Carrying Capacity (TCC) is composed of two parts. It follows (in principle) the conceptual framework for TCC as described by Shelby and Heberlein (1986), and these parts are described as follows:

Descriptive part (A): Describes how the system (tourist destination) under study works, including physical, ecological, social, political and economic aspects of tourist development. Within this context of particular importance is the identification of:

- Constraints: limiting factors that cannot be easily managed. They are inflexible, in the sense that the application of organisational, planning, and management approaches, or the development of appropriate infrastructure does not alter the thresholds associated with such constraints.
- Bottlenecks: limiting factors of the system which managers can manipulate (number of visitors at a particular place).
- Impacts: elements of the system affected by the intensity and type of use. The type of impact determines the type of capacity (ecological-physical, social, etc). Emphasis should be placed on significant impacts.

Evaluative part (B): Describes how an area should be managed and the level of acceptable environmental impacts. This part of the process starts with the identification (if it does not already exist) of the desirable condition or preferable type of development. Within this context, goals and management objectives need to be defined, alternative fields of actions evaluated and a strategy for tourist development formulated. On the basis of this, Tourism Carrying Capacity can be defined. Within this context, of particular importance is the identification of:

- Goals and/or objectives: (i.e. to define the type of experience or other outcomes which a recreational setting should provide).

Differing definitions

First of all, the carrying capacity can be the motivation to attract tourists visit the destination. The tourism industry, especially in national parks and protected areas, is subject to the concept of carrying capacity so as to determine the scale of tourist activities which can be sustained at specific times in different places. Various scholar over the years have developed several arguments developed about the definition of carrying capacity. Middleton and Hawkins defined carrying capacity as a measure of the tolerance of a site or building which is open to tourist activities, and the limit beyond which an area may suffer from the adverse impacts of tourism (Middleton & Hawkins, 1998). Chamberlain defined it as the level of human activity which an area can accommodate without either it deteriorating, the resident community being adversely affected or the quality of visitors' experience declining (Chamberlain, 1997). Clark defined carrying capacity as a certain threshold (level) of tourism activity, beyond which there will be damage to the environment and its natural inhabitants (Clark, 1997).

The World Tourism Organisation argues that carrying capacity is the maximum number of people who may visit a tourist destination at the same time, without causing destruction of the physical, economic and socio-cultural environment and/or an unacceptable decrease in the quality of visitors' satisfaction (http://ec.europa.eu/environment/iczm/pdf/tcca_material.pdf. Date assessed 08/03/07). In the publication, 'Agenda 21 for the Travel and Tourism Venture: towards environmentally sustainable development', the Secretary-General of the World Tourism Organization.

As part of a planning system

The definitions of carrying capacity need to be considered as processes within a planning process for tourism development which involves:

- Setting capacity limits for sustaining tourism activities in an area. This involves a vision about local development & decisions about managing tourism.
- Overall measuring of tourism carrying capacity does not have to lead to a single number, like the number of visitors (http://ec.europa.eu/environment/iczm/pdf/tcca_material.pdf. Date assessed 08/03/07).
- In addition, carrying capacity may contain various limits in respect to the three components (physical-ecological, socio-demographic and political-economic).

“Carrying capacity is not just a scientific concept or formula of obtaining a number beyond which development should cease, but a process where the eventual limits must be considered as guidance. They should be carefully assessed and monitored, complemented with other standards, etc. Carrying capacity is not fixed. It develops with time and the growth of tourism and can be affected by management techniques and controls” (Saveriades, 2000).

The reason for considering carrying capacity as a process, rather than a means of protection of various areas is in spite of the fact that carrying capacity was once a guiding concept in recreation and tourism management literature. Because of its conceptual elusiveness, lack of management utility and inconsistent effectiveness in minimising visitors' impacts, carrying capacity has been largely re-conceptualized into management by objectives approaches, namely: the limits of acceptable change (LAC), and the visitor experience and resource protection (VERP) as the two planning and management decision-making processes based on the new understanding of carrying capacity (Lindberg and McCool, 1998). These two have been deemed more appropriate in the tourism planning processes of protected areas, especially in the United States, and have over the years been adapted and modified for use in sustainable tourism and ecotourism contexts (Wallace, 1993; McCool, 1994; Harroun and Boo, 1995).

Chapter- 5

Sustainability and Environmental Management

At the global scale and in the broadest sense **sustainability and environmental management** involves managing the oceans, freshwater systems, land and atmosphere, according to sustainability principles.

Land use change is fundamental to the operations of the biosphere because alterations in the relative proportions of land dedicated to urbanisation, agriculture, forest, woodland, grassland and pasture have a marked effect on the global water, carbon and nitrogen biogeochemical cycles. Management of the Earth's atmosphere involves assessment of all aspects of the carbon cycle to identify opportunities to address human-induced climate change and this has become a major focus of scientific research because of the potential catastrophic effects on biodiversity and human communities. Ocean circulation patterns have a strong influence on climate and weather and, in turn, the food supply of both humans and other organisms.

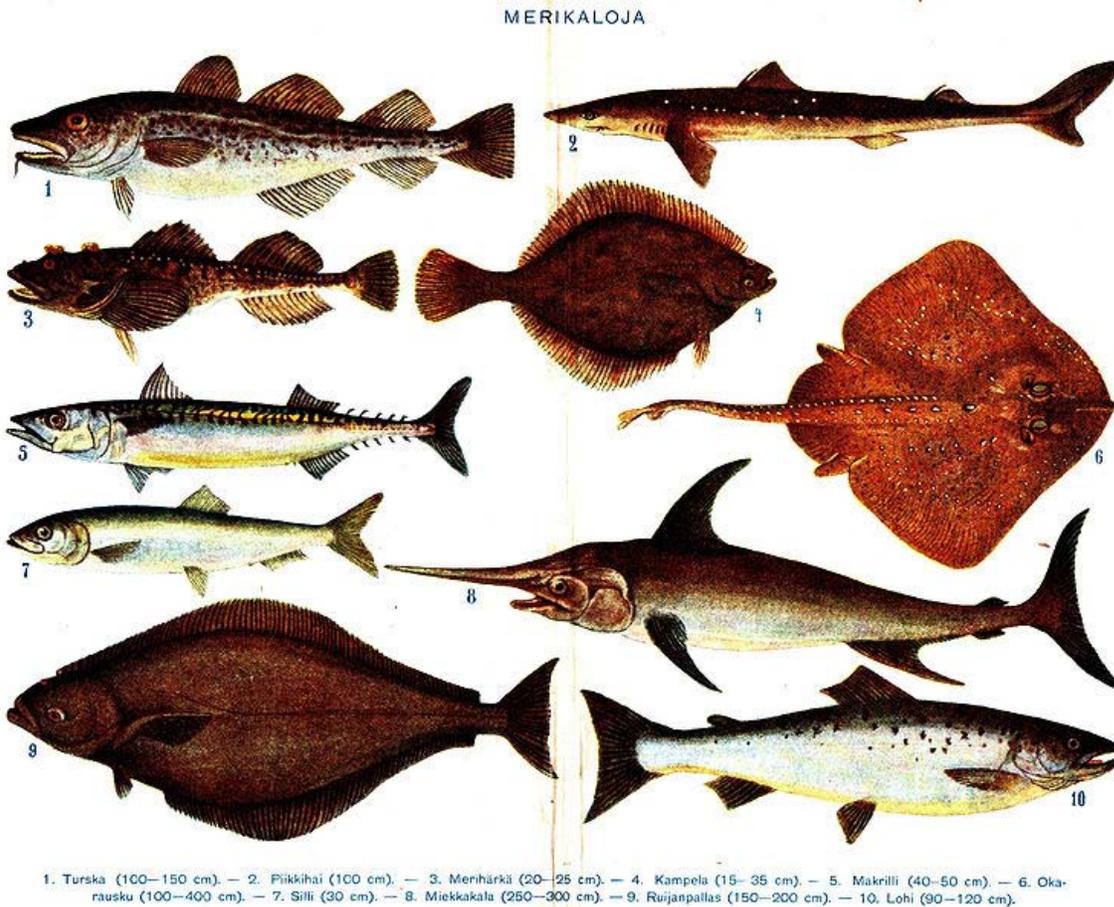
Atmosphere

In March 2009 at a meeting of the Copenhagen Climate Council 2,500 climate experts from 80 countries issued a keynote statement that there is now "no excuse" for failing to act on global warming and that without strong carbon reduction targets "abrupt or irreversible" shifts in climate may occur that "will be very difficult for contemporary societies to cope with". Management of the global atmosphere now involves assessment of all aspects of the carbon cycle to identify opportunities to address human-induced climate change and this has become a major focus of scientific research because of the potential catastrophic effects on biodiversity and human communities.

Other human impacts on the atmosphere include the air pollution in cities, the pollutants including toxic chemicals like nitrogen oxides, sulphur oxides, volatile organic compounds and particulate matter that produce photochemical smog and acid rain, and the chlorofluorocarbons that degrade the ozone layer. Anthropogenic particulates such as sulphate aerosols in the atmosphere reduce the direct irradiance and reflectance (albedo) of the Earth's surface. Known as global dimming the decrease is estimated to have been about 4% between 1960 and 1990 although the trend has subsequently reversed. Global

dimming may have disturbed the global water cycle by reducing evaporation and rainfall in some areas. It also creates a cooling effect and this may have partially masked the effect of greenhouse gases on global warming.

Oceans



A selection of the world's saltwater fish

Ocean circulation patterns have a strong influence on climate and weather and, in turn, the food supply of both humans and other organisms. Scientists have warned of the possibility, under the influence of climate change, of a sudden alteration in circulation patterns of ocean currents that could drastically alter the climate in some regions of the globe. Major human environmental impacts occur in the more habitable regions of the ocean fringes – the estuaries, coastline and bays. Ten per cent of the world's population – about 600 million people – live in low-lying areas vulnerable to sea level rise. Trends of concern that require management include: over-fishing (beyond sustainable levels); coral bleaching due to ocean warming and ocean acidification due to increasing levels of dissolved carbon dioxide; and sea level rise due to climate change. Because of their vastness oceans also act as a convenient dumping ground for human waste. Remedial strategies include: more careful waste management, statutory control of overfishing by

adoption of sustainable fishing practices and the use of environmentally sensitive and sustainable aquaculture and fish farming, reduction of fossil fuel emissions and restoration of coastal and other marine habitat.

Freshwater

Water covers 71% of the Earth's surface. Of this, 97.5% is the salty water of the oceans and only 2.5% freshwater, most of which is locked up in the Antarctic ice sheet. The remaining freshwater is found in lakes, rivers, wetlands, the soil, aquifers and atmosphere. All life depends on the solar-powered global water cycle, the evaporation from oceans and land to form water vapour that later condenses from clouds as rain, which then becomes the renewable part of the freshwater supply. Awareness of the global importance of preserving water for ecosystem services has only recently emerged as, during the 20th century, more than half the world's wetlands have been lost along with their valuable environmental services. Biodiversity-rich freshwater ecosystems are currently declining faster than marine or land ecosystems making them the world's most vulnerable habitats. Increasing urbanization pollutes clean water supplies and much of the world still does not have access to clean, safe water. In the industrial world demand management has slowed absolute usage rates but increasingly water is being transported over vast distances from water-rich natural areas to population-dense urban areas and energy-hungry desalination is becoming more widely used. Greater emphasis is now being placed on the improved management of blue (harvestable) and green (soil water available for plant use) water, and this applies at all scales of water management.

Land

Loss of biodiversity stems largely from the habitat loss and fragmentation produced by the human appropriation of land for development, forestry and agriculture as natural capital is progressively converted to man-made capital. Land use change is fundamental to the operations of the biosphere because alterations in the relative proportions of land dedicated to urbanisation, agriculture, forest, woodland, grassland and pasture have a marked effect on the global water, carbon and nitrogen biogeochemical cycles and this can impact negatively on both natural and human systems. At the local human scale major sustainability benefits accrue from the pursuit of green cities and sustainable parks and gardens.

Forests



Beech Forest – Grib Skov, Denmark

Since the Neolithic Revolution about 47% of the world's forests have been lost to human use. Present-day forests occupy about a quarter of the world's ice-free land with about half of these occurring in the tropics. In temperate and boreal regions forest area is gradually increasing (with the exception of Siberia), but deforestation in the tropics is of major concern.

Forests moderate the local climate and the global water cycle through their light reflectance (albedo) and evapotranspiration. They also conserve biodiversity, protect water quality, preserve soil and soil quality, provide fuel and pharmaceuticals, and purify the air. These free ecosystem services are not given a market value under most current economic systems, and so forest conservation has little appeal when compared with the economic benefits of logging and clearance which, through soil degradation and organic

decomposition returns carbon dioxide to the atmosphere. The United Nations Food and Agriculture Organization (FAO) estimates that about 90% of the carbon stored in land vegetation is locked up in trees and that they sequester about 50% more carbon than is present in the atmosphere. Changes in land use currently contribute about 20% of total global carbon emissions (heavily logged Indonesia and Brazil are a major source of emissions). Climate change can be mitigated by sequestering carbon in reforestation schemes, plantations and timber products. Also wood biomass can be utilized as a renewable carbon-neutral fuel. The FAO has suggested that, over the period 2005–2050, effective use of tree planting could absorb about 10–20% of man-made emissions – so monitoring the condition of the world's forests must be part of a global strategy to mitigate emissions and protect ecosystem services. However, climate change may preempt this FAO scenario as a study by the International Union of Forest Research Organizations in 2009 concluded that the stress of a 2.5C (4.5F) temperature rise above pre-industrial levels could result in the release of vast amounts of carbon so the potential of forests to act as carbon "sinks" is "at risk of being lost entirely".

