ISSUES, CONCEPTS AND APPLICATIONS FOR SUSTAINABILITY

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Abstract: Humanity and societies today face important challenges related to sustainability and these are expected to become more significant in the future. Making societies and their development more sustainable requires the consideration of economic, social, environmental and other factors. Sustainability assessment tools are needed to evaluate how is the sustainability of a process or system, and how that is affected when a change is made. To account for all relevant factors, a comprehensive set of indicators is required, including both quantitative indicators which are measurable and practical and qualitative indicators where necessary. In this article, sustainability concepts and definitions are reviewed and the historical context for sustainability is briefly described. Then sustainability is discussed, focusing on its economic, environmental and social dimensions, and the related concept of sustainable development is examined. Issues related to sustainability are discussed throughout. Finally, assessment measures for sustainability are examined, and several applications are presented.

Keywords: sustainability, sustainable development, environment, climate change, equity.

Acronyms: CFC = Chlorofluorocarbon; GHG = Greenhouse gas; UV = Ultraviolet radiation.

INTRODUCTION

Humanity and societies today face challenges to sustainability, which fundamentally relates to the ability to sustain humanity, civilizations and ecosystems on Earth. These challenges are expected to become more significant in the future. Achieving sustainability is therefore one of the most important objectives of a society and its people.

The issues and concerns embodied by sustainability are broad and numerous. They cover such diverse issues as resource supply (water, energy, mineral, food), climate change and pollution, management of wastes (toxic, hazardous, radioactive, convention-

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al), sanitation, land use and desertification, species extinction and loss of biodiversity, ecosystem degradation, water quality and drought, industrial development, production and consumption patterns, population growth, urbanization, globalization, cultural and social sustainability, natural and anthropogenic disasters, peace and stability and government policies.

The breadth of topics related to sustainability suggests that a holistic and comprehensive approach to sustainability is necessary. Sustainability activities are increasingly becoming part of the agendas and operating plans of governments and businesses. The elements of sustainability need to be connected if activities are to attain sustainability goals.

In the remainder of this article, the historical context for sustainability is briefly described, sustainability concepts and definitions are reviewed, and sustainability is discussed, focusing on its economic, environmental and social dimensions as well as issues and concerns. The related concept of sustainable development is examined. Then, assessment measures for sustainability are considered, and some sustainability applications are presented.

HISTORICAL CONTEXT

The challenge of achieving sustainability for societies is not limited to the present day, even though the global nature of the problem has come to the fore in recent decades. Sustainability was an objective, at least implicitly, for early civilizations.

Since humans transitioned from mobile hunter-gatherers to agriculture and settlements approximately 12,000 years ago during the Neolithic age, in what has come to be known as the agricultural revolution, the sustainability of the lifestyle was crucial in determining if society would thrive or collapse.

The decline of the Western Roman Empire constitutes another noteworthy historical illustration of a society that failed to sustain itself and ultimately collapsed. Waning returns from natural resource production as well as social factors contributed to the decline (Tainter 1998).

The multidimensional nature of sustainability became more evident in more recent history, especially with concerns over environmental degradation.

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The case of the Polynesians on Easter Island, located in the Pacific Ocean, provides an important historical illustration of how unsustainable practices and lifestyles can contribute or lead to societal collapse. The inhabitants of Easter Island exhausted the resources of their remote habitat to such an extent that they could no longer feed themselves or even build canoes to escape. The ecological damage to Easter Island led to a total societal collapse that decimated its population compared to its peak in the 1600s (Graedel, Allenby 2010).

SUSTAINABILITY CONCEPTS AND DEFINITIONS

Numerous definitions of sustainability exist, but none apply for all circumstances. Making sustainability operational rather than vague and theoretical is a challenge, which is made all the more daunting due to the numerous definitions of sustainability.

In theory, sustainability can be defined as "enduring in perpetuity". However, such a definition is neither practical nor useful. Little if anything can be sustained forever, while much can be sustained over the very short term. A timescale of 50 to 100 years, representing two to four generations, is often viewed as more practical.

