USDA

United States Department of Agriculture

Forest Service

**Northern Research Station**

General Technical Report NRS-P-107

# Environmental Futures Research: Experiences, Approaches, and Opportunities

## Abstract

These papers, presented in a special session at the International Symposium on Society and Resource Management in June 2011, explore the transdisciplinary field of futures research and its application to long-range environmental analysis, planning, and policy. Futures research began in the post-World War II era and has emerged as a mature research field. Although the future of complex social-ecological systems cannot be predicted, these papers show how futures research can offer perspectives and methods that help researchers, decisionmakers, and other stakeholders explore alternative futures and gain environmental foresight—insight that can inform decisionmaking on environmental challenges. One author points out that the study of the future can be thought of as the study of change. He discusses three types of futures: the expected future, a range of plausible alternatives, and the preferred future, which decisionmakers can shape depending on their choice of action. An example of the methodology of futures research is provided in another chapter, which illustrates the use of scenario development. Another chapter identifies global trends that could dramatically change social-ecological systems.

The second half of the collection applies the methods and approaches of futures research to natural resource management. A global and a regional scenario illustrate scenario planning, a methodology that produces sets of plausible futures that could develop from current conditions depending on alternative human choices and drivers of change. Another example demonstrates how analysts can incorporate global scenarios and modeling, and scoping of trends and issues, into forest inventory data to gain insight into the regional forests of tomorrow. A chapter on linking global scenarios with assessments of U.S. natural resources as required under the Resources Planning Act considers both opportunities and challenges. Lessons learned from an analysis of futures research conducted since the 1970s at the U.S. Environmental Protection Agency are also offered. These papers suggest that the perspectives and methods of futures research hold great potential for developing the foresight needed to meet environmental challenges of the 21st century.



Manuscript received for publication 1 June 2012

Published by:

U.S. FOREST SERVICE
11 CAMPUS BLVD SUITE 200
NEWTOWN SQUARE PA 19073

November 2012

For additional copies:

U.S. Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015-8640
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# Environmental Futures Research: Experiences, Approaches, and Opportunities

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# FOREWORD

*David N. Bengston*

Environmental foresight is insight into future environmental challenges and opportunities, and the ability to apply that insight to prepare wisely for a sustainable future. Successful environmental planning, management, and policy require the development and continual updating of foresight. U.S. Environmental Protection Agency (EPA) Administrator Stephen Johnson has stated: “Failure to look beyond present conditions only ensures that emerging problems will be more difficult to address and that opportunities may be missed” (U.S. EPA 2005: 1). The soundness and acuity of our environmental foresight are key determinants of success in addressing critical environmental issues.

Rapid technological, socio-cultural, and economic changes with the potential for sweeping environmental effects have greatly increased the need for environmental foresight. In addition to the increasing pace of change, some who study social-ecological systems believe that “surprise” is pervasive and increasing along with the expanding scale of human impacts (Gunderson and Folke 2008, Kates and Clark 1996). Examples of environmental surprise range from sudden disasters like the collapse of fisheries to more gradual events such as unexpected effects of climate change. Surprise greatly complicates the challenge of developing environmental foresight. The prevalence of surprise in social-ecological systems implies that some important uncertainties are irreducible and that traditional scientific tools are blunt instruments for developing environmental foresight. New approaches are needed.

Although no one can predict the future of complex social-ecological systems, the authors of the papers in this compilation believe that it is both possible and urgent to develop useful insights into emerging environmental problems and needs, and to apply these insights to help achieve a sustainable future. The authors explore the potential of futures research, a transdisciplinary field of inquiry that has been developing for more than 50 years, to address this important challenge. The papers were presented in two sessions at the International Symposium on Society and Resource Management, held in Madison, WI, on June 6, 2011. Speakers in these sessions included academic and professional futurists, as well as environmental researchers who have applied futures methods in their work.

The first four papers introduce futures research as a broad approach to developing environmental foresight and highlight some fundamental principles of futures thinking. In the opening paper I provide an overview of futures research. The goal of futures research is to explore possible, plausible, and preferable futures in order to anticipate and prepare for those futures. I briefly trace the development of futures research from its beginnings in the post-World War II era, to a mature transdisciplinary field with a considerable body of literature, many specialized journals, professional organizations, and distinct methods. The paper concludes with a call for environmental futures research to help develop the foresight needed for a sustainable future.

In an insightful paper, Peter Bishop, professor and director of the graduate program in Futures Studies at the University of Houston, identifies some fundamental perspectives for thinking about and approaching the study of the future. He begins with a consideration of change because, as he states, “the study of the future is the study of change.” After describing the four main attributes of change, Professor Bishop addresses an approach to forecasting that takes uncertainty seriously. He concludes by identifying three broad drivers of the future and how each driver can be thought of as creating a different type of future: the baseline future, a range of alternative futures, and the preferred future.

Futurist and economist Kay Strong of Baldwin-Wallace College—and a graduate of and former instructor in the Futures Studies program at the University of Houston—describes a framework for developing foresight that has been used to prepare professional futurists at the University of Houston. Framework forecasting is an organizing technique for gathering and sorting information about the topic of interest when conducting futures research. Professor Strong also briefly describes the process of scenario development, a core method of futures research that can use the information from framework forecasting.