Cultivated land



A rice paddy. Rice, wheat, corn and potatoes make up more than half the world's food supply

Feeding more than six billion human bodies takes a heavy toll on the Earth's resources. This begins with the appropriation of about 38% of the Earth's land surface and about 20% of its net primary productivity. Added to this are the resource-hungry activities of industrial agribusiness – everything from the crop need for irrigation water, synthetic fertilizers and pesticides to the resource costs of food packaging, transport (now a major part of global trade) and retail. Food is essential to life. But the list of environmental costs of food production is a long one: topsoil depletion, erosion and conversion to desert from constant tillage of annual crops; overgrazing; salinization; sodification; waterlogging; high levels of fossil fuel use; reliance on inorganic fertilisers and synthetic organic

pesticides; reductions in genetic diversity by the mass use of monocultures; water resource depletion; pollution of waterbodies by run-off and groundwater contamination; social problems including the decline of family farms and weakening of rural communities.

All of these environmental problems associated with industrial agriculture and agribusiness are now being addressed through such movements as sustainable agriculture, organic farming and more sustainable business practices.

Extinctions



The extinct Dodo (*Raphus cucullatus*)

Although biodiversity loss can be monitored simply as loss of species, effective conservation demands the protection of species within their natural habitats and ecosystems. Following human migration and population growth, species extinctions have progressively increased to a rate unprecedented since the Cretaceous–Tertiary extinction event. Known as the Holocene extinction event this current human-induced extinction of species ranks as one of the world's six mass extinction events. Some scientific estimates indicate that up to half of presently existing species may become extinct by 2100. Current extinction rates are 100 to 1000 times their prehuman levels with more than 10% birds and mammals threatened, about 8% of plants, 5% of fish and more than 20% of freshwater species.

The 2008 IUCN Red List warns that long-term droughts and extreme weather put additional stress on key habitats and, for example, lists 1,226 bird species as threatened with extinction, which is one-in-eight of all bird species. The Red List Index also identifies 44 tree species in Central Asia as under threat of extinction due to over-exploitation and human development and threatening the region's forests which are home to more than 300 wild ancestors of modern domesticated fruit and nut cultivars.

Biological invasions



Kudzu (*Pueraria lobata*) infesting trees in Atlanta, Georgia, USA

In many parts of the industrial world land clearing for agriculture has diminished and here the greatest threat to biodiversity, after climate change, has become the destructive effect of invasive species. Increasingly efficient global transport has facilitated the spread of organisms across the planet. The potential danger of this aspect of globalization is starkly illustrated through the spread of human diseases like HIV AIDS, mad cow disease, bird flu and swine flu, but invasive plants and animals are also having a devastating impact on native biodiversity. Non-indigenous organisms can quickly occupy disturbed land and natural areas where, in the absence of their natural predators, they are able to thrive. At the global scale this issue is being addressed through the Global Invasive Species Information Network but there is improved international biosecurity legislation to minimise the transmission of pathogens and invasive organisms. Also, through CITES legislation there is control the trade in rare and threatened species. Increasingly at the local level public awareness programs are alerting communities, gardeners, the nursery industry, collectors, and the pet and aquarium industries, to the harmful effects of potentially invasive species.

Chapter- 6

Sustainable Energy



Concentrating solar power systems are a fast growing source of sustainable energy

Sustainable energy is the provision of energy such that it meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy sources are most often regarded as including all renewable sources, such as plant matter, solar power, wind power, wave power, geothermal power and tidal power. It usually also includes technologies that improve energy efficiency. Conventional fission power is sometimes referred to as sustainable, but this is controversial politically due to concerns about peak uranium, radioactive waste disposal and the risks of disaster due to accident, terrorism, or natural disaster.

Distinction from other terms

Energy efficiency and renewable energy are said to be the *twin pillars* of sustainable energy. Some ways in which *sustainable energy* has been defined are:

- "Effectively, the provision of energy such that it meets the needs of the future without compromising the ability of future generations to meet their own needs. ...Sustainable Energy has two key components: renewable energy and energy efficiency." – *Renewable Energy and Efficiency Partnership* (British)
- "Dynamic harmony between equitable availability of energy-intensive goods and services to all people and the preservation of the earth for future generations." And, "the solution will lie in finding sustainable energy sources and more efficient means of converting and utilizing energy." – *Sustainable energy* by J. W. Tester, et al, from MIT Press.
- "Any energy generation, efficiency & conservation source where: Resources are available to enable massive scaling to become a significant portion of energy generation, long term, preferably 100 years.." – *Invest*, a green technology non-profit organization.
- "Energy which is replenishable within a human lifetime and causes no long-term damage to the environment." – *Jamaica Sustainable Development Network*

This sets *sustainable energy* apart from other renewable energy terminology such as *alternative energy* and *green energy*, by focusing on the ability of an energy source to continue providing energy. Sustainable energy can produce some pollution of the environment, as long as it is not sufficient to prohibit heavy use of the source for an indefinite amount of time. Sustainable energy is also distinct from Low-carbon energy, which is only sustainable only in the sense that it does not add to the CO₂ in the atmosphere.

Green power is a subset of renewable energy and represents those renewable energy resources and technologies that provide the highest environmental benefit. The U.S. Environmental Protection Agency defines green power as electricity produced from solar, wind, geothermal, biogas, biomass, and low-impact small hydroelectric sources. Customers often buy green power for avoided environmental impacts and its greenhouse gas reduction benefits.

Renewable energy technologies

Renewable energy technologies are essential contributors to sustainable energy as they generally contribute to world energy security, reducing dependence on fossil fuel resources, and providing opportunities for mitigating greenhouse gases. The International Energy Agency states that:

Conceptually, one can define three generations of renewables technologies, reaching back more than 100 years.

First-generation technologies emerged from the industrial revolution at the end of the 19th century and include hydropower, biomass combustion, and geothermal power and heat. Some of these technologies are still in widespread use.

Second-generation technologies include solar heating and cooling, wind power, modern forms of bioenergy, and solar photovoltaics. These are now entering markets as a result of research, development and demonstration (RD&D) investments since the 1980s. The initial investment was prompted by energy security concerns linked to the oil crises (1973 and 1979) of the 1970s but the continuing appeal of these renewables is due, at least in part, to environmental benefits. Many of the technologies reflect significant advancements in materials.

Third-generation technologies are still under development and include advanced biomass gasification, biorefinery technologies, concentrating solar thermal power, hot dry rock geothermal energy, and ocean energy. Advances in nanotechnology may also play a major role.

—International Energy Agency, *RENEWABLES IN GLOBAL ENERGY SUPPLY, An IEA Fact Sheet*

First- and second-generation technologies have entered the markets, and third-generation technologies heavily depend on long term research and development commitments, where the public sector has a role to play.

A 2008 comprehensive cost-benefit analysis review of energy solutions in the context of global warming and other issues ranked wind power combined with battery electric vehicles (BEV) as the most efficient, followed by concentrated solar power, geothermal power, tidal power, photovoltaic, wave power, coal capture and storage, nuclear energy, and finally biofuels.

First-generation technologies



One of many power plants at The Geysers, a geothermal power field in northern California, with a total output of over 750 MW.

First-generation technologies are most competitive in locations with abundant resources. Their future use depends on the exploration of the available resource potential, particularly in developing countries, and on overcoming challenges related to the environment and social acceptance.

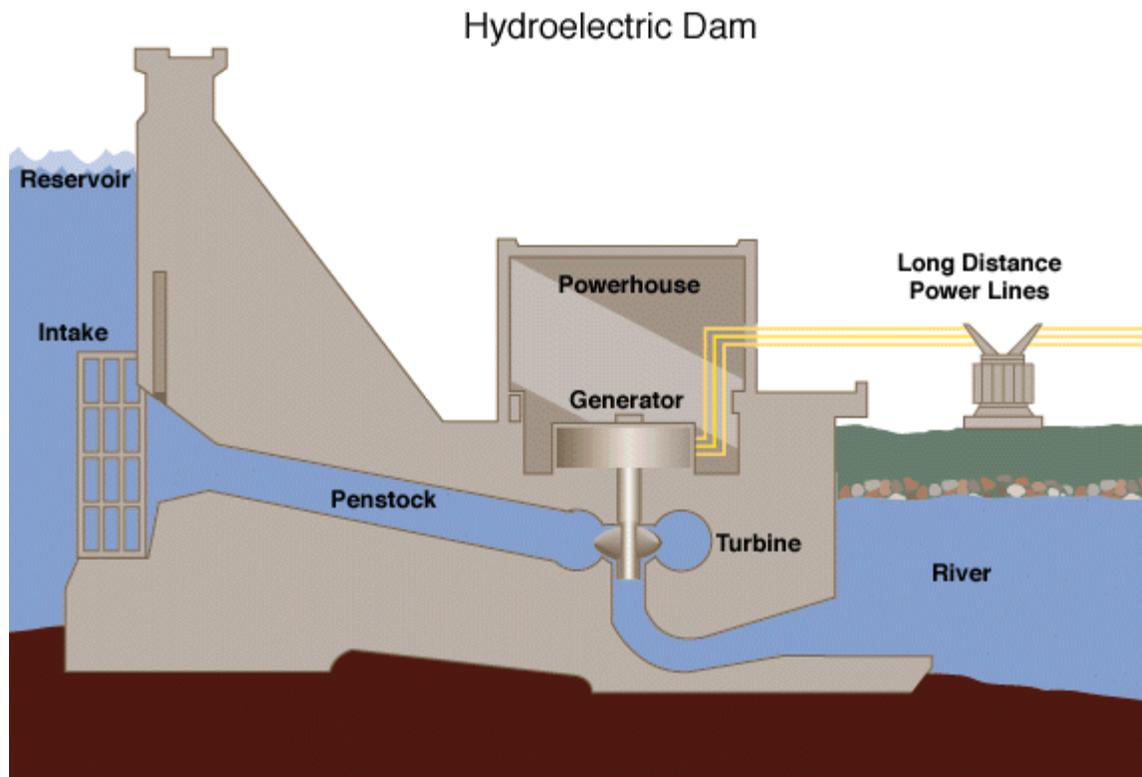
—International Energy Agency, *RENEWABLES IN GLOBAL ENERGY SUPPLY, An IEA Fact Sheet*

Among sources of renewable energy, hydroelectric plants have the advantages of being long-lived—many existing plants have operated for more than 100 years. Also, hydroelectric plants are clean and have few emissions. Criticisms directed at large-scale hydroelectric plants include: dislocation of people living where the reservoirs are planned, and release of significant amounts of carbon dioxide during construction and flooding of the reservoir.



Hydroelectric dams are one of the most widely deployed sources of sustainable energy

However, it has been found that high emissions are associated only with shallow reservoirs in warm (tropical) locales. Generally speaking, hydroelectric plants produce much lower life-cycle emissions than other types of generation. Hydroelectric power, which underwent extensive development during growth of electrification in the 19th and 20th centuries, is experiencing resurgence of development in the 21st century. The areas of greatest hydroelectric growth are the booming economies of Asia. China is the development leader; however, other Asian nations are installing hydropower at a rapid pace. This growth is driven by much increased energy costs—especially for imported energy—and widespread desires for more domestically produced, clean, renewable, and economical generation.



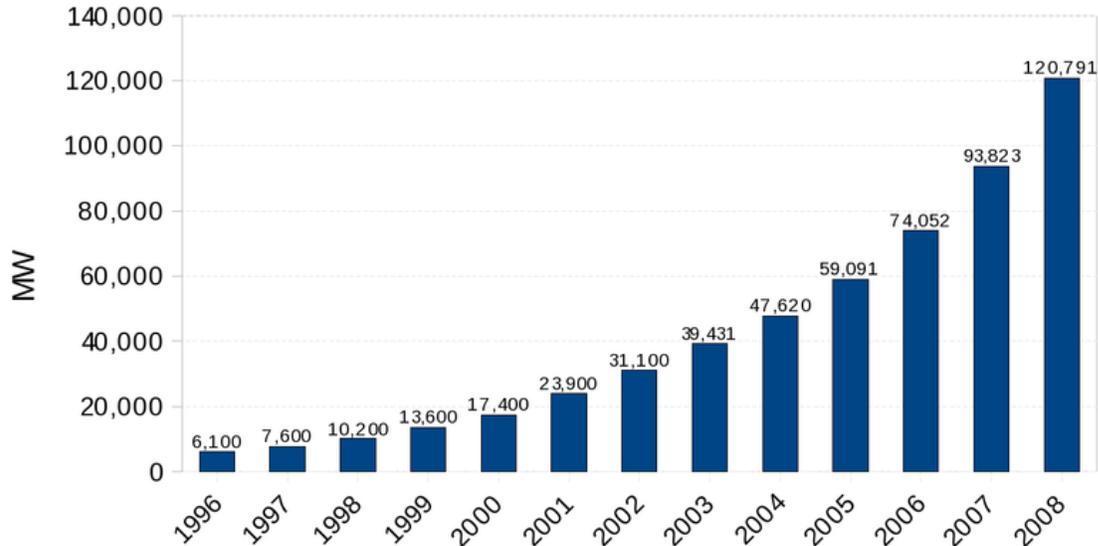
Hydroelectric dam in cross section

Geothermal power plants can operate 24 hours per day, providing base-load capacity, and the world potential capacity for geothermal power generation is estimated at 85 GW over the next 30 years. However, geothermal power is accessible only in limited areas of the world, including the United States, Central America, Indonesia, East Africa and the Philippines. The costs of geothermal energy have dropped substantially from the systems built in the 1970s. Geothermal heat generation can be competitive in many countries producing geothermal power, or in other regions where the resource is of a lower temperature. Enhanced geothermal system (EGS) technology does not require natural convective hydrothermal resources, so it can be used in areas that were previously unsuitable for geothermal power, if the resource is very large. EGS is currently under research at the U.S. Department of Energy.