A simple definition sustainability was stated by Ehrenfeld, who defined sustainability as "the possibility that human and other forms of life will flourish on the planet forever". Although this definition incorporates environmental and societal aspects, the timescale is impractical.

Taking a more technical perspective, sustainability can be defined in terms of carrying capacity, which indicates the maximum number of people that can be supported in a given area, accounting for availability of resources and the ability of the environment to accept waste emissions. The carrying capacity for a region is in particular dependent on the demand and supply of natural resources.

But sustainability encompasses more than technical factors and cannot be defined from an environmental perspective exclusively. Rather, sustainability is often conceptually defined as having three dimensions: environmental, economic and social. An important feature of this approach is the extension of sustainability beyond carrying capacity to include economic and social fac-

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tors. A multidimensional view of sustainability is consistent with the understanding of how several factors affect whether societies thrive or decline. But these three dimensions are often in tension (e.g., environmental and social sustainability may be achieved to the detriment of economic sustainability). Achieving a sustainable balance is challenging.

Sustainability, and its three main dimensions, can be conceptually illustrated in various ways: *a*) Sustainability can be viewed as founded or supported by three legs or pillars, representing environmental, economic and social sustainability (fig. 1). This is akin to a three-leg table that can only remain standing if environmental, economic and social sustainability dimensions are satisfied. This balance can prove challenging, since the sustainability dimensions are often in conflict; *b*) Sustainability can also can be thought of as the common point of overlap of three intersecting circles, where the three circles represent the environmental, economic and social dimensions of sustainability (fig. 2); *c*) A variation on this representation displays sustainability using concentric circles (fig. 3). Economic sustainability, being an activity of people and occurring within communities, is seen to be a subset of social sustainability, which involves many social and cultural dimensions as well as economic factors. Then social sustainability is seen to be a subset of environmental sustainability, since activities of people and societies are carried out within the environment and thus threaten environmental sustainability; *d*) The three dimensions of sustainability can be also shown in a hierarchal structure, where the economy is a subsystem of society, and society is embedded in the environment (fig. 4).

These illustrations are similar, but have subtle differences. All of the illustrations demonstrate the interconnected nature of the environment, the economy and society, and their relations to and effects on sustainability for any a system or process.

The above points also demonstrate the truly multidisciplinary nature of sustainability, and its linkages to diverse fields such as science, engineering, environment, ecology, economics, business, sociology and philosophy. Addressing sustainability requires consideration of topics such as resource use (energy and material), economic development, social development, health, environmental stewardship, engineering, design and architecture. It also requires an understanding of how people in the different disciplines interact and relate in addressing these factors.

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Fig. 1. *Illustration of relations between sustainability dimensions, in which sustainability is supported by pillars representing environmental, economic and social sustainability*

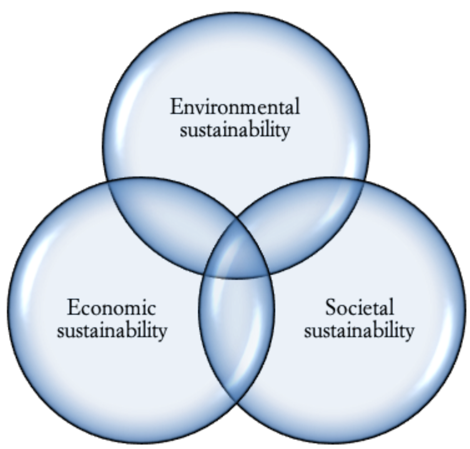

Fig. 2. *Illustration of relations between sustainability dimensions, in which sustainability is represented as the common intersection of the three spheres of environmental, economic and societal sustainability*

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Fig. 3. *Illustration of relations between sustainability dimensions, in which achieving environmental sustainability is shown to require societal sustainability since the environment includes elements of society as well as other dimensions (e.g. ecological systems), while achieving societal sustainability is shown to require economic sustainability since society includes elements of economics and industry as well as other dimensions (e.g. cultural systems)*

