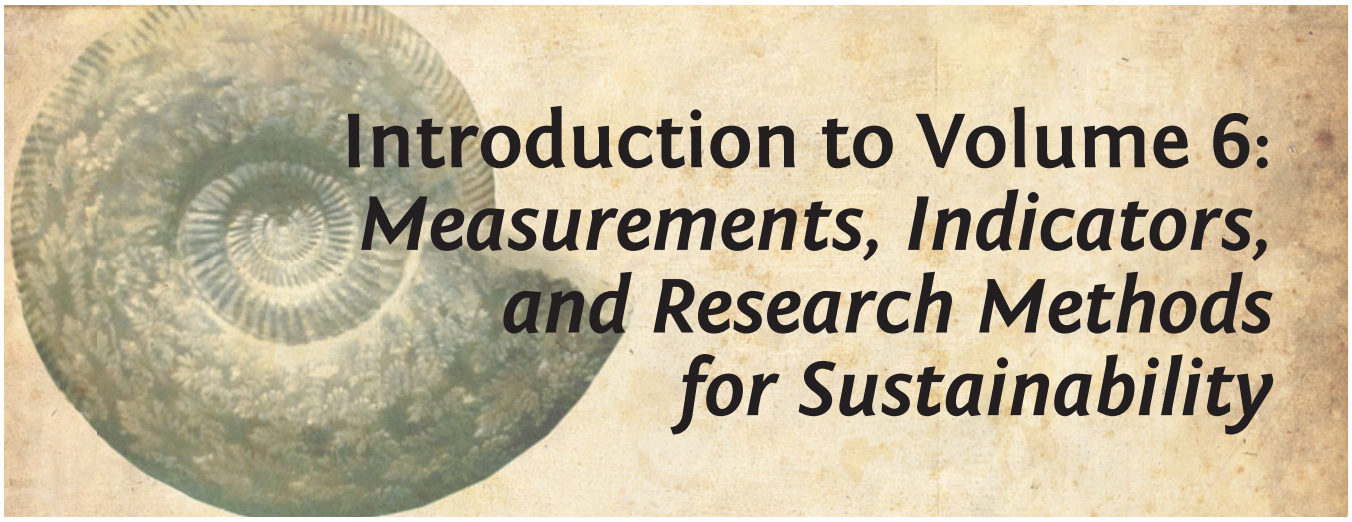

Introduction to Volume 6: *Measurements, Indicators, and Research Methods for Sustainability*

Measurements can be made in many ways. Sometimes we use meters to measure things: most people, for instance, are familiar with the meter in a motor vehicle that measures speed (speedo*meter*), and measuring temperatures has been undertaken for many years with the use of thermo*meters*. The information provided by such meters helps us to manage our own safety and our health. There are many kinds of meters, some of which are very relevant to sustainability. The world meter, for example, quite startling to look at and think about (see it at www.worldometers.info/), measures the current world population, as well as other things that increase in number, one by one, faster than the human eye can track. During production of this volume in 2011, the sixth of the *Berkshire Encyclopedia of Sustainability,* the world population passed 7 billion (7,000,000,000).

Measuring and Sustainability

Some of us may ask, "Why measure things—what's the incentive?" The promise of a reward or a prize has sometimes been the incentive to measure what's happening or to measure where we are. For example, the ancient Greek thinker Eratosthenes first calculated (remarkably accurately, considering) the circumference of the Earth and proposed a system of latitude and longitude in order to measure one's location on the planet's surface. Latitude was easy to determine for navigators at sea—those who most depend on this measurement: they simply had to look to the stars to find their relative east or west position on the ocean. It took until the seventeenth century, however, to develop an accurate way of determining longitude at sea, a navigational problem with enormous consequences. Ships loaded with precious cargo from far-off lands were being lost at an alarming rate because ship captains had no way of determining their north–south position. What led to the eventual discovery of a way to measure longitude? Essentially, several governments offered prizes, and fame and fortune, to the person or people who could solve the problem.