Biomass briquettes are increasingly being used in the developing world as an alternative to charcoal. The technique involves the conversion of almost any plant matter into compressed briquettes that typically have about 70% the calorific value of charcoal. There are relatively few examples of large scale briquette production. One exception is in North Kivu, in eastern Democratic Republic of Congo, where forest clearance for charcoal production is considered to be the biggest threat to Mountain Gorilla habitat. The staff of Virunga National Park have successfully trained and equipped over 3500 people to produce biomass briquettes, thereby replacing charcoal produced illegally

inside the national park, and creating significant employment for people living in extreme poverty in conflict affected areas.

Second-generation technologies



Worldwide installed wind power capacity 1996-2008

Markets for second-generation technologies are strong and growing, but only in a few countries. The challenge is to broaden the market base for continued growth worldwide. Strategic deployment in one country not only reduces technology costs for users there, but also for those in other countries, contributing to overall cost reductions and performance improvement.

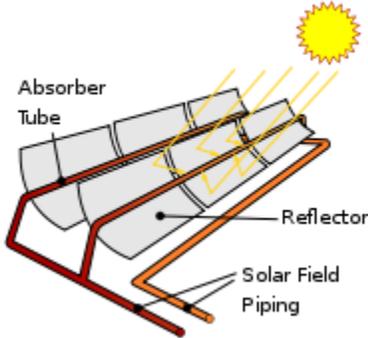
—International Energy Agency, *RENEWABLES IN GLOBAL ENERGY SUPPLY, An IEA Fact Sheet*

Solar heating systems are a well known second-generation technology and generally consist of solar thermal collectors, a fluid system to move the heat from the collector to its point of usage, and a reservoir or tank for heat storage and subsequent use. The systems may be used to heat domestic hot water, swimming pool water, or for space heating. The heat can also be used for industrial applications or as an energy input for other uses such as cooling equipment. In many climates, a solar heating system can provide a very high percentage (50 to 75%) of domestic hot water energy. Energy received from the sun by the earth is that of electromagnetic radiation. Light ranges of visible, infrared, ultraviolet, x-rays, and radio waves received by the earth through solar energy. The highest power of radiation comes from visible light. Solar power is complicated due to changes in seasons and from day to night. Cloud cover can also add to complications of solar energy, and not all radiation from the sun reaches earth because it is absorbed and dispersed due to clouds and gases within the earth's atmospheres.



11 MW solar power plant near Serpa, Portugal 🌐 $38^{\circ}1'51''\text{N } 7^{\circ}37'22''\text{W} / 38.03083^{\circ}\text{N } 7.62278^{\circ}\text{W}$

In the 1980s and early 1990s, most photovoltaic modules provided remote-area power supply, but from around 1995, industry efforts have focused increasingly on developing building integrated photovoltaics and power plants for grid connected applications. Currently the largest photovoltaic power plant in North America is the Nellis Solar Power Plant (15 MW). There is a proposal to build a Solar power station in Victoria, Australia, which would be the world's largest PV power station, at 154 MW. Other large photovoltaic power stations include the Girassol solar power plant (62 MW), and the Waldpolenz Solar Park (40 MW).



Sketch of a Parabolic Trough Collector

Some of the second-generation renewables, such as wind power, have high potential and have already realised relatively low production costs. At the end of 2008, worldwide wind farm capacity was 120,791 megawatts (MW), representing an increase of 28.8 percent during the year, and wind power produced some 1.3% of global electricity consumption. Wind power accounts for approximately 20% of electricity use in Denmark, 9% in Spain, and 7% in Germany. However, it may be difficult to site wind turbines in some areas for aesthetic or environmental reasons, and it may be difficult to integrate wind power into electricity grids in some cases.

Solar thermal power stations have been successfully operating in California commercially since the late 1980s, including the largest solar power plant of any kind, the 350 MW Solar Energy Generating Systems. Nevada Solar One is another 64MW plant which has recently opened. Other parabolic trough power plants being proposed are two 50MW plants in Spain, and a 100MW plant in Israel.



Information on pump, California

Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18 percent of the country's automotive fuel. As a result of this, together with the exploitation of domestic deep water oil sources, Brazil, which years ago had to import a large share of the petroleum needed for domestic consumption, recently reached complete self-sufficiency in oil.

Most cars on the road today in the U.S. can run on blends of up to 10% ethanol, and motor vehicle manufacturers already produce vehicles designed to run on much higher ethanol blends. Ford, DaimlerChrysler, and GM are among the automobile companies that sell “flexible-fuel” cars, trucks, and minivans that can use gasoline and ethanol blends ranging from pure gasoline up to 85% ethanol (E85). By mid-2006, there were approximately six million E85-compatible vehicles on U.S. roads.

Third-generation technologies



MIT's Solar House #1 built in 1939 used seasonal thermal storage for year round heating. Third-generation technologies are not yet widely demonstrated or commercialised. They are on the horizon and may have potential comparable to other renewable energy technologies, but still depend on attracting sufficient attention and RD&D funding. These newest technologies include advanced biomass gasification, biorefinery technologies, solar thermal power stations, hot dry rock geothermal energy, and ocean energy.
—International Energy Agency, *RENEWABLES IN GLOBAL ENERGY SUPPLY, An IEA Fact Sheet*

According to the International Energy Agency, new bioenergy (biofuel) technologies being developed today, notably cellulosic ethanol biorefineries, could allow biofuels to play a much bigger role in the future than previously thought. Cellulosic ethanol can be made from plant matter composed primarily of inedible cellulose fibers that form the stems and branches of most plants. Crop residues (such as corn stalks, wheat straw and rice straw), wood waste, and municipal solid waste are potential sources of cellulosic biomass. Dedicated energy crops, such as switchgrass, are also promising cellulose sources that can be sustainably produced in many regions of the United States.



The world's first commercial tidal stream generator — SeaGen — in Strangford Lough. The strong wake shows the power in the tidal current.

In terms of Ocean energy, another third-generation technology, Portugal has the world's first commercial wave farm, the Aguçadora Wave Park, under construction in 2007. The farm will initially use three Pelamis P-750 machines generating 2.25 MW. and costs are put at 8.5 million euro. Subject to successful operation, a further 70 million euro is likely to be invested before 2009 on a further 28 machines to generate 525 MW. Funding for a wave farm in Scotland was announced in February, 2007 by the Scottish Executive, at a cost of over 4 million pounds, as part of a £13 million funding packages for ocean power in Scotland. The farm will be the world's largest with a capacity of 3 MW generated by four Pelamis machines.

In 2007, the world's first turbine to create commercial amounts of energy using tidal power was installed in the narrows of Strangford Lough in Ireland. The 1.2 MW underwater tidal electricity generator takes advantage of the fast tidal flow in the lough which can be up to 4m/s. Although the generator is powerful enough to power up to a thousand homes, the turbine has a minimal environmental impact, as it is almost entirely submerged, and the rotors turn slowly enough that they pose no danger to wildlife.

Solar power panels that use nanotechnology, which can create circuits out of individual silicon molecules, may cost half as much as traditional photovoltaic cells, according to executives and investors involved in developing the products. Nanosolar has secured more than \$100 million from investors to build a factory for nanotechnology thin-film solar panels. The company's plant has a planned production capacity of 430 megawatts peak power of solar cells per year. Commercial production started and first panels have been shipped to customers in late 2007.

Most current solar power plants are made from an array of similar units where each unit is continuously adjusted, e.g., with some step motors, so that the light converter stays in focus of the sun light. The cost of focusing light on converters such as high-power solar panels, Stirling engine, etc. can be dramatically decreased with a simple and efficient rope mechanics. In this technique many units are connected with a network of ropes so that pulling two or three ropes is sufficient to keep all light converters simultaneously in focus as the direction of the sun changes.

Energy efficiency

Moving towards energy sustainability will require changes not only in the way energy is supplied, but in the way it is used, and reducing the amount of energy required to deliver various goods or services is essential. Opportunities for improvement on the demand side of the energy equation are as rich and diverse as those on the supply side, and often offer significant economic benefits.

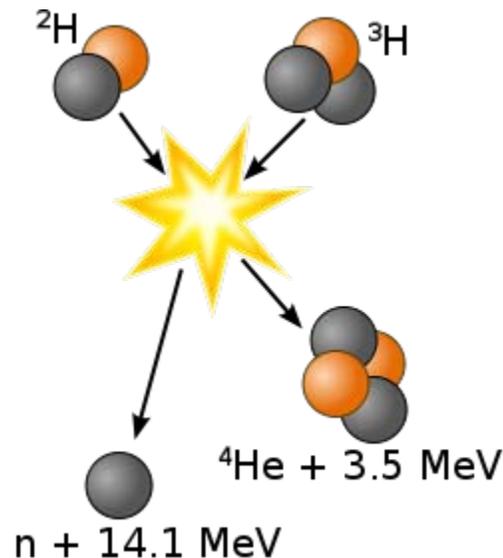
Renewable energy and energy efficiency are sometimes said to be the “twin pillars” of sustainable energy policy. Both resources must be developed in order to stabilize and reduce carbon dioxide emissions. Efficiency slows down energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use. If energy use grows too fast, renewable energy development will chase a receding target. Likewise, unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total emissions; reducing the carbon content of energy sources is also needed. Any serious vision of a sustainable energy economy thus requires commitments to both renewables and efficiency.

Renewable energy (and energy efficiency) are no longer niche sectors that are promoted only by governments and environmentalists. The increased levels of investment and the fact that much of the capital is coming from more conventional financial actors suggest that sustainable energy options are now becoming mainstream.

Climate change concerns coupled with high oil prices and increasing government support are driving increasing rates of investment in the sustainable energy industries, according to a trend analysis from the United Nations Environment Programme. According to UNEP, global investment in sustainable energy in 2007 was higher than previous levels, with \$148 billion of new money raised in 2007, an increase of 60% over 2006. Total financial transactions in sustainable energy, including acquisition activity, was \$204 billion.

Investment flows in 2007 broadened and diversified, making the overall picture one of greater breadth and depth of sustainable energy use. The mainstream capital markets are "now fully receptive to sustainable energy companies, supported by a surge in funds destined for clean energy investment".

Nuclear power



The deuterium-tritium (D-T) reaction is one of the more promising for producing fusion power.

It is said that nuclear has the potential to be sustainable, such as by the use of breeder reactors. However, this is often qualified with the argument that there are serious challenges that must be dealt with before it can drastically increase its role.

There are potentially two sources of nuclear power. Fission is used in all current nuclear power plants. Fusion is the reaction that powers stars, including the sun, which remains impractical for use on earth. Both types create radioactive waste in the form of activated structural material, which is one of the sustainability issues. Note that Aneutronic fusion such as He3-D fusion or Boron-Proton fusion produce far less or virtually zero radioactivity but are more difficult to fuse.

Fission power's long-term sustainability depends on the amount of uranium and thorium that are available to be mined, on the operators' abilities safely to dispose of the waste and on the continued prevention of major accidents. Estimates for fuel reserves vary widely. Fusion power's long-term sustainability depends on whether or not a practical, affordable technology can be developed.

Technical sustainability of nuclear power

Proponents, such as Christine Todd Whitman and Patrick Moore (both co-chairs of the Clean and Safe Energy Coalition) also claim that nuclear power is at least as environmentally friendly as traditional sources of renewable energy, making it part of the solution to global warming and the world's currently growing demand for energy. They note that nuclear power plants, once built and before decommissioning begins, produce little carbon dioxide emissions and point out that the radioactive waste produced is

minimal and well-contained, especially compared to fossil fuels. Robert Bryce argues that a future dominated by nuclear power is unavoidable since it is inherently superior, in terms of energy density, reliability, and land required per unit of energy, to any other method of low carbon power generation. Some people object to this claim on the grounds that the nuclear option is not price competitive without heavy government subsidy and the use of government bodies to store and protect such a hazardous waste component. An examination of figures from the Energy Information Administration, however, show that in 2007, for every megawatt-hour produced, refined coal received \$29.81 in federal support, solar power received \$24.34, and wind power received \$23.37. Nuclear power received \$1.59, although this did not include the costs of nuclear decommissioning and spent fuel storage.

Green energy



A wind turbine at Greenpark, Reading, England, generating green electricity for approx 1000 homes.

Green energy is the term used to describe sources of energy that are considered to be environmentally friendly and non-polluting, such as geothermal, wind, solar, and hydro. Sometimes nuclear power is also considered a green energy source. Green energy sources are often considered "green" because they are perceived to lower carbon emissions and create less pollution.

Green energy is commonly thought of in the context of electricity generation. A fuller picture requires appreciation of efficient energy use as well as mechanical power, heating and cogeneration. Consumers, businesses, and organizations may purchase green energy to support further development, help reduce the environmental impacts of conventional electricity generation, and increase their nation's energy independence. Renewable energy certificates (green certificates or green tags) have been one way for consumers and businesses to support green energy.

Related terms

In the media, green energy is often used interchangeably with the term *Renewable energy*. *Alternative energy* and *clean technologies* are other terms often used instead of renewable energy. The terms suggest a non-polluting, non-fossil-fuel source. *Green power* is sometimes used in reference to electricity generated from "green" sources. *Brown energy* has been used to contrast non-renewable or polluting energy sources with green energy.

Sustainable energy is the provision of energy such that it meets the needs of the present without compromising the ability of future generations to meet their needs. In practice, this is equivalent to *green energy* although the different terms can imply a difference of emphasis. For example, hydroelectricity can result in a large-scale damage to local ecosystems and hence might not be considered green. The damage, in terms of the global ecosystem (or biosphere) would be relatively minor and so hydroelectricity might be considered sustainable if used to a limited extent.