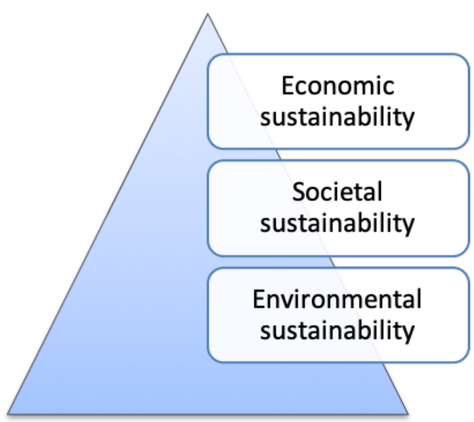

Fig. 4. *Illustration of sustainability as a hierarchy of the environmental, economic and societal dimensions of sustainability*

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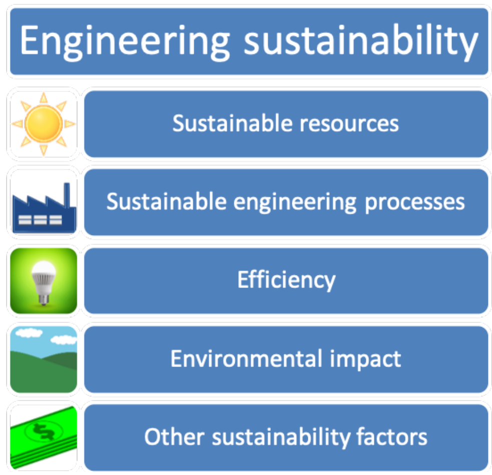

Fig. 5. *Engineering sustainability requirements. The final box includes many factors, including economics, living standards, lifestyles, health and social and cultural acceptability*

Sustainability concepts can be focused around a discipline when needed or useful. For example, consider sustainability in engineering, which constitutes the application of science and mathematics principles for practical purposes such as the design, manufacturing and operation of products and processes, while accounting for economic, environmental, sociological and other constraints. Engineering significantly affects economic development, standards of living, societal well-being, the environment and cultural development. Numerous factors need to be addressed in moving towards engineering sustainability (fig. 5), including appropriate selection of resources bearing in mind sustainability criteria, use of sustainable engineering processes, enhancement of efficiency of engineering processes and resource use, and holistic adoption of environmental stewardship in engineering activities. In moving towards engineering sustainability, other key sustainability measures also need to be addressed, such as economics, equity, land use, lifestyle, sociopolitical factors and population.

The multidimensional nature of sustainability suggests that achieving it is a systems challenge. That is because the overall in-

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teraction between subsystems needs to be integrated to achieve a sustainable system or process. For clarity, the three main dimensions of sustainability are each examined below.

ENVIRONMENTAL SUSTAINABILITY

The economy and society are subsystems of the environment, which is the source and sink of all material and energy interactions on Earth. The sustainability of humanity implies ensuring an ability of the Earth to support human and activities related to it. Human economies and populations have grown such that anthropogenic activities now have global and long-term impacts, with various consequences. These can degrade the ability of the planet to support life.

Many environmental issues affect sustainability. The loss of biodiversity throughout the world, due to economic development and other factors, and threatens the sustainability. Deforestation and development often lead to the destruction of natural habitats and cause the migration of animals to suitable environs.

The extraction or use of limited resources and the release into the environment of emissions and wastes to the air, water and land also put sustainability at risk (Aghbashlo, Rosen 2018). Air pollutants released by internal combustion engines in vehicles, fossil fuel-fired electrical power plants and various industrial activities can adversely affect air quality and the health of humans and other living species. Industrial liquid emissions, including wastewater, and runoff from agricultural activity can lead to environmental problems, e.g., bioaccumulation of toxic compounds in the cells of aquatic animals, and eutrophication of water bodies.