Another incentive to measure what is happening around us is the concern held by many that we are not living within nature's limits. Convincing evidence exists that we are making a continuing, unsustainable, and inequitable use of nature and the environment. Therefore we need information to help us shape policy and to help us manage what we have. As the old adage says, "You cannot manage what you don't measure." Those words are especially relevant to sustainability. For example, measuring the size of fish populations, or the level of acidification in oceans, or what contributes to a carbon footprint are actions whose results can help us monitor the condition of (and changes in) our environment.

Measuring things may seem straightforward, but there are many exciting challenges involved. One is to identify and agree on what best to measure. Keeping in mind the sustainability objective, is it better to measure by single entities (such as the number of trees in a plantation or the amount of waste going to a landfill), or is it better to measure holistically (environmental and social impacts, or gross domestic happiness, or energy efficiency). There is also the challenge of how to measure sustainability as a whole, and to track progress (or lack of progress) toward sustainability. Just as the environment is continually changing, so is the economic world. For example, what happens when Green Company X decides to ship their parts from an entirely different region of the world because their usual supply chain got interrupted by, say, flooding or a tsunami, both of which have happened in the early twenty-first century? How does this choice affect Green Company X's global environmental footprint? Then there are wild cards to watch out for. What if communal Laundromats come into fashion and people stop buying their own washing machines? Bring in

the contentious topic of nanomaterials that never need washing (or indeed, washing machines that never need replacing), and the complications increase exponentially. These are just a few examples. They are simplistic but they do demonstrate the interrelated nature of economics and ecology.

A second challenge is to decide how often to measure. One-off measurements may in some instance be appropriate but more often than not there is a need to take measurements at intervals over time. This is called monitoring, and it is used to help detect trends. It is not just a question of deciding the frequency of the measurements but also the duration of the time over which trends may or may not be detected. A danger lies in being selective when it comes to choosing the time period, because one time series can be quite different from another time series. Such selectivity has found its way into the controversies about global temperature trends. Depending on which time periods researchers select, the results will show either decreases or increases in global temperature.

Measuring cause and effect is likely the most difficult challenge because it is not always easy to link a possible cause to an observed effect. This dilemma also has been at the heart of controversy about the causes of climate change. Are such changes and trends random events? Is there really a link between the increasing levels of carbon dioxide in the atmosphere and increasing global temperatures? These questions have concentrated the minds of scientists and scientific organizations around the world. The consensus attributes increasing levels of carbon dioxide in the atmosphere to human activity and industrial activities, and it acknowledges that accumulation of this and other gases is having an effect on global temperatures and climate change.

For the sake of sustainability, never before has there been a need to have the best science and most competent scientists provide information on which to base environmental management and policies. This is not to say that good science alone is sufficient. Policy decisions are often made not by scientists but by laypeople, and very often the decision is not based on science but on ethics. To manage our resources and environmental practices we do need to measure. But due to a lack of data (and to uncertainties and complexities of gathering data), the connection between science and policy is not always direct. There has also been a tendency for measurements and monitoring to take place—just for the sake of measuring and monitoring. Indeed, some would say that the biggest challenge in the past has been the lack of a mechanism for evaluating measurement as a tool to change or affect policy.

But even more urgent than the need to measure things is the need to make clear that measuring is not enough. Measuring our impact is one of the first steps toward acting on the knowledge that choices we make in our daily lives affect the sustainability of our planet. We will revisit that theme in volume 10, *The Future of Sustainability.* In the meantime, the articles in this volume provide a necessary framework to examine the tools that researchers and scientists may use to do the crucial job of measuring our impact on the Earth.

How do we, in fact, deal with the complexities of measuring nature and the environment? Experience has shown that the diversity of things being measured can become overwhelming. The Earth's ecosystems and the ways to manage them are so unfathomably complicated (a topic covered in depth in volume 5 of this series, *Ecosystem Management and Sustainability*) that we often need to resort to very, very complicated methods to determine what is going on. For example, modeling (which is both an art and a science), has been used widely to help understand the changes taking place around us. Experience has also taught us that because of this complexity it is sometimes easier to use indicators.