Green sources



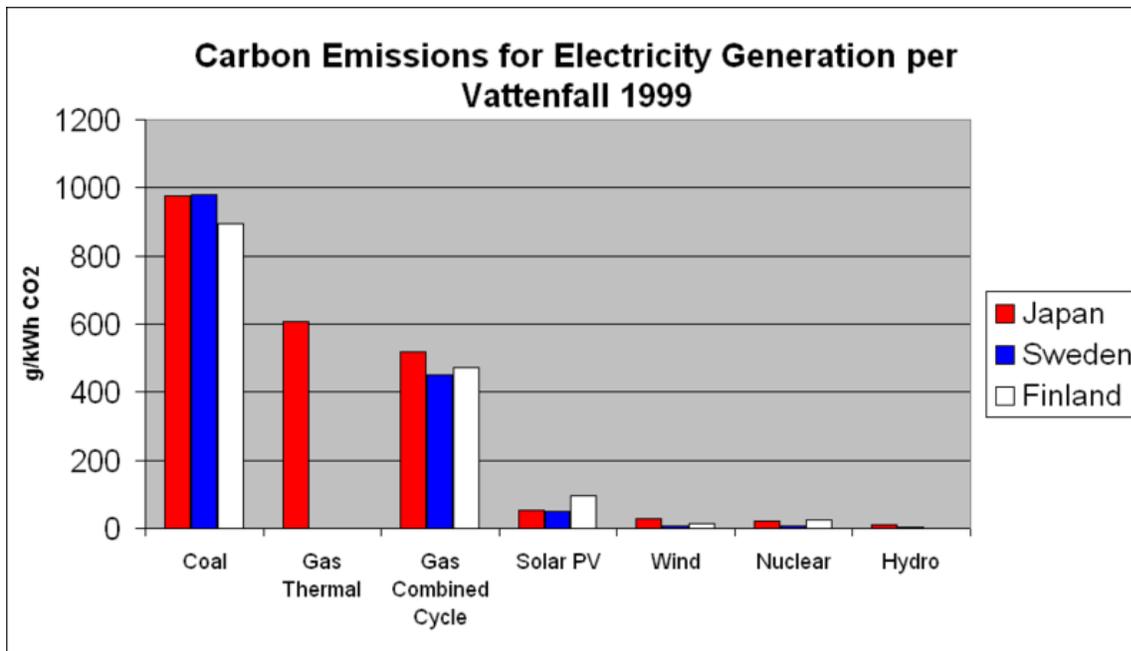
A solar trough array is an example of green energy

Green energy includes natural energetic processes that can be harnessed with little pollution. Anaerobic digestion, geothermal power, wind power, small-scale hydropower, solar energy, biomass power, tidal power, and wave power fall under such a category. Some definitions may also include power derived from the incineration of waste.

Some people, including George Monbiot and James Lovelock have specifically classified nuclear power as green energy. Others, including Greenpeace disagree, claiming that the problems associated with radioactive waste and the risk of nuclear accidents (such as the Chernobyl disaster) pose an unacceptable risk to the environment and to humanity.

No power source is entirely impact-free. All energy sources require energy and give rise to some degree of pollution from manufacture of the technology.

Comparison to non-green sources



The Vattenfall study found Nuclear, Hydro, and Wind to have far less greenhouse emissions than other sources represented.

The Swedish utility Vattenfall did a study of full life cycle emissions of nuclear, hydro, coal, gas, solar cell, peat and wind which the utility uses to produce electricity. The net result of the study was that nuclear power produced 3.3 grams of carbon dioxide per kilowatt-hour of produced power. This compares to 400 g/(kW·h) for natural gas and 700 g/(kW·h) for coal (according to this study). The study also concluded that nuclear power produced the smallest amount of CO₂ of any of their electricity sources.

Claims exist that the problems of nuclear waste do not come anywhere close to approaching the problems of fossil fuel waste. A 2004 article from the BBC states: "The World Health Organization (WHO) says 3 million people are killed worldwide by

outdoor air pollution annually from vehicles and industrial emissions, and 1.6 million indoors through using solid fuel." In the U.S. alone, fossil fuel waste kills 20,000 people each year. A coal power plant releases 100 times as much radiation as a nuclear power plant of the same wattage. It is estimated that during 1982, US coal burning released 155 times as much radioactivity into the atmosphere as the Three Mile Island incident. In addition, fossil fuel waste causes global warming, which leads to increased deaths from hurricanes, flooding, and other weather events. The World Nuclear Association provides a comparison of deaths due to accidents among different forms of energy production. In their comparison, deaths per TW-yr of electricity produced from 1970 to 1992 are quoted as 885 for hydropower, 342 for coal, 85 for natural gas, and 8 for nuclear.

Purchasing green energy through the electrical grid

In several countries with common carrier arrangements, electricity retailing arrangements make it possible for consumers to purchase green electricity (renewable electricity) from either their utility or a green power provider.

When energy is purchased from the electricity network, the power reaching the consumer will not necessarily be generated from green energy sources. The local utility company, electric company, or state power pool buys their electricity from electricity producers who may be generating from fossil fuel, nuclear or renewable energy sources. In many countries green energy currently provides a very small amount of electricity, generally contributing less than 2 to 5% to the overall pool. In some U.S. states, local governments have formed regional power purchasing pools using Community Choice Aggregation and Solar Bonds to achieve a 51% renewable mix or higher, such as in the City of San Francisco.

By participating in a green energy program a consumer may be having an effect on the energy sources used and ultimately might be helping to promote and expand the use of green energy. They are also making a statement to policy makers that they are willing to pay a price premium to support renewable energy. Green energy consumers either obligate the utility companies to increase the amount of green energy that they purchase from the pool (so decreasing the amount of non-green energy they purchase), or directly fund the green energy through a green power provider. If insufficient green energy sources are available, the utility must develop new ones or contract with a third party energy supplier to provide green energy, causing more to be built. However, there is no way the consumer can check whether or not the electricity bought is "green" or otherwise.

In some countries such as the Netherlands, electricity companies guarantee to buy an equal amount of 'green power' as is being used by their green power customers. The Dutch government exempts green power from pollution taxes, which means green power is hardly any more expensive than other power.

In the United States, one of the main problems with purchasing green energy through the electrical grid is the current centralized infrastructure that supplies the consumer's electricity. This infrastructure has led to increasingly frequent brown outs and black outs,

high CO₂ emissions, higher energy costs, and power quality issues. An additional \$450 billion will be invested to expand this fledgling system over the next 20 years to meet increasing demand. In addition, this centralized system is now being further overtaxed with the incorporation of renewable energies such as wind, solar, and geothermal energies. Renewable resources, due to the amount of space they require, are often located in remote areas where there is a lower energy demand. The current infrastructure would make transporting this energy to high demand areas, such as urban centers, highly inefficient and in some cases impossible. In addition, despite the amount of renewable energy produced or the economic viability of such technologies only about 20 percent will be able to be incorporated into the grid. To have a more sustainable energy profile, the United States must move towards implementing changes to the electrical grid that will accommodate a mixed-fuel economy.

However, several initiatives are being proposed to mitigate these distribution problems. First and foremost, the most effective way to reduce USA's CO₂ emissions and slow global warming is through conservation efforts. Opponents of the current US electrical grid have also advocated for decentralizing the grid. This system would increase efficiency by reducing the amount of energy lost in transmission. It would also be economically viable as it would reduce the amount of power lines that will need to be constructed in the future to keep up with demand. Merging heat and power in this system would create added benefits and help to increase its efficiency by up to 80-90%. This is a significant increase from the current fossil fuel plants which only have an efficiency of 34%.

A more recent concept for improving our electrical grid is to beam microwaves from Earth-orbiting satellites or the moon to directly when and where there is demand. The power would be generated from solar energy captured on the lunar surface. In this system, the receivers would be "broad, translucent tent-like structures that would receive microwaves and convert them to electricity". NASA said in 2000 that the technology was worth pursuing but it is still too soon to say if the technology will be cost-effective.

Abuses

In countries where suppliers are legally obliged to purchase a proportion of their electricity from renewable sources (for example under the Renewables Obligation in the United Kingdom), there is a danger that energy suppliers may sell such green electricity under a premium "green energy" tariff, rather than sourcing additional green electricity supplies. Where a Renewable Energy Certificate or similar scheme is in operation it is also possible for the energy supplier to sell the green electricity to the consumer, and also sell the certificate to another supplier who has failed to meet their quota, rather than "retiring" the certificate from the marketplace. In other cases green energy tariffs may involve carbon offsetting rather than purchasing or investing in renewable energy.

Certification schemes to minimise these and similar questionable practices are in place or are being developed in a few countries.

International standards

The World Wide Fund for Nature and several green electricity labelling organizations have created the Eugene Green Energy Standard under which the national green electricity certification schemes can be accredited to ensure that the purchase of green energy leads to the provision of additional new green energy resources.

Purchasing green energy through the gas grid

The market for heating is mostly serviced by gas and oil rather than electric power, due to the high cost per kilowatt of electricity in many countries. Distribution of renewable electric power via the electrical grid has made it possible in many countries for consumers to choose renewable electric power, and in the same manner bionatural gas may in the future be made available to the average consumer via the existing natural gas grid.

Local green energy systems

Those not satisfied with the third-party grid approach to green energy via the power grid can install their own locally based renewable energy system. Renewable energy electrical systems from solar to wind to even local hydro-power in some cases, are some of the many types of renewable energy systems available locally. Additionally, for those interested in heating and cooling their dwelling via renewable energy, geothermal heat pump systems that tap the constant temperature of the earth, which is around 7 to 15 degrees Celsius a few feet underground, are an option and save money over conventional natural gas and petroleum-fueled heat approaches.

United States

The advantage of this approach in the United States is that many states offer incentives to offset the cost of installation of a renewable energy system. In California, Massachusetts and several other U.S. states, a new approach to community energy supply called Community Choice Aggregation has provided communities with the means to solicit a competitive electricity supplier and use municipal revenue bonds to finance development of local green energy resources. Individuals are usually assured that the electricity they are using is actually produced from a green energy source that they control. Once the system is paid for, the owner of a renewable energy system will be producing their own renewable electricity for essentially no cost and can sell the excess to the local utility at a profit.

Using green energy

Renewable energy, after its generation, needs to be stored in a medium for use with autonomous devices as well as vehicles. Also, to provide household electricity in remote areas (that is areas which are not connected to the mains electricity grid), energy storage

is required for use with renewable energy. Energy generation and consumption systems used in the latter case are usually stand-alone power systems.

Some examples are:

- energy carriers as hydrogen, liquid nitrogen, compressed air, oxyhydrogen, batteries, to power vehicles.
- flywheel energy storage, pumped-storage hydroelectricity is more usable in stationary applications (eg to power homes and offices. In household power systems, conversion of energy can also be done to reduce smell. For example organic matter such as cow dung and spoilable organic matter can be converted to biochar. To eliminate emissions, carbon capture and storage is then used.

Usually however, renewable energy is derived from the mains electricity grid. This means that energy storage is mostly not used, as the mains electricity grid is organised to produce the exact amount of energy being consumed at that particular moment. Energy production on the mains electricity grid is always set up as a combination of (large-scale) renewable energy plants, as well as other power plants as fossil-fuel power plants and nuclear power. This combination however, which is essential for this type of energy supply (as eg wind turbines, solar power plants etc.) can only produce when the wind blows and the sun shines. This is also one of the main drawbacks of the system as fossil fuel powerplants are polluting and are a main cause of global warming (nuclear power being an exception). Although fossil fuel power plants too can made emissionless (through carbon capture and storage), as well as renewable (if the plants are converted to e.g. biomass) the best solution is still to phase out the latter power plants over time. Nuclear power plants too can be more or less eliminated from their problem of nuclear waste through the use of nuclear reprocessing and newer plants as fast breeder and nuclear fusion plants.

Renewable energy power plants do provide a steady flow of energy. For example hydropower plants, ocean thermal plants, osmotic power plants all provide power at a regulated pace, and are thus available power sources at any given moment (even at night, windstill moments etc.). At present however, the number of steady-flow renewable energy plants alone is still too small to meet energy demands at the times of the day when the irregular producing renewable energy plants cannot produce power.

Besides the greening of fossil fuel and nuclear power plants, another option is the distribution and immediate use of power from solely renewable sources. In this set-up energy storage is again not necessary. For example, TREC has proposed to distribute solar power from the Sahara to Europe. Europe can distribute wind and ocean power to the Sahara and other countries. In this way, power is produced at any given time as at any point of the planet as the sun or the wind is up or ocean waves and currents are stirring. This option however is probably not possible in the short-term, as fossil fuel and nuclear power are still the main sources of energy on the mains electricity net and replacing them will not be possible overnight.

Several large-scale energy storage suggestions for the grid have been done. This improves efficiency and decreases energy losses but a conversion to a energy storing mains electricity grid is a very costly solution. Some costs could potentially be reduced by making use of energy storage equipment the consumer buys and not the state. An example is car batteries in personal vehicles that would double as an energy buffer for the electricity grid. However besides the cost, setting-up such a system would still be a very complicated and difficult procedure. Also, energy storage apparatus' as car batteries are also built with materials that pose a threat to the environment (eg sulphuric acid). The combined production of batteries for such a large part of the population would thus still not quite environmental. Besides car batteries however, other large-scale energy storage suggestions for the grid have been done which make use of less polluting energy carriers (eg compressed air tanks and flywheel energy storage).

Green energy and labelling by region

European Union

Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market includes the article 5 (*Guarantee of origin of electricity* from high-efficiency cogeneration).

Finland

Finnish electricity markets are among the most liberal of the world. Markets were partially opened for big electricity users in 1995 and for all users in 1997.