Two of the most significant challenges regarding environmental sustainability follow:

Climate change. Stabilizing the concentrations of greenhouse gases (GHGs) in the atmosphere, in order to prevent the harmful effects of global warming and climate change, constitutes according to most studies one of today's most significant challenges. In the atmosphere, GHGs absorb infrared radiation emitted at the surface of the Earth. This leads to a greenhouse effect and the associated planetary warming. The primary GHG is carbon dioxide

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(CO_2), but there are others such as methane (CH_4) and nitrous oxide (N_2O). The main anthropogenic sources of GHG emissions include fossil fuel combustion, agricultural nitrogen utilization, and enteric fermentation in ruminant animals. Global warming and the risks of climate destabilization are exacerbated by positive feedback effects, such as increased solar radiation absorption from the loss of reflecting surfaces like ice. The Intergovernmental Panel on Climate Change (IPCC) has since 1990 published comprehensive assessment reports reviewing the latest climate science and predictions about future trends. The fifth assessment report, finalized in 2014, reports warming trends due to anthropogenic activities as "very likely". As climate models become more sophisticated, the predicted amount of warming has increased, as have the related climate and other impacts. Much effort globally and at the United Nations is focused on achieving international agreements or treaties to stabilize greenhouse gas concentrations in the atmosphere at a level that avoids dangerous anthropogenic climate change (e.g. Berthiaume, Rosen 2017).

Stratospheric ozone depletion. The layer of ozone (O_3) in the stratosphere reduces the transmission of solar radiation to the surface of the Earth. This stratospheric ozone absorbs ultraviolet radiation, particularly UV-B, which can harm animals and plants. Declines in ozone levels in the stratosphere, especially over polar regions, were observed since the late 1970s. The main ozone depleting substances are chlorofluorocarbons (CFCs), used for decades as refrigerants, which participate in ozone-destroying chemical reactions in the stratosphere. A phase out of CFCs was agreed to in 1989 via the Montreal Protocol, but they are still used in low-income countries. The long residence times of CFCs in the atmosphere implies that the reduced ozone layer concentrations will persist for many decades.

ECONOMIC SUSTAINABILITY

An economy that provides good living standards, the services that people require and jobs is necessary for sustainability in society. A sustainable society requires long-term economic development rather than just economic growth. This latter, often meas-

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ured as growth in gross domestic product, is what occurs today, where capitalist economies depend on economic growth to generate wealth and jobs. Since the economy operates within a planet having finite resources and capacities (Aghbashlo, Rosen 2018), a continually growing economy is not necessarily sustainable over the long term. Eventually, therefore, the global economy needs to operate more in a steady-state manner, with little or zero growth.

The best options for economic sustainability may vary from country to country. For instance, Daly (1990) suggests that wealthy countries need to develop instead of grow their economies in order to conserve resources and waste-assimilation capacities, and that poor countries benefit more from economic growth.

Sometimes, economic sustainability arguments are divided into strong and weak sustainability categories:

Strong sustainability. This view of sustainability is based on natural capital (the planet's stock of natural resources, including air, water, geology, soils and all living organisms) providing ecosystem services that are not substitutable with human capital (the stock of knowledge, habits, social and personality attributes, creativity, and labor). Environmentalists and natural scientists often prefer this viewpoint of sustainability, seeing natural and human capital as complementary, but not interchangeable.

Weak sustainability. This view of sustainability is based on the concept of a constant total capital stock, which is the sum of human and natural capital, and allows for human capital to substitute for natural capital. Economists often favor this view of sustainability, which permits natural resources to decline provided there is an increase in human capital, including know-how and knowledge.

The difference between these two views of economic sustainability mainly focuses on the substitutability of human for natural capital.

SOCIETAL SUSTAINABILITY

Societal sustainability is a broad concept, including health, equity, cultural development and many other factors. A precise definition of social sustainability and what contributes to it has not been agreed to universally.

The evolution of sustainability thinking to include a strong societal component took time. Early work on sustainability often focused on either environmental sustainability or economic sustainability. The emphasis on human and societal development has come about more recently.