Indicators

Strictly speaking, indicators include both indicators and indices. Both terms are widely used in sustainability studies and often used to good effect. An indicator is the presence or absence or condition of something. For example, obesity is an indicator of an unhealthy life style. This simple observation indicates (is an indicator of) an unhealthy life style. The observation neither confirms nor denies that unhealthy eating is the cause. An index is a measurement or calculation. (*Indices* is the plural form of the term preferred by most to distinguish it from *indexes,* the plural used for the alphabetical "back-of-the-book" lists we use to locate information.) For example we use body-mass indices to determine if our height-to-mass ratio is healthy. Another example could be based on waste management. The observation that materials are going to landfill could be said to be an indicator of an unsustainable society. An index of poor waste management could be the amount of waste per capita. Such an index could be used to compare the performance of cities in regard to their waste management. Both indicators and indices have a very important

role in helping to achieve sustainability, but both need to be used with an understanding of the context for selecting the indicator or calculating the index. That is why research is so important, be it economic, cultural, social, or environmental.

Research for Sustainability

Research is about seeking the truth. Research is about asking the right question. Research is about methods, methodology, gathering data, analysis, interpretation, application, and presentation of results. Research is about trying to be objective and separating fact from opinion. It can become complicated. Of course the downside of all this complicated research is that all researchers (scientists in particular), tend to get caught up in their work and perhaps lose sight of the importance of what they are measuring in the first place.

Research is about communication. Researchers must consider how they can best get their point across to the average person. Of all the challenges researchers face, effective communication with laypeople can be the most daunting, but it is the most crucial factor when attempting to increase public awareness of sustainability studies.

Long-Term Planning

Another interesting research challenge explored in this volume involves the ways in which the application of research results may have implications in both the short term and in the long term. Although it is difficult to predict what the long-term effects might be, it is important to try and assess what such impacts could be, whether environmental, social, cultural, and/or economic. For example, if a government invests a certain amount of money in solar or wind energy, the following question must be asked: "What are the likely repercussions in ten or twenty years, in terms of job creation, industrial output, and general home consumer behavior?" If a neighborhood votes down a new golf course in favor of a nature preserve, or decides to bring back long-defunct train service, what effect will those decisions have on area real estate prices? Looking back to the mid-twentieth century, who could predict that the liberal use of herbicides and insecticides would have a catastrophic effect on nature? It took a courageous US journalist in the early 1960s (Rachel Carson) to challenge the lack of long-term thinking. Clearly, it's important to figure out both the short-term and long-term repercussions of policies that governments, international agencies, and even local communities make.

Research and Decisions

Good research is so very important because we need to do our best to obtain the best results so that we can then try to make the best interpretations of the data, whether in terms of the implications of climate change, or the impacts of public versus private transportation, or in terms of the establishment of marine and nature preserves. People need to trust science and scientists. People need to believe the scientists who are telling them that their big cars are contributing to the melting of ice caps in faraway places, or that their electricity is burning up our resources of coal. People often need to learn from scientists *why* these things are so before they are inclined to do something about them. But think of the classic "simple" question, "Why does the sky appear to be blue?" The world is a very complicated place and it is often difficult to describe these things. Communication and trust are extraordinarily important in applying research to the real world.

What You'll Find in This Book

Volume 6 presents a thorough and accessible overview of the ways in which sustainability is charted worldwide. Some articles introduce basic concepts, such as qualitative versus quantitative data or the "weak" versus "strong" sustainability debate. Other articles describe how indicators have been used to address climate change, soil conservation, agriculture, and mining. Research analysts explain the modes and media through which these measurements are broadcast, stressing the importance of developing methods that can be understood by experts and laypeople. The researchers also examine the process of monitoring, itself a highly interesting topic very relevant to national or international policy, law, rules, and regulations. This volume divides the material into six sections; as with most things on this planet, many articles fit into more than one category.