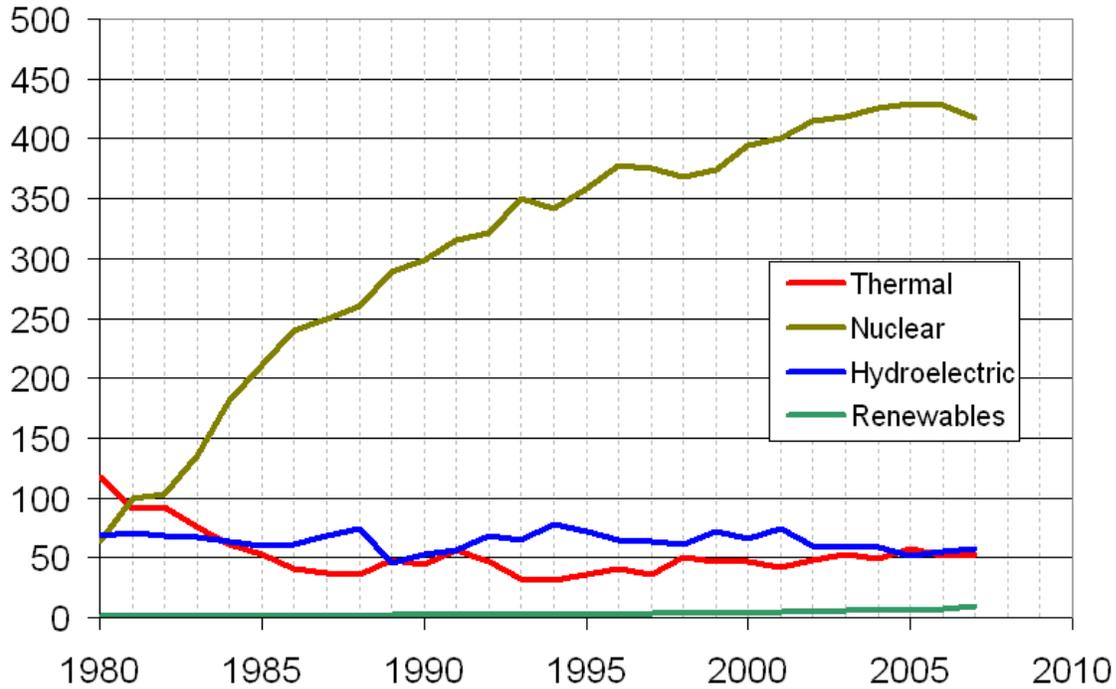
In 1998 the Finnish Association for Nature Conservation launched an ecolabel for electricity. The ecolabel is called EKOenergy. 10 out of 70 Finnish electricity retailers have managed to fulfill the criteria of EKOenergy. Almost 4% of the electricity in Finland was sold under the label in 2008. End users buying EKOenergy influence in profitability of different electricity production plants.

In 2009 25.7% of all the energy consumed in Finland was from renewable energy sources. Only part of electricity produced by renewables fulfills the EKOenergy criteria.

United Kingdom

France

**Electricity Production in France by Source
(TW-h)**



Nuclear power gives France the cleanest air of any industrialized country in the world.

■ Thermofossil ■ Hydroelectric ■ Nuclear ■ Other renewables

Over 75% of french electricity comes from nuclear power plants. France is the largest net exporter of electricity in the world. Electricity exports generate over 3 billion euros of revenue a year for France. French electricity costs are among the lowest in Europe. A major factor in the low cost of electricity in France is the use of a single reactor design, which allows for economies of scale. French CO₂ emissions are among the lowest in the developed world, with 10 tons of CO₂ equivalents per person per year. Danish citizens emit an average of 14 tons of CO₂ equivalents per person per year. Even Iceland, with its abundance of geothermal energy for heating, has higher per capita emissions at 10.4 tons of CO₂ equivalents per capita.

Spain

In Spain green energy is regulated by the Orden ITC/1522/2007.

Portugal

José Sócrates, the Portuguese Prime-minister said that Portugal is to become one of the largest producers and users of this type of energy in Europe by 2010, and that Portugal has a great potential to produce solar, water, waves, geothermic and wind energies.

United States

The United States Department of Energy (DOE), the Environmental Protection Agency (EPA), and the Center for Resource Solutions (CRS) recognizes the voluntary purchase of electricity from renewable energy sources (also called renewable electricity or green electricity) as green power.

The most popular way to purchase renewable energy as revealed by NREL data is through purchasing Renewable Energy Certificates (RECs). According to a Natural Marketing Institute (NMI) survey 55 percent of American consumers want companies to increase their use of renewable energy.

DOE selected six companies for its 2007 Green Power Supplier Awards, including Constellation NewEnergy; 3Degrees; Sterling Planet; SunEdison; Pacific Power and Rocky Mountain Power; and Silicon Valley Power. The combined green power provided by those six winners equals more than 5 billion kilowatt-hours per year, which is enough to power nearly 465,000 average U.S. households.

The U.S. Environmental Protection Agency (USEPA) Green Power Partnership is a voluntary program that supports the organizational procurement of renewable electricity by offering expert advice, technical support, tools and resources. This can help organizations lower the transaction costs of buying renewable power, reduce carbon footprint, and communicate its leadership to key stakeholders.

The USEPA recognized the West Division of Macy's Inc., The Timberland Company, and the City of Chico, California, for their on-site generation of solar power, and also recognized New York University and six companies for purchasing green power. The EPA also named the city of Bellingham, Washington, and six more companies as their Green Power Partners of the Year. Among all the companies, PepsiCo stands out as a partner of the year, because three of its bottling companies were also honored for buying green power. In addition, CRS awarded its Market Development Awards to the Western Washington Green Power Campaign, Clif Bar, and two individuals: John Schaeffer and Bill Spratley.

Throughout the country, more than half of all U.S. electricity customers now have an option to purchase some type of green power product from a retail electricity provider. Roughly one-quarter of the nation's utilities offer green power programs to customers, and voluntary retail sales of renewable energy in the United States totaled more than 12 billion kilowatt-hours in 2006, a 40% increase over the previous year.

Renewable energy



Burbo Bank Offshore Wind Farm, at the entrance to the River Mersey in North West England.



American President Barack Obama speaks at the DeSoto Next Generation Solar Energy Center, in the USA.

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). In 2008, about 19% of global final energy consumption came from renewables, with 13% coming from traditional biomass, which is mainly used for heating, and 3.2% from hydroelectricity. New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 2.7% and are growing very rapidly. The share of renewables in electricity generation is around 18%, with 15% of global electricity coming from hydroelectricity and 3% from new renewables.

Wind power is growing at the rate of 30% annually, with a worldwide installed capacity of 158 gigawatts (GW) in 2009, and is widely used in Europe, Asia, and the United States. At the end of 2009, cumulative global photovoltaic (PV) installations surpassed 21 GW and PV power stations are popular in Germany and Spain. Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 megawatt (MW) SEGS power plant in the Mojave Desert. The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel. Ethanol fuel is also widely available in the USA, the world's largest producer in absolute terms, although not as a percentage of its total motor fuel use.

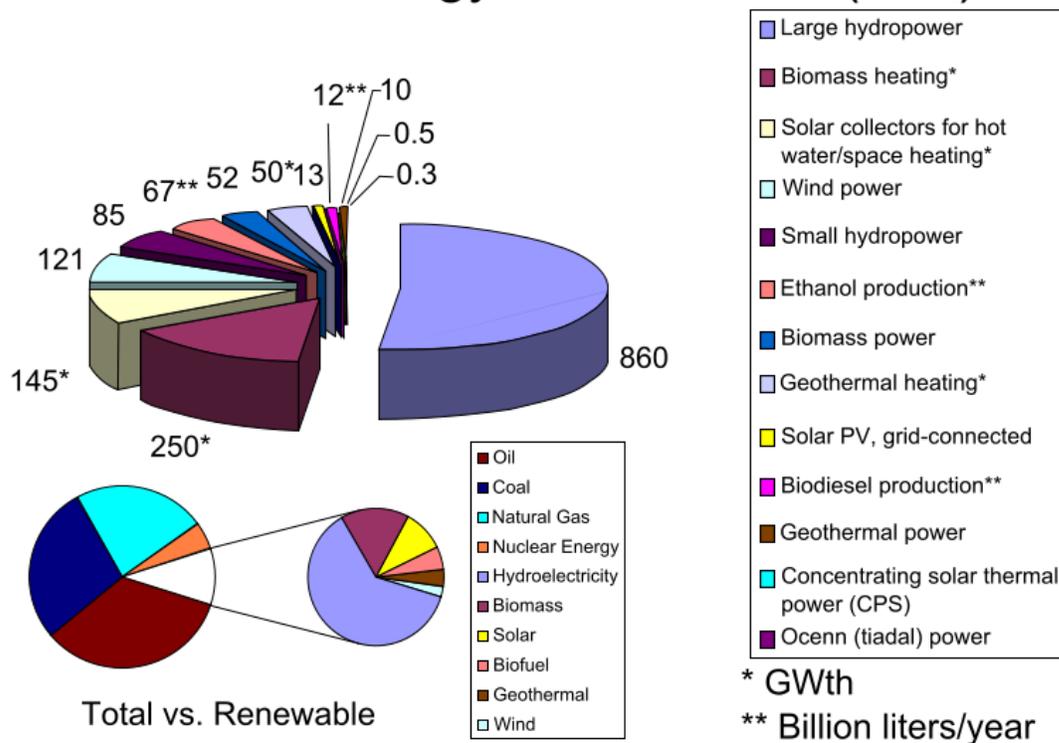
While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas, where energy is often crucial in human development. Globally, an estimated 3 million households get power from small solar PV systems. Micro-hydro systems configured into village-scale or county-scale mini-grids serve many

areas. More than 30 million rural households get lighting and cooking from biogas made in household-scale digesters. Biomass cookstoves are used by 160 million households.

Climate change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization. New government spending, regulation and policies helped the industry weather the 2009 economic crisis better than many other sectors.

Overview

Renewable energy, end of 2008 (GW)



2008 worldwide renewable-energy sources. *Source: REN21*

Renewable energy flows involve natural phenomena such as sunlight, wind, tides and geothermal heat, as the International Energy Agency explains:

Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

Renewable energy replaces conventional fuels in four distinct areas: power generation, hot water/ space heating, transport fuels, and rural (off-grid) energy services:

- **Power generation.** Renewable energy provides 18 percent of total electricity generation worldwide. Renewable power generators are spread across many countries, and wind power alone already provides a significant share of electricity in some areas: for example, 14 percent in the U.S. state of Iowa, 40 percent in the northern German state of Schleswig-Holstein, and 20 percent in Denmark. Some countries get most of their power from renewables, including Iceland (100 percent), Brazil (85 percent), Austria (62 percent), New Zealand (65 percent), and Sweden (54 percent).
- **Heating.** Solar hot water makes an important contribution in many countries, most notably in China, which now has 70 percent of the global total (180 GWth). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households. The use of biomass for heating continues to grow as well. In Sweden, national use of biomass energy has surpassed that of oil. Direct geothermal for heating is also growing rapidly.
- **Transport fuels.** Renewable biofuels have contributed to a significant decline in oil consumption in the United States since 2006. The 93 billion liters of biofuels produced worldwide in 2009 displaced the equivalent of an estimated 68 billion liters of gasoline, equal to about 5 percent of world gasoline production.

Mainstream forms of renewable energy

Wind power

Airflows can be used to run wind turbines. Modern wind turbines range from around 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use; the power output of a turbine is a function of the cube of the wind speed, so as wind speed increases, power output increases dramatically. Areas where winds are stronger and more constant, such as offshore and high altitude sites, are preferred locations for wind farms. Typical capacity factors are 20–40%, with values at the upper end of the range in particularly favourable sites.

Globally, the long-term technical potential of wind energy is believed to be five times total current global energy production, or 40 times current electricity demand. This could require large amounts of land to be used for wind turbines, particularly in areas of higher wind resources. Offshore resources experience mean wind speeds of ~90% greater than that of land, so offshore resources could contribute substantially more energy.

Wind power is renewable and produces no greenhouse gases during operation, such as carbon dioxide and methane.

Hydropower



The Hoover Dam when completed in 1936 was both the world's largest electric-power generating station and the world's largest concrete structure.

Energy in water can be harnessed and used. Since water is about 800 times denser than air, even a slow flowing stream of water, or moderate sea swell, can yield considerable amounts of energy. There are many forms of water energy:

- Hydroelectric energy is a term usually reserved for large-scale hydroelectric dams. Examples are the Grand Coulee Dam in Washington State and the Akosombo Dam in Ghana.
- Micro hydro systems are hydroelectric power installations that typically produce up to 100 kW of power. They are often used in water rich areas as a remote-area power supply (RAPS). There are many of these installations around the world, including several delivering around 50 kW in the Solomon Islands.
- Damless hydro systems derive kinetic energy from rivers and oceans without using a dam.
- Ocean energy describes all the technologies to harness energy from the ocean and the sea. This includes marine current power, ocean thermal energy conversion, and tidal power.

Solar energy



Monocrystalline solar cell

Solar energy is the energy derived from the sun through the form of solar radiation. Solar powered electrical generation relies on photovoltaics and heat engines. A partial list of other solar applications includes space heating and cooling through solar architecture, daylighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes.

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

Biomass

Biomass (plant material) is a renewable energy source because the energy it contains comes from the sun. Through the process of photosynthesis, plants capture the sun's energy. When the plants are burned, they release the sun's energy they contain. In this way, biomass functions as a sort of natural battery for storing solar energy. As long as biomass is produced sustainably, with only as much used as is grown, the battery will last indefinitely.

In general there are two main approaches to using plants for energy production: growing plants specifically for energy use, and using the residues from plants that are used for other things. The best approaches vary from region to region according to climate, soils and geography.

Biofuel



Information on pump regarding ethanol fuel blend up to 10%, California

Liquid biofuel is usually either bioalcohol such as bioethanol or an oil such as biodiesel.

Bioethanol is an alcohol made by fermenting the sugar components of plant materials and it is made mostly from sugar and starch crops. With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstocks for

ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil.

Biodiesel is made from vegetable oils, animal fats or recycled greases. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

Biofuels provided 1.8% of the world's transport fuel in 2008.