What constitutes societal sustainability may change temporally. For instance, people in the future may inhabit smaller houses, live in higher density neighborhoods, possess less material goods and travel less. Even if this leads to a lower gross domestic product per capita in the future, it may lead to a higher quality of life.

Two major factors in societal sustainability follow:

Equity. The concept of societal sustainability includes equity within and between generations. Intragenerational equity speaks to equity between people of the same generation, and requires more balanced distribution of wealth. This may necessitate shifts in resources between rich and poor nations and within them. Intergenerational equity focuses on equity between present and future generations, so as to ensure that future generations have are able to a attain a reasonably good quality of life compared to preceding generations. Intergenerational equity spanning two to four generations into the future, roughly equivalent to 50 to 100 years, is often envisioned as a necessary factor for societal sustainability.

Health. Human health and well-being is an important factor social sustainability. Important measures of human health include life expectancy and infant mortality (Smil 2007). Many factors contribute to human health, including access to healthy and clean food and drinking water, safe waste disposal, and an environment without harmful substances that can lead to chronic or acute diseases (e.g. toxins and carcinogens).

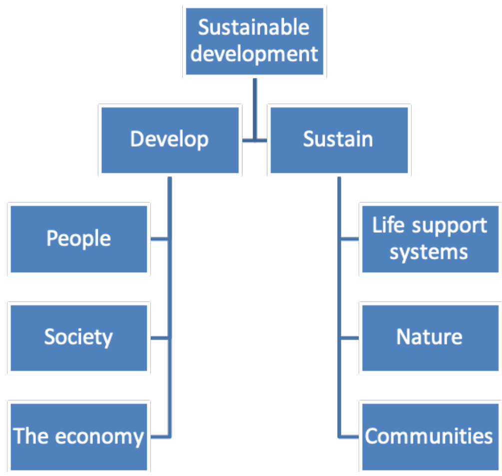

Fig. 6. *Interpreting sustainable development based on what is to be developed and what is to be sustained*

SUSTAINABLE DEVELOPMENT

Sustainable development can be thought of as development that has the ability to be sustained into the future for some lengthy period of time, and can be viewed as the sustained and continuous improvement of a system or process (Kates et al. 2005; Rosen 2017a). Development implies a qualitative improvement and differs from simple growth, which is a quantitative increase scale.
The term sustainable development was introduced by the World Commission on Environment and Development (1987) of the United Nations in its 1987 report "Our Common Future". Sustainable development is defined therein as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Sustainable development can be interpreted based on what is to be sustained and what is to be developed. One such interpretation is provided in fig. 6, based on that of the U.S. National Research Council's Board on Sustainable Development (1999). This interpretation of sustainable development states the following: *a*)

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To be developed: people (e.g., life expectancy, quality of life, education, equity), society (e.g., security, institutions) and the economy (e.g. wealth creation, jobs). Social and economic systems of people can be enhanced through development. For instance, the quality of life of people in developing countries can be improved through more equitable distribution of wealth, better education, and less reliance on non-renewable resources, leading to a more equitable society; *b*) *To be developed: people (e.g., life expectancy, quality of life, education, equity), society (e.g., security, institutions) and the economy (e.g. wealth creation, jobs).* Social and economic systems of people can be enhanced through development. For instance, the quality of life of people in developing countries can be improved through more equitable distribution of wealth, better education, and less reliance on non-renewable resources, leading to a more equitable society; *c*) *To be sustained: life support systems (e.g. resources, land, soil, water, air), nature (e.g. ecosystems, habitats, biodiversity) and communities (e.g. cultures).* Earth and its ecosystems provide ecosystem services (e.g. climate stability, water and air purification) and natural resources. These permit human communities to endure into the future and thrive. Thus, to sustain the services provided by nature that people have adapted to and depend upon, the Earth and its life-support systems need to be sustained.