Concepts and Theories

Articles on topics that explore measurement concepts and theories, such as "Intellectual Property Rights," "Systems Thinking," the "$I = P \times A \times T$ Equation," (which specifies that environmental *Impacts* are the combined product

of *Population, Affluence,* and *Technology*), "Quantitative vs. Qualitative Studies," and "Community and Stakeholder Input" help us to examine the ways in which we study and measure things. Are we going about it the right way, generally speaking? What happens when the developed world's standards of living are applied to the (upwardly mobile, and quickly) developing world? What can we learn by studying how others do things, in the classroom, in the lab, or in the workplace? What influence can "regular" people and their communities have on how their environment's resources get allocated? Why is it important that researchers be trained in both quantitative (dealing with "how much") and qualitative (dealing with "how and why") methods of research? In a nutshell, these questions are important so that their research asks the right questions in the first place.

Impact and Implementation

Global programs for measuring sustainability have a tremendous impact on the ways in which sustainability studies may be implemented to effect change. Articles such as "Reducing Emissions from Deforestation and Forest Degradation (REDD)," the "Global Strategy for Plant Conservation," the "Global Reporting Initiative (GRI)," and "Green Building Rating Systems," provide examples of efforts worldwide. These programs are often, although not always, United Nations–sponsored, and are a heartening indication that people around the world can work together to solve problems. Other topics such as "Risk Assessment" explore the ways in which businesses and governments (and even individuals) can anticipate the environmental impacts, either positive or negative, of various plans of action.

Indicators

The presence or the absence of something can reveal a "big picture" of the impacts stemming from different social, economic, and environmental spheres: fisheries (freshwater and marine), air pollution, population, environmental justice, and the relative effects of various green taxation strategies.

It may be hard to believe, but some indicators can be used to monitor past environmental events. Such topics include the study of tree rings (dendrochronology) that allow us to peer into the past and learn something about conditions and changes in the climate hundreds and thousands of years ago. Indices such as the Index of Biological Integrity (IBI), which scientists base on a number of different biological indicators (such as species abundance and distribution), are used to determine the relative health of aquatic ecosystems. Several articles in this category study facets of the relatively new field of industrial ecology, such as "Life Cycle Assessment, "Material Flow Analysis," and "Supply Chain Analysis."

Methods of Displaying Results

Results from monitoring may be presented in many different ways. The choice of the method is an integral part of communication and depends largely on the audience. It is imperative that we must have good "communication." This category covers topics such as "Advertising," "Ecolabels," "Energy Efficiency Measurement," and "Organic and Consumer Labels." An example of the need to communicate what all the facts and figures mean is the so-called Climategate scandal that began in late 2009, during which several climate scientists at the University of East Anglia in the United Kingdom (who were eventually exonerated for their actions) circulated emails among themselves, wondering how best to make their data (which unequivocally stated that the world's climate was becoming warmer) more readily understood by the public. Word quickly got out that the scientists were exaggerating the dangers of climate change, when in fact they were simply grasping at the best way to make an extremely complicated subject more easily understood by policymakers and the general public. This unfortunate episode has likely set back the general public's trust in climate science by many years, but we can only hope that we have learned from our mistakes.

Research Methods and Measurement Tools

Do we have the best tools to research these important issues? This category explores the fascinating range of research options open to us in such articles as "Geographic Information Systems (GIS)," "Long-Term Ecological Research (LTER)," "Social Network Analysis (SNA)," and "Computer Modeling." Although many of these methods are technology based, other articles, such as "Focus Groups," "Citizen Science," and "Transdisciplinary Research," explore ways in which scientists (and others) can use relatively simple methods—such as getting different peoples' opinions and strengths involved in the research process—to do the job correctly.

Planning for the Future

Measuring the impacts of the world population on nature and the environment must be based on the best science and be undertaken by the most competent scientists. This is the basis for achieving change. There has to be change in all levels of education so as to achieve sustainability. There has to be a change in behavior so that there is no longer inequitable and unsustainable use of nature and the environment. We must embrace the inspiring innovations brought to us from monitoring, indicators, and research so as to learn to live within nature's limits. That's what sustainability is all about.

In the time (roughly twelve or thirteen minutes) that it has taken you to read this introduction, the world population has increased by around 3,000 people. That's a measurement to think about.

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