Geothermal energy



Krafla Geothermal Station in northeast Iceland

Geothermal energy is energy obtained by tapping the heat of the earth itself, both from kilometers deep into the Earth's crust in some places of the globe or from some meters in geothermal heat pump in all the places of the planet. It is expensive to build a power station but operating costs are low resulting in low energy costs for suitable sites. Ultimately, this energy derives from heat in the Earth's core.

Three types of power plants are used to generate power from geothermal energy: dry steam, flash, and binary. Dry steam plants take steam out of fractures in the ground and use it to directly drive a turbine that spins a generator. Flash plants take hot water, usually at temperatures over 200 °C, out of the ground, and allows it to boil as it rises to the surface then separates the steam phase in steam/water separators and then runs the steam through a turbine. In binary plants, the hot water flows through heat exchangers, boiling an organic fluid that spins the turbine. The condensed steam and remaining geothermal fluid from all three types of plants are injected back into the hot rock to pick up more heat.

The geothermal energy from the core of the Earth is closer to the surface in some areas than in others. Where hot underground steam or water can be tapped and brought to the surface it may be used to generate electricity. Such geothermal power sources exist in certain geologically unstable parts of the world such as Chile, Iceland, New Zealand, United States, the Philippines and Italy. The two most prominent areas for this in the United States are in the Yellowstone basin and in northern California. Iceland produced 170 MW geothermal power and heated 86% of all houses in the year 2000 through geothermal energy. Some 8000 MW of capacity is operational in total.

There is also the potential to generate geothermal energy from hot dry rocks. Holes at least 3 km deep are drilled into the earth. Some of these holes pump water into the earth, while other holes pump hot water out. The heat resource consists of hot underground radiogenic granite rocks, which heat up when there is enough sediment between the rock and the earths surface. Several companies in Australia are exploring this technology.

Renewable energy commercialization

Growth of renewables

During the five-years from the end of 2004 through 2009, worldwide renewable energy capacity grew at rates of 10–60 percent annually for many technologies. For wind power and many other renewable technologies, growth accelerated in 2009 relative to the previous four years. More wind power capacity was added during 2009 than any other renewable technology. However, grid-connected PV increased the fastest of all renewables technologies, with a 60-percent annual average growth rate for the five-year period.

Selected renewable energy indicators

Selected global indicators	2007	2008	2009
Investment in new renewable capacity (annual)	104	130	150 billion USD
Existing renewables power capacity, including large-scale hydro	1,070	1,140	1,230 GWe
Existing renewables power capacity, excluding large hydro	240	280	305 GWe

Wind power capacity (existing)	94	121	159 GWe
Solar PV capacity (grid-connected)	7.6	13.5	21 GWe
Solar hot water capacity	126	149	180 GWth
Ethanol production (annual)	50	69	76 billion liters
Biodiesel production (annual)	10	15	17 billion liters
Countries with policy targets for renewable energy use	68	75	85

Economic trends

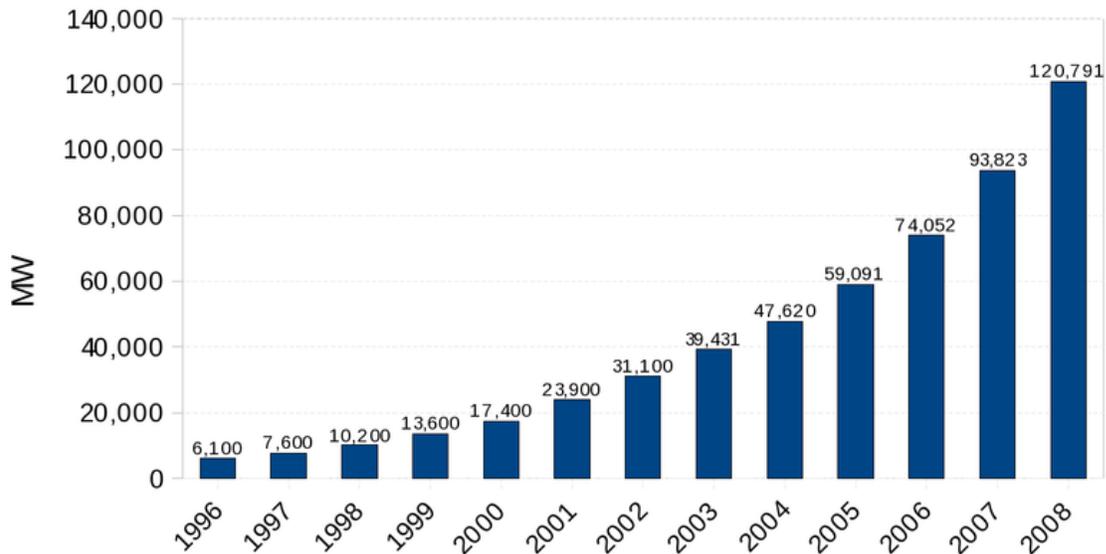
All forms of energy are expensive, but as time progresses, renewable energy generally gets cheaper, while fossil fuels generally get more expensive. Al Gore has explained that renewable energy technologies are declining in price for three main reasons:

First, once the renewable infrastructure is built, the fuel is free forever. Unlike carbon-based fuels, the wind and the sun and the earth itself provide fuel that is free, in amounts that are effectively limitless.

Second, while fossil fuel technologies are more mature, renewable energy technologies are being rapidly improved. So innovation and ingenuity give us the ability to constantly increase the efficiency of renewable energy and continually reduce its cost.

Third, once the world makes a clear commitment to shifting toward renewable energy, the volume of production will itself sharply reduce the cost of each windmill and each solar panel, while adding yet more incentives for additional research and development to further speed up the innovation process.

Wind power market



Wind power: worldwide installed capacity 1996-2008

At the end of 2009, worldwide wind farm capacity was 157,900 MW, representing an increase of 31 percent during the year, and wind power supplied some 1.3% of global electricity consumption. Wind power accounts for approximately 19% of electricity use in Denmark, 9% in Spain and Portugal, and 6% in Germany and the Republic of Ireland. The United States is an important growth area and installed U.S. wind power capacity reached 25,170 MW at the end of 2008. As of September 2009, the Roscoe Wind Farm (781 MW) is the world's largest wind farm.

As of 2009, the 209 megawatt (MW) Horns Rev 2 wind farm in Denmark is the world's largest offshore wind farm. The United Kingdom is the world's leading generator of offshore wind power, followed by Denmark.

New generation of solar thermal plants



Solar Towers from left: PS10, PS20

Large solar thermal power stations include the 354 MW Solar Energy Generating Systems power plant in the USA, Nevada Solar One (USA, 64 MW), Andasol 1 (Spain, 50 MW), Andasol 2 (Spain, 50 MW), PS20 solar power tower (Spain, 20 MW), and the PS10 solar power tower (Spain, 11 MW).

The solar thermal power industry is growing rapidly with 1.2 GW under construction as of April 2009 and another 13.9 GW announced globally through 2014. Spain is the epicenter of solar thermal power development with 22 projects for 1,037 MW under construction, all of which are projected to come online by the end of 2010. In the United States, 5,600 MW of solar thermal power projects have been announced. In developing countries, three World Bank projects for integrated solar thermal/combined-cycle gas-turbine power plants in Egypt, Mexico, and Morocco have been approved.

Photovoltaic market



40 MW PV Array installed in Waldpolenz, Germany

Photovoltaic production has been increasing by an average of some 20 percent each year since 2002, making it a fast-growing energy technology. At the end of 2009, the cumulative global PV installations surpassed 21,000 megawatts.

As of September 2010, the largest photovoltaic (PV) power plants in the world are the Sarnia Photovoltaic Power Plant (Canada, 80 MW), Olmedilla Photovoltaic Park (Spain, 60 MW), the Strasskirchen Solar Park (Germany, 54 MW), the Lieberose Photovoltaic Park (Germany, 53 MW), the Puertollano Photovoltaic Park (Spain, 50 MW), the Moura Photovoltaic Power Station (Portugal, 46 MW), and the Waldpolenz Solar Park (Germany, 40 MW). Many of these plants are integrated with agriculture and some use innovative tracking systems that follow the sun's daily path across the sky to generate more electricity than conventional fixed-mounted systems. There are no fuel costs or emissions during operation of the power stations.

Topaz Solar Farm is a proposed 550 MW solar photovoltaic power plant which is to be built northwest of California Valley in the USA at a cost of over \$1 billion. High Plains Ranch is a proposed 250 MW solar photovoltaic power plant which is to be built on the Carrizo Plain, northwest of California Valley.

However, when it comes to renewable energy systems and PV, it is not just large systems that matter. Building-integrated photovoltaics or "onsite" PV systems use existing land and structures and generate power close to where it is consumed.

Use of ethanol for transportation



E95 trial bus operating in São Paulo, Brazil

Since the 1970s, Brazil has had an ethanol fuel program which has allowed the country to become the world's second largest producer of ethanol (after the United States) and the world's largest exporter. Brazil's ethanol fuel program uses modern equipment and cheap sugar cane as feedstock, and the residual cane-waste (bagasse) is used to process heat and power. There are no longer light vehicles in Brazil running on pure gasoline. By the end of 2008 there were 35,000 filling stations throughout Brazil with at least one ethanol pump.

Nearly all the gasoline sold in the United States today is mixed with 10 percent ethanol, a mix known as E10, and motor vehicle manufacturers already produce vehicles designed to run on much higher ethanol blends. Ford, DaimlerChrysler, and GM are among the automobile companies that sell "flexible-fuel" cars, trucks, and minivans that can use gasoline and ethanol blends ranging from pure gasoline up to 85% ethanol (E85). By mid-2006, there were approximately six million E85-compatible vehicles on U.S. roads. The challenge is to expand the market for biofuels beyond the farm states where they have been most popular to date. Flex-fuel vehicles are assisting in this transition because they allow drivers to choose different fuels based on price and availability. The *Energy*

Policy Act of 2005, which calls for 7.5 billion gallons of biofuels to be used annually by 2012, will also help to expand the market.

Geothermal energy commercialization



The West Ford Flat power plant is one of 22 power plants at The Geysers

The International Geothermal Association (IGA) has reported that 10,715 megawatts (MW) of geothermal power in 24 countries is online, which is expected to generate 67,246 GWh of electricity in 2010. This represents a 20% increase in geothermal power online capacity since 2005. IGA projects this will grow to 18,500 MW by 2015, due to the large number of projects presently under consideration, often in areas previously assumed to have little exploitable resource.

In 2010, the United States led the world in geothermal electricity production with 3,086 MW of installed capacity from 77 power plants; the largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California. The Philippines follows the US as the second highest producer of geothermal power in the world, with 1,904 MW of capacity online; geothermal power makes up approximately 18% of the country's electricity generation.

Geothermal (ground source) heat pumps represented an estimated 30 GWth of installed capacity at the end of 2008, with other direct uses of geothermal heat (i.e., for space heating, agricultural drying and other uses) reaching an estimated 15 GWth. As of 2008, at least 76 countries use direct geothermal energy in some form.

Wave farms expansion



One of 3 Pelamis Wave Energy Converters in the harbor of Peniche, Portugal

Portugal now has the world's first commercial wave farm, the *Agucadoura Wave Park*, officially opened in September 2008. The farm uses three Pelamis P-750 machines generating 2.25 MW. Initial costs are put at € 8.5 million. A second phase of the project is now planned to increase the installed capacity to 21MW using a further 25 Pelamis machines.

Funding for a wave farm in Scotland was announced in February, 2007 by the Scottish Government, at a cost of over 4 million pounds, as part of a UK£13 million funding packages for ocean power in Scotland. The farm will be the world's largest with a capacity of 3MW generated by four Pelamis machines.

Developing country markets

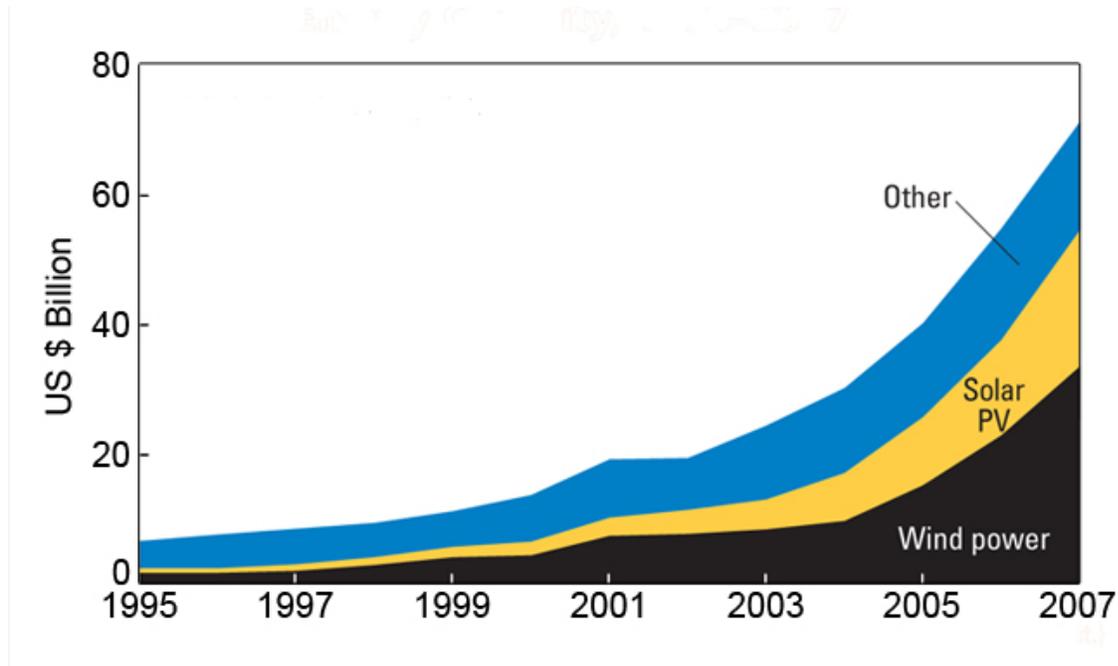
Renewable energy can be particularly suitable for developing countries. In rural and remote areas, transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Producing renewable energy locally can offer a viable alternative.