Ensuring that sustainable development is incorporated pervasively and comprehensively into industry, government, planners and people's lives is of great importance. Policies and strategies for sustainable development are needed that are sound, coordinated, meaningful realistic and achievable. Political efforts have recently come to the fore in this regard, with the adoption of the UN Sustainable Development Goals for 2015-2030 at the 70th Session of the United Nations General Assembly in 2015, as part of the 2030 Agenda for Sustainable Development (United Nations 2015). The goals are broad, covering such outcomes as addressing climate change, eliminating inequality and injustice, and ending poverty. The UN Sustainable Development Goals encompass the following 17 specific goals, which are illustrated in fig. 7, and descriptively outlined in tab. 1. It is anticipated that the Sustainable Development Goals will be tailored by countries to suit their circumstances, needs and priorities (Rosen 2017b).

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Fig. 7. *Sustainable Development Goals adopted in 2015 by the United Nations*

Source: http://www.un.org/sustainabledevelopment/news/communications-material.

Tab 1. *Descriptive Outline of Sustainable Development Goals adopted in 2015 by the United Nations*

Goal number	*Description*
1	End poverty everywhere, in all its forms
2	End hunger, achieve food security and improved nutrition, promote sustainable agriculture
3	Ensure healthy lives, promote well-being for all at all ages
4	Ensure inclusive and equitable quality education, promote lifelong learning for all
5	Achieve gender equality, empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization, foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: Adapted from United Nations (2015).

Note that the term sustainable development is similar to but different from sustainability, even though they are often used interchangeably. Sustainability is a state that can be maintained into the future. But, since development means "bringing gradually to an improved state", sustainable development implies a course of action that improves the quality of life of people and societies, and that can endure into the future.

ASSESSING SUSTAINABILITY

The assessment of sustainability is important for making sustainability operational and measuring and monitoring progress towards sustainability.

But assessing sustainability is challenging, since no universally accepted method exists for the task. There are many reasons for this, including the difficulty in measuring the main dimensions of sustainability (Hacatoglu et al. 2016). For example, although emissions of GHGs and ozone depleting substances are measurable, quantifying their economic and social impacts is challenging. Also, despite standard of living often being measured as gross domestic product per capita, quality of life can be a more significant measure of human well-being and satisfaction. Sustainability assessment can also be contentious (Morse, Fraser 2005). Nonetheless, various methods for assessing or measuring sustainability have been developed. Some examples: *a*) Some assessment methods utilize sustainability indicators, which are typically simple quantitative proxies that measure economic, social, and environmental factors. Some indicators are integrated, combining various dimensions of the environment, the economy and society, while others are not integrated, measuring only a single aspect of sustainability; *b*) Some sustainability indexes have been developed based on an aggregate or composite of selected sustainability indicators. A single-value measure of sustainability based on an aggregate index is beneficial for understanding and communication, due to its simplicity. But the determination of such indicators necessitates normalization, weighting and aggregation of data. These steps usually lead to a loss of useful information and can be challenging in their own right. A single-value sustainability measure can mask details associated with the multidimensional nature of

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sustainability and thus be misleading. Nonetheless, aggregate sustainability indexes are often preferred by policy makers in industry and government since they can be more easily interpreted and communicated to stakeholders or the public than multiple sustainability values; *c*) Daly (1990) developed operational principles for sustainable development. Although useful, these are limited to quasi-sustainable use of non-renewable resources and the use of renewable resources.

Few if any sustainability assessment methods consider the environment, the economy and society together. Rather, many assessment methodologies focus on only one dimension of sustainability (e.g. economic development or environmental sustainability). Several examples are considered to illustrate this. First, biophysical assessment approaches are suited to assessing environmental sustainability, by quantifying resource use and environmental impact. But they are normally inadequate for addressing societal and economic facets of sustainability. Second, monetary values can be applied to social and environmental capital to assess sustainability. However, financial valuations for non-market goods and services are not well developed, improper valuations, and difficult due to our limited understanding of ecosystems and the services they provide. Third, the Environmental Sustainability Index ranks countries based on an aggregate of several environmental indicators. But these are usually unable to correlate environmental sustainability and economic growth.

A weakness of many existing methods of assessing sustainability is their lack of a systems approach, which regards the system being considered as a whole and accounts for the interactions among its subsystems. This is important because achieving a more sustainable society is a systems problem, where the environment, the economy and society are all interdependent. Coupled human-environmental systems have interactions among different systems that lead to trade-offs, e.g. reducing costs may cause a process to have higher emissions or lower efficiency. A non-systems approach focusing on single factors can usually be seen to be inadequate for assessing sustainability holistically. As noted earlier, for example, biophysical approaches focus mainly on environmental sustainability and neglect economic and social dimensions, while methods based on weak sustainability focus on economic factors and neglect the biophysical facets of sustainability. Clearly, the sustainability of a system needs to be assessed with a systems approach. Life cycle analysis is usually part of such an approach, as it identifies material and energy inputs and outputs of a system or process and uses this information to assess environmental, economic and social effects.

APPLICATIONS

Sustainability principles have been applied to a wide range of areas in recent years. Various examples follow: *a*) Efforts to improve energy sustainability have been made. Gomez-Echeverri et al. (2012), for example, led a global energy assessment to identify sustainable routes, Evans et al. (2009) assessed sustainability indicators for renewable energy, and Gnanapragasam et al. (2011) examined the sustainability of a national energy conversion system using hydrogen from solid fuels; *b*) The sustainability of infrastructure and buildings has also been investigated. For example, Khalid et al. (2015) developed and analyzed sustainable building HVAC, while Russell-Smith et al. (2015) used sustainable target value design to improve buildings; *c*) The sustainability of manufacturing operations has also been examined. For instance, Nazzal et al. (2013) considered sustainability as a tool for manufacturing decision making; *d*) Sustainability as it relates to energy, water and environment systems have been investigated. Krajacic et al. (2015, 2018), for instance, provide an overview of the topic and describe sample studies; *e*) Dewulf et al. (2000) quantified the sustainability of technology via a range of illustrations; *f*) Broader studies of regional sustainability have been undertaken. For example, Ali Mansoori et al. (2016) examined sustainable development for a state, while Gnanapragasam et al. (2011) examined countries and Gomez-Echeverri et al. (2012) the world.

The Red Sea-Dead Sea canal project provides an interesting example of a sustainability initiative. Rosen and Abu Rukah (2011) investigated this project and its interface with sustainability. The Dead Sea and its unique environment are degrading due to anthropogenic activity affecting its water balance. The Dead Sea level has dropped since 1900 by more than 40 meters, to 430m below mean sea level in 2016. Annually, 0.1 m of salt is accumulating at the bottom, and the volume is decreasing by 700

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million cubic meters, leaving an annual freshwater deficit of about 850 million cubic meters. The negative water balance is mainly due to the diversion of water from its catchments area by Israel, Jordan, Syria and Lebanon, as well as industrial activity in the southern basin of the Dead Sea. In 2002 Israel and Jordan jointly announced interest in stopping the water level decline and deterioration by constructing a Red Sea-Dead Sea canal to pipe water from the Red Sea to the Dead Sea. The project represents an important plan developed to avoid the loss of the Dead Sea and to desalinate sea water as well as to generate electricity for Jordan, the Palestinian National Authority and Israel. The proposed desalination plant with an annual capacity of 850 million cubic meters of fresh water that will utilize the 400-meter elevation difference between the Seas. In 2005 Israel, Jordan and the Palestinian National Authority submitted to the World Bank terms of reference for a "Feasibility Study – Environmental, Technical and Economic, and Environmental and Social Assessment", which describes the environmental concerns associated with the project. The World Bank announced that steps towards the realization of the feasibility study would take place in 2007. The project, with continual modifications of details, now seems ready to proceed, with Israel and Jordan advancing $800 million US for the project recently (United Nations 2015).