Biomass cookstoves are used by 40 percent of the world's population. These stoves are being manufactured in factories and workshops worldwide, and more than 160 million households now use them. More than 30 million rural households get lighting and cooking from biogas made in household-scale digesters. An estimated 3 million households get power from small solar PV systems. Micro-hydro systems configured into village-scale or county-scale mini-grids serve many areas.

Kenya is the world leader in the number of solar power systems installed per capita. More than 30,000 very small solar panels, each producing 12 to 30 watts, are sold in Kenya annually.

Renewable energy projects in many developing countries have demonstrated that renewable energy can directly contribute to poverty alleviation by providing the energy needed for creating businesses and employment. Renewable energy technologies can also make indirect contributions to alleviating poverty by providing energy for cooking, space heating, and lighting. Renewable energy can also contribute to education, by providing electricity to schools.

Industry and policy trends



Global renewable energy investment growth (1995-2007)

Global revenues for solar photovoltaics, wind power, and biofuels expanded from \$76 billion in 2007 to \$115 billion in 2008. New global investments in clean energy technologies expanded by 4.7 percent from \$148 billion in 2007 to \$155 billion in 2008. U.S. President Barack Obama's American Recovery and Reinvestment Act of 2009 includes more than \$70 billion in direct spending and tax credits for clean energy and associated transportation programs. Clean Edge suggests that the commercialization of clean energy will help countries around the world pull out of the current economic malaise. Leading renewable energy companies include First Solar, Gamesa, GE Energy, Q-Cells, Sharp Solar, Siemens, SunOpta, Suntech, and Vestas.

The International Renewable Energy Agency (IRENA) is an intergovernmental organization for promoting the adoption of renewable energy worldwide. It aims to provide concrete policy advice and facilitate capacity building and technology transfer. IRENA was formed on January 26, 2009, by 75 countries signing the charter of IRENA. As of March 2010, IRENA has 143 member states who all are considered as founding members, of which 14 have also ratified the statute.

Renewable energy policy targets exist in some 73 countries around the world, and public policies to promote renewable energy use have become more common in recent years. At least 64 countries have some type of policy to promote renewable power generation. Mandates for solar hot water in new construction are becoming more common at both national and local levels. Mandates for blending biofuels into vehicle fuels have been enacted in 17 countries.

New and emerging renewable energy technologies

New and emerging renewable energy technologies are still under development and include cellulosic ethanol, hot-dry-rock geothermal power, and ocean energy. These technologies are not yet widely demonstrated or have limited commercialization. Many are on the horizon and may have potential comparable to other renewable energy technologies, but still depend on attracting sufficient attention and research, development and demonstration (RD&D) funding.

Cellulosic ethanol

Companies such as Iogen, Broin, and Abengoa are building refineries that can process biomass and turn it into ethanol, while companies such as Diversa, Novozymes, and Dyadic are producing enzymes which could enable a cellulosic ethanol future. The shift from food crop feedstocks to waste residues and native grasses offers significant opportunities for a range of players, from farmers to biotechnology firms, and from project developers to investors.

Selected Commercial Cellulosic Ethanol Plants in the U.S.
(Operational or under construction)

Company	Location	Feedstock
Abengoa Bioenergy	Hugoton, KS	Wheat straw
BlueFire Ethanol	Irvine, CA	Multiple sources
Gulf Coast Energy	Mossy Head, FL	Wood waste
Mascoma	Lansing, MI	Wood
POET LLC	Emmetsburg, IA	Corn cobs
Range Fuels	Treutlen County, GA	Wood waste
SunOpta	Little Falls, MN	Wood chips
Xethanol	Auburndale, FL	Citrus peels

Ocean energy

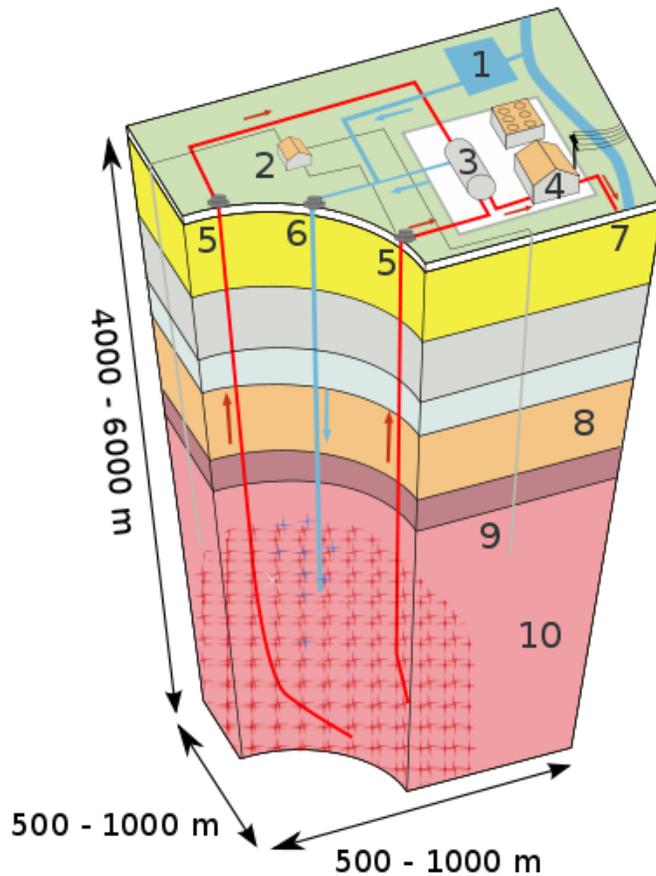
Systems to harvest utility-scale electrical power from ocean waves have recently been gaining momentum as a viable technology. The potential for this technology is considered promising, especially on west-facing coasts with latitudes between 40 and 60 degrees:

In the United Kingdom, for example, the Carbon Trust recently estimated the extent of the economically viable offshore resource at 55 TWh per year, about 14% of current national demand. Across Europe, the technologically achievable resource has been estimated to be at least 280 TWh per year. In 2003, the U.S. Electric Power Research Institute (EPRI) estimated the viable resource in the United States at 255 TWh per year (6% of demand).

The world's first commercial tidal power station was installed in 2007 in the narrows of Strangford Lough in Ireland. The 1.2 megawatt underwater tidal electricity generator, part of Northern Ireland's Environment & Renewable Energy Fund scheme, takes advantage of the fast tidal flow (up to 4 metres per second) in the lough. Although the generator is powerful enough to power a thousand homes, the turbine has minimal environmental impact, as it is almost entirely submerged, and the rotors pose no danger to wildlife as they turn quite slowly.

Ocean thermal energy conversion (OTEC) uses the temperature difference that exists between deep and shallow waters to run a heat engine.

Enhanced Geothermal Systems



Enhanced geothermal system 1:Reservoir 2:Pump house 3:Heat exchanger
 4:Turbine hall 5:Production well 6:Injection well 7:Hot water to district heating
 8:Porous sediments 9:Observation well 10:Crystalline bedrock

Enhanced Geothermal Systems are a new type of geothermal power technologies that do not require natural convective hydrothermal resources. The vast majority of geothermal energy within drilling reach is in dry and non-porous rock. EGS technologies "enhance" and/or create geothermal resources in this "hot dry rock (HDR)" through hydraulic stimulation.

EGS / HDR technologies, like hydrothermal geothermal, are expected to be baseload resources which produce power 24 hours a day like a fossil plant. Distinct from hydrothermal, HDR / EGS may be feasible anywhere in the world, depending on the economic limits of drill depth. Good locations are over deep granite covered by a thick (3–5 km) layer of insulating sediments which slow heat loss. HDR wells are expected to have a useful life of 20 to 30 years before the outflow temperature drops about 10 degrees Celsius and the well becomes uneconomic. If left for 50 to 300 years the temperature will recover.

There are HDR and EGS systems currently being developed and tested in France, Australia, Japan, Germany, the U.S. and Switzerland. The largest EGS project in the world is a 25 megawatt demonstration plant currently being developed in the Cooper Basin, Australia. The Cooper Basin has the potential to generate 5,000–10,000 MW.

Nanotechnology thin-film solar panels

Solar power panels that use nanotechnology, which can create circuits out of individual silicon molecules, may cost half as much as traditional photovoltaic cells, according to executives and investors involved in developing the products. Nanosolar has secured more than \$100 million from investors to build a factory for nanotechnology thin-film solar panels.

Other

Osmotic power (or *salinity gradient power*) is the energy retrieved from the difference in the salt concentration between seawater and river water. Two practical methods for this are reverse electrodialysis (RED) and pressure retarded osmosis. (PRO).

A microbial fuel cell is a bio-electrochemical system that drives a current by mimicking bacterial interactions found in nature - converting chemical energy to electrical energy by the catalytic reaction of microorganisms.

Renewable energy debate

Renewable electricity production, from sources such as wind power and solar power, is sometimes criticized for being variable or intermittent. However, the International Energy Agency has stated that deployment of renewable technologies usually increases the diversity of electricity sources and, through local generation, contributes to the flexibility of the system and its resistance to central shocks.

There have been "not in my back yard" (NIMBY) concerns relating to the visual and other impacts of some wind farms, with local residents sometimes fighting or blocking construction. In the USA, the Massachusetts Cape Wind project was delayed for years partly because of aesthetic concerns. However, residents in other areas have been more positive and there are many examples of community wind farm developments. According to a town councilor, the overwhelming majority of locals believe that the Ardrossan Wind Farm in Scotland has enhanced the area.

Chapter- 7

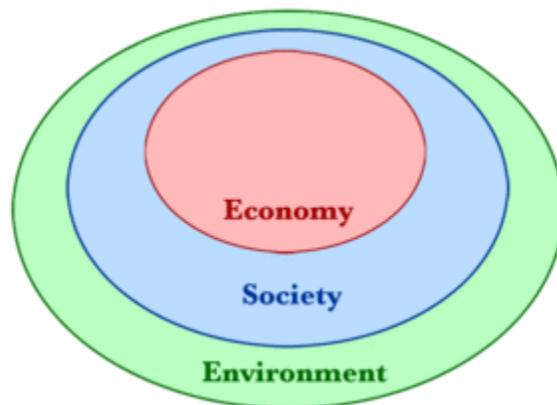
Sustainable Development

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for generations to come. The term was used by the Brundtland Commission which coined what has become the most often-quoted definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."

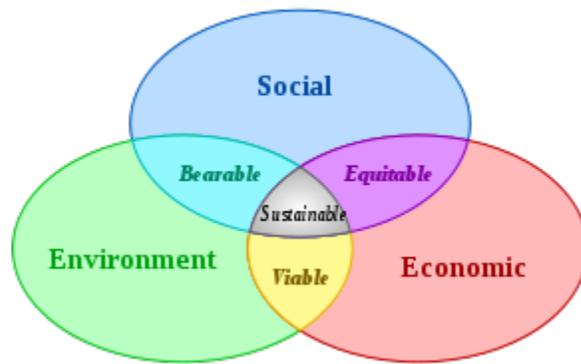
Sustainable development ties together concern for the carrying capacity of natural systems with the social challenges facing humanity. As early as the 1970s "sustainability" was employed to describe an economy "in equilibrium with basic ecological support systems." Ecologists have pointed to *The Limits to Growth*, and presented the alternative of a "steady state economy" in order to address environmental concerns.

The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability.

Scope and definitions



A representation of sustainability showing how both economy and society are constrained by environmental limits (2003)



Scheme of sustainable development: at the confluence of three constituent parts.(2006)



The natural resource of wind powers these 5MW wind turbines on this wind farm 28 km off the coast of Belgium.

The concept has included notions of weak sustainability, strong sustainability and deep ecology. Sustainable development does not focus solely on environmental issues.

In 1987, the United Nations released the Brundtland Report, which defines sustainable development as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs.'

The United Nations 2005 World Summit Outcome Document refers to the "interdependent and mutually reinforcing pillars" of sustainable development as economic development, social development, and environmental protection.

Indigenous peoples have argued, through various international forums such as the United Nations Permanent Forum on Indigenous Issues and the Convention on Biological Diversity, that there are *four* pillars of sustainable development, the fourth being cultural. *The Universal Declaration on Cultural Diversity* (UNESCO, 2001) further elaborates the concept by stating that "...cultural diversity is as necessary for humankind as biodiversity is for nature"; it becomes "one of the roots of development understood not simply in terms of economic growth, but also as a means to achieve a more satisfactory intellectual, emotional, moral and spiritual existence". In this vision, cultural diversity is the fourth policy area of sustainable development.

Economic Sustainability: Agenda 21 clearly identified information, integration, and participation as key building blocks to help countries achieve development that recognises these interdependent pillars. It emphasises that in sustainable development everyone is a user and provider of information. It stresses the need to change from old sector-centred ways of doing business to new approaches that involve cross-sectoral co-ordination and the integration of environmental and social concerns into all development processes. Furthermore, Agenda 21 emphasises that broad public participation in decision making is a fundamental prerequisite for achieving sustainable development.

According to Hasna Vancock, sustainability is a process which tells of a development of all aspects of human life affecting sustenance. It means resolving the conflict between the various competing goals, and involves the simultaneous pursuit of economic prosperity, environmental quality and social equity famously known as three dimensions (triple bottom line) with is the resultant vector being technology, hence it is a continually evolving process; the 'journey' (the process of achieving sustainability) is of course vitally important, but only as a means of getting to the destination (the desired future state). However, the 'destination' of sustainability is not a fixed place in the normal sense that we understand destination. Instead, it is a set of wishful characteristics of a future system.



Solar towers utilize the natural resource of the sun, and are a renewable energy source. From left: PS10 and PS20 solar towers.