Although there are environmental concerns regarding the project, it nonetheless is viewed as providing significant environmental benefits. The Red-Mediterranean-Dead Seas Canal project has been shown to be the type of large project that may contribute significantly to sustainability. The benefits, which in many ways drive its contribution to numerous facets of sustainability, are shown in fig. 8. Surveys also indicate examples of common applications of sustainability, and these typically show that there is a strong focus on the implementation of sustainability concepts, actions, by both individuals and corporations. For example, the present author recently examined the actions of engineering practitioners regarding sustainability (Rosen 2013). Some specific findings were that the main sustainable technology priorities are using less energy and natural resources, reducing emissions and material wastes, and utilizing renewable, recyclable and recycled materials, and that challenges to sustainability exist, like economics viability. A breakdown of the degree of involvement of engineers with

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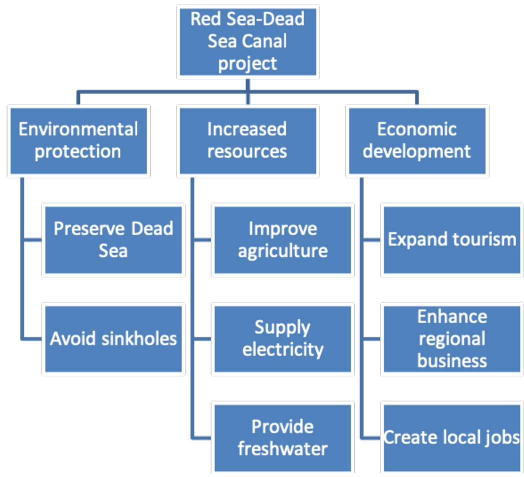

Fig. 8. *Benefits of Red Sea-Dead Sea canal project, supporting its contribution to numerous elements of sustainability*

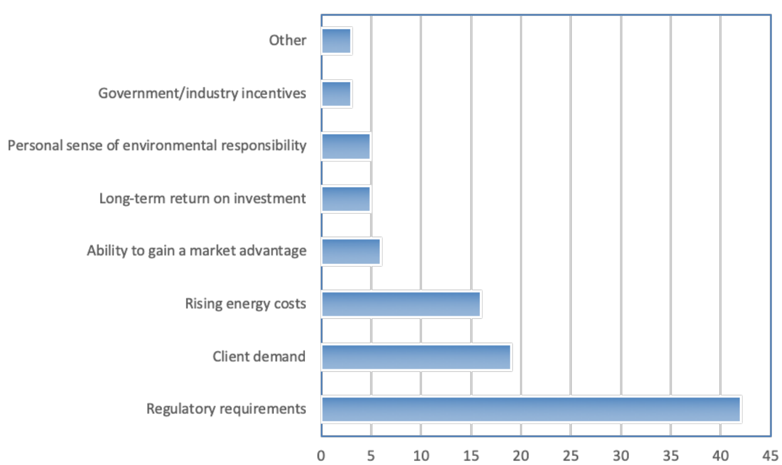

Fig. 9. *Factors most likely to influence an organization's use of green design practices and procedures, showing percentage of respondents for each*

sustainability or sustainable technologies showed that more than two-thirds of engineers are involved to some degree in sustainability, usually by working on sustainable products and processes. Also, the factors most likely to influence an organization's use of green design practices and procedures are regulatory requirements, client demand and rising energy costs (fig. 9).

CLOSING REMARKS

Although sometimes vague and often complex, sustainability is an important aim for societies and humanity. Sustainability is a multidimensional concept, encompassing economic, social, environmental and other factors. Sustainability assessment tools are needed to evaluate processes and systems, and how changes affect their sustainability. This usually necessitates a comprehensive set of indicators of the sustainability of the environment, the economy, technology, society, and institutional systems. Many human civilizations in the past proved to be unsustainable to some degree. It is hoped that the coverage provided in this article, including sustainability definitions and historical contexts, its economic, environmental and social dimensions, sustainable development, sustainability assessment measures and relevant applications, will assist efforts to address sustainability challenges today and, as an even more important priority, in the future.

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