Green development is generally differentiated from sustainable development in that Green development prioritizes what its proponents consider to be environmental

sustainability over economic and cultural considerations. Proponents of Sustainable Development argue that it provides a context in which to improve overall sustainability where cutting edge Green development is unattainable. For example, a cutting edge treatment plant with extremely high maintenance costs may not be sustainable in regions of the world with fewer financial resources. An environmentally ideal plant that is shut down due to bankruptcy is obviously less sustainable than one that is maintainable by the community, even if it is somewhat less effective from an environmental standpoint.

Some research activities start from this definition to argue that the environment is a combination of nature and culture. The Network of Excellence "Sustainable Development in a Diverse World", sponsored by the European Union, integrates multidisciplinary capacities and interprets cultural diversity as a key element of a new strategy for sustainable development.

Still other researchers view environmental and social challenges as opportunities for development action. This is particularly true in the concept of sustainable enterprise that frames these global needs as opportunities for private enterprise to provide innovative and entrepreneurial solutions. This view is now being taught at many business schools including the Center for Sustainable Global Enterprise at Cornell University and the Erb Institute for Global Sustainable Enterprise at the University of Michigan.

The United Nations Division for Sustainable Development lists the following areas as coming within the scope of sustainable development:

Sustainable development is an eclectic concept, as a wide array of views fall under its umbrella. The concept has included notions of weak sustainability, strong sustainability and deep ecology. Different conceptions also reveal a strong tension between ecocentrism and anthropocentrism. Many definitions and images (Visualizing Sustainability) of sustainable development coexist. Broadly defined, the sustainable development mantra enjoins current generations to take a systems approach to growth and development and to manage natural, produced, and social capital for the welfare of their own and future generations.

During the last ten years, different organizations have tried to measure and monitor the proximity to what they consider sustainability by implementing what has been called sustainability metrics and indices.

Sustainable development is said to set limits on the developing world. While current first world countries polluted significantly during their development, the same countries encourage third world countries to reduce pollution, which sometimes impedes growth. Some consider that the implementation of sustainable development would mean a reversion to pre-modern lifestyles.

Others have criticized the overuse of the term:

"[The] word sustainable has been used in too many situations today, and ecological sustainability is one of those terms that confuse a lot of people. You hear about sustainable development, sustainable growth, sustainable economies, sustainable societies, sustainable agriculture. Everything is sustainable (Temple, 1992)."

Environmental sustainability



Water is an important natural resource that covers 71% of the Earth's surface. Image is the Earth photographed from Apollo 17.

Environmental sustainability is the process of making sure current processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behavior.

An "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is used up faster than it can be replenished. Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally. Inherently the concept of sustainable development is intertwined with the concept of carrying capacity. Theoretically, the long-term result of environmental degradation is the inability to sustain human life. Such degradation on a global scale could imply extinction for humanity.

Consumption of renewable resources	State of environment	Sustainability
More than nature's ability to replenish	Environmental degradation	Not sustainable
Equal to nature's ability to replenish	Environmental equilibrium	Steady state economy
Less than nature's ability to replenish	Environmental renewal	Environmentally sustainable

The notion of capital in sustainable development



Deforestation of native rain forest in Rio de Janeiro City for extraction of clay for civil engineering (2009 picture).

The sustainable development debate is based on the assumption that societies need to manage three types of capital (economic, social, and natural), which may be non-substitutable and whose consumption might be irreversible. Daly (1991), for example, points to the fact that natural capital can not necessarily be substituted by economic capital. While it is possible that we can find ways to replace some natural resources, it is much more unlikely that they will ever be able to replace eco-system services, such as the protection provided by the ozone layer, or the climate stabilizing function of the Amazonian forest. In fact natural capital, social capital and economic capital are often complementarities. A further obstacle to substitutability lies also in the multi-functionality of many natural resources. Forests, for example, not only provide the raw material for paper (which can be substituted quite easily), but they also maintain biodiversity, regulate water flow, and absorb CO₂.

Another problem of natural and social capital deterioration lies in their partial irreversibility. The loss in biodiversity, for example, is often definite. The same can be true for cultural diversity. For example with globalisation advancing quickly the number of indigenous languages is dropping at alarming rates. Moreover, the depletion of natural and social capital may have non-linear consequences. Consumption of natural and social capital may have no observable impact until a certain threshold is reached. A lake can, for example, absorb nutrients for a long time while actually increasing its productivity. However, once a certain level of algae is reached lack of oxygen causes the lake's ecosystem to break down suddenly.

Market failure



Before flue gas desulfurization was installed, the air-polluting emissions from this power plant in New Mexico contained excessive amounts of sulfur dioxide.

If the degradation of natural and social capital has such important consequence the question arises why action is not taken more systematically to alleviate it. Cohen and Winn (2007) point to four types of market failure as possible explanations: First, while the benefits of natural or social capital depletion can usually be privatized the costs are often externalized (i.e. they are borne not by the party responsible but by society in general). Second, natural capital is often undervalued by society since we are not fully aware of the real cost of the depletion of natural capital. Information asymmetry is a third reason—often the link between cause and effect is obscured, making it difficult for actors to make informed choices. Cohen and Winn close with the realization that contrary to economic theory many firms are not perfect optimizers. They postulate that firms often do not optimize resource allocation because they are caught in a "business as usual" mentality.

The business case for sustainable development

The most broadly accepted criterion for corporate sustainability constitutes a firm's efficient use of natural capital. This eco-efficiency is usually calculated as the economic value added by a firm in relation to its aggregated ecological impact. This idea has been popularised by the World Business Council for Sustainable Development (WBCSD) under the following definition: "Eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's carrying capacity." (DeSimone and Popoff, 1997: 47)

Similar to the eco-efficiency concept but so far less explored is the second criterion for corporate sustainability. Socio-efficiency describes the relation between a firm's value added and its social impact. Whereas, it can be assumed that most corporate impacts on the environment are negative (apart from rare exceptions such as the planting of trees) this is not true for social impacts. These can be either positive (e.g. corporate giving, creation of employment) or negative (e.g. work accidents, mobbing of employees, human rights abuses). Depending on the type of impact socio-efficiency thus either tries to minimize negative social impacts (i.e. accidents per value added) or maximise positive social impacts (i.e. donations per value added) in relation to the value added.

Both eco-efficiency and socio-efficiency are concerned primarily with increasing economic sustainability. In this process they instrumentalize both natural and social capital aiming to benefit from win-win situations. However, as Dyllick and Hockerts point out the business case alone will not be sufficient to realise sustainable development. They point towards eco-effectiveness, socio-effectiveness, sufficiency, and eco-equity as four criteria that need to be met if sustainable development is to be reached.

Critique of the concept of sustainable development



Deforestation and increased road-building in the Amazon Rainforest are a significant concern because of increased human encroachment upon wilderness areas, increased resource extraction and further threats to biodiversity.

The concept of "Sustainable Development" raises several critiques at different levels.

Purpose

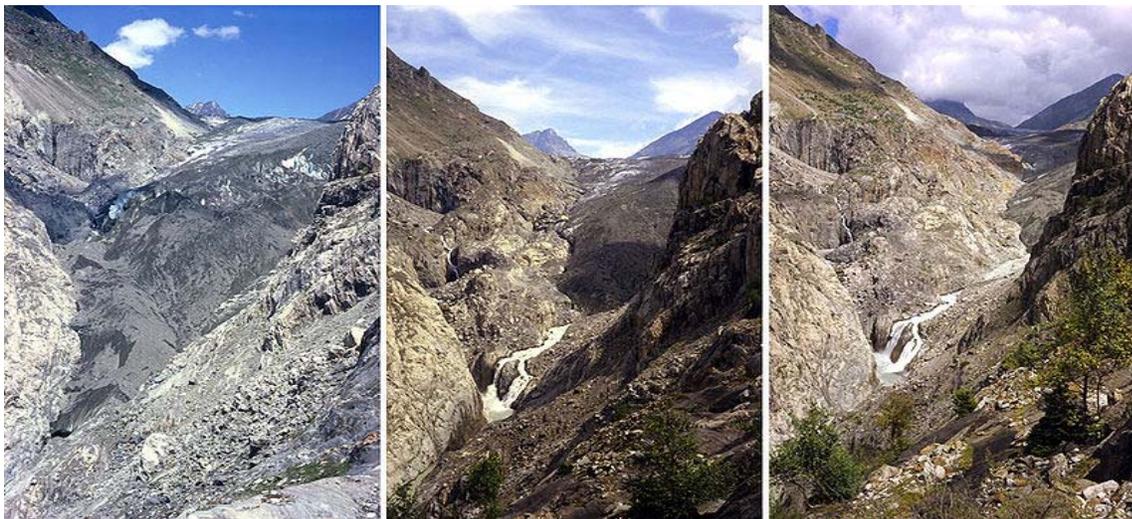
Various writers have commented on the population control agenda that seems to underlie the concept of sustainable development. Maria Sophia Aguirre writes:

"Sustainable development is a policy approach that has gained quite a lot of popularity in recent years, especially in international circles. By attaching a specific interpretation to sustainability, population control policies have become the overriding approach to development, thus becoming the primary tool used to "promote" economic development in developing countries and to protect the environment."

Mary Jo Anderson suggests that the real purpose of sustainable development is to contain and limit economic development in developing countries, and in so doing control population growth. It is suggested that this is the reason the main focus of most programs is still on low-income agriculture. Joan Veon, a businesswoman and international reporter, who covered 64 global meetings on sustainable development posits that:

"Sustainable development has continued to evolve as that of protecting the world's resources while its true agenda is to control the world's resources. It should be noted that Agenda 21 sets up the global infrastructure needed to manage, count, and control all of the world's assets."

Consequences



The retreat of Aletsch Glacier in the Swiss Alps (situation in 1979, 1991 and 2002), due to global warming.

John Baden views the notion of sustainable development as dangerous because the consequences have unknown effects. He writes: "In economy like in ecology, the interdependence rule applies. Isolated actions are impossible. A policy which is not carefully enough thought will carry along various perverse and adverse effects for the ecology as much as for the economy. Many suggestions to save our environment and to promote a model of 'sustainable development' risk indeed leading to reverse effects." Moreover, he evokes the bounds of public action which are underlined by the public choice theory: the quest by politicians of their own interests, lobby pressure, partial disclosure etc. He develops his critique by noting the vagueness of the expression, which can cover anything. It is a gateway to interventionist proceedings which can be against the principle of freedom and without proven efficacy. Against this notion, he is a proponent of private property to impel the producers and the consumers to save the natural resources. According to Baden, "the improvement of environment quality depends on the market economy and the existence of legitimate and protected property rights." They enable the effective practice of personal responsibility and the development

of mechanisms to protect the environment. The State can in this context “create conditions which encourage the people to save the environment.”

Vagueness of the term



A sewage treatment plant that uses environmentally friendly solar energy, located at Santuari de Lluc monastery.

Some criticize the term "sustainable development", stating that the term is too vague. For example, both Jean-Marc Jancovici or the philosopher Luc Ferry express this view. The latter writes about sustainable development: "I know that this term is obligatory, but I find it also absurd, or rather so vague that it says nothing." Luc Ferry adds that the term is trivial by a proof of contradiction: "who would like to be a proponent of an “untenable development! Of course no one! [...] The term is more charming than meaningful. [...] Everything must be done so that it does not turn into Russian-type administrative planning with ill effects."

Basis

Sylvie Brunel, French geographer and specialist of the Third World, develops in *A qui profite le développement durable* (Who benefits from sustainable development?) (2008) a critique of the basis of sustainable development, with its binary vision of the world, can be compared to the Christian vision of Good and Evil, a idealized nature where the human being is an animal like the others or even an alien. Nature – as Rousseau thought – is better than the human being. It is a parasite, harmful for the nature. But the human is the one who protects the biodiversity, where normally only the strong survive.

Moreover, she thinks that the ideas of sustainable development can hide a will to protectionism from the developed country to impede the development of the other countries. For Sylvie Brunel, the sustainable development serves as a pretext for the protectionism and "I have the feeling about sustainable development that it is perfectly helping out the capitalism".

"De-growth"

The proponents of the de-growth reckon that the term of sustainable development is an oxymoron. According to them, on a planet where 20% of the population consumes 80% of the natural resources, a sustainable development cannot be possible for this 20%: "According to the origin of the concept of sustainable development, a development which meets the needs of the present without compromising the ability of future generations to meet their own needs, the right term for the developed countries should be a sustainable de-growth".

Sustainable development in economics

The Venn diagram of sustainable development shown above has many versions, but was first used by economist Edward Barbier (1987). However, Pearce, Barbier and Markandya (1989) criticized the Venn approach due to the intractability of operationalizing separate indices of economic, environmental, and social sustainability and somehow combining them. They also noted that the Venn approach was inconsistent with the Brundtland Commission Report, which emphasized the interlinkages between economic development, environmental degradation, and population pressure instead of three objectives. Economists have since focused on viewing the economy and the environment as a single interlinked system with a unified valuation methodology (Hamilton 1999, Dasgupta 2007). Intergenerational equity can be incorporated into this approach, as has become common in economic valuations of climate change economics (Heal, 2009). Ruling out discrimination against future generations and allowing for the possibility of renewable alternatives to petro-chemicals and other non-renewable resources, efficient policies are compatible with increasing human welfare, eventually reaching a golden-rule steady state (Ayong le Kama, 2001 and Endress et al. 2005). Thus the three pillars of sustainable development are interlinkages, intergenerational equity, and dynamic efficiency (Stavins, et al. 2003).

Arrow et al. (2004) and other economists (e.g. Asheim, 1999 and Pezzey, 1989 and 1997) have advocated a form of the weak criterion for sustainable development – the requirement that the wealth of a society, including human-capital, knowledge-capital and natural-capital (as well as produced capital) not decline over time. Others, including Barbier 2007, continue to contend that strong sustainability – non-depletion of essential forms of natural capital – may be appropriate.