George Kubik of the Anticipatory Futures Group, LLC and the University of Minnesota discusses "global mega forces," defined as major emerging trends with the potential for high-impact outcomes in the future. He first identifies seven broad categories of global mega forces and briefly discusses their implications for natural resource futures. Kubik then examines two technological mega forces in detail: networked sensor-actuator technologies and electronic performanceware systems. These two developments are highlighted because of their potential to significantly affect the future of society and natural resources.

The next four papers provide examples of futures research methods and approaches applied to natural resource issues. Stephen Carpenter and Adena Rissman of the University of Wisconsin discuss scenario planning, which they describe as a method for thinking creatively and systematically about plausible futures. The sets of plausible stories produced by scenario planning explore how the future might develop from current conditions under a range of alternative human choices and the effects of uncontrollable drivers. Carpenter and Rissman describe examples of global (Millennium Ecosystem Assessment) and regional (Yahara Watershed, Madison, WI) scenario planning. They conclude that scenarios can help address some fundamental challenges in sustainability science.

The Northern Forest Futures Program (NFFP) is described by Keith Moser and Stephen Shifley, scientists with the U.S. Forest Service, Northern Research Station. The NFFP is a cooperative effort involving the Northern Research Station, the Northeastern Area Association of State Foresters, and academic scientists. Using data from existing assessments and inventories, a scoping of trends and issues, and scenarios from the Intergovernmental Panel on Climate Change (IPCC) linked with selected global circulation models, the NFFP is a "window on tomorrow's forests" for the Northeast and Midwest.

A long-standing and prominent futures assessment of renewable natural resources is discussed by Linda Langner, National Program Leader for the Resources Planning Act Assessment, U.S. Forest Service Research and Development, and Peter Ince, a research forester with the U.S. Forest Service, Forest Products Laboratory. As required by the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974, the periodic RPA Assessments project resource conditions and trends 50 years into the future. The 2010 RPA Assessment included scenarios linked to global scenarios developed by the IPCC. Ince and Langner discuss the development of quantitative linkages with the IPCC scenarios and methodological challenges that were faced in disaggregating the IPCC data.

Finally, Robert Olson, Senior Fellow at the Institute for Alternative Futures, describes the futures research carried out by the U.S. EPA dating back to the 1970s. More than any other environmental or natural resource agency in the United States, the EPA has pursued futures research, albeit with varying levels of commitment over time, in an effort to anticipate emerging environmental issues, threats, and opportunities rather than simply react to them after the fact. Olson was involved in much of this work first-hand as a consultant to the agency. He reviews past and current efforts to develop a capacity for environmental foresight within the EPA, and discusses important lessons for other agencies and institutions concerned with our environmental future.

Given the pace and complexity of change today, the need to anticipate emerging environmental issues, threats, and opportunities is great. Attempting to "look beyond the headlights," anticipate change, and prepare for a range of alternative futures is vital in environmental affairs. The problem is that we are often ineffective, not systematic, or just plain naïve in our attempts to anticipate change. This collection of papers suggests that the methods and perspectives of futures research offer a promising set of approaches to develop the foresight needed to successfully address the environmental challenges of tomorrow.

## LITERATURE CITED

Gunderson, L.; Folke, C. 2008. **A different future (editorial)**. Ecology and Society. 13(2): 57. Available at http://www.ecologyandsociety.org/vol13/iss2/art57/. (Accessed 27 June 2012).

Kates, R.W.; Clark, W.C. 1996. **Environmental surprise: expecting the unexpected**. Environment. 38(2): 6-11, 28-34.

U.S. Environmental Protection Agency (EPA). 2005. **Shaping our environmental future: foresight in the Office of Research and Development**. Washington, DC: U.S. Environmental Protection Agency, Office of Science Policy, Office of Research and Development. 20 p.

# FUTURES RESEARCH: A NEGLECTED DIMENSION IN ENVIRONMENTAL POLICY AND PLANNING

*David N. Bengston*

**Abstract.** The need for strategic foresight in an increasingly complex and rapidly changing world poses a formidable challenge to environmental planners and policy makers. This paper introduces futures research as an under used but fruitful set of approaches to addressing this challenge. Futures research is a transdisciplinary social science that uses a wide range of methods to explore possible, plausible, and preferable futures with the goal of anticipating and preparing for those futures. The historical context for environmental futures is briefly reviewed, an overview of futures research as a distinct field of study is presented, and several of the main methods of futures studies are described.

## INTRODUCTION

Futures research is a transdisciplinary field of inquiry that uses a variety of distinctive methods to explore alternative futures. This paper introduces futures research as an underused but fruitful set of approaches to the formidable challenge of anticipating change in a complex and rapidly changing world. Futurists have developed important insights into the nature of change, perspectives for thinking creatively and deeply about the future, and an array of methods for exploring alternative futures. Futures research has the potential to enrich environmental and natural resource planning and policy with a cross-fertilization of new ideas and approaches. The next section describes the historical context for environmental futures. An overview of futures research as a distinct field of study follows. A final section describes several of the main methods developed and employed by futurists.

### The Historical Context for Environmental Futures

Conservationists, environmentalists, and environmental professionals have always been motivated by a strong concern for future generations and by visions of sustainable—or more often unsustainable—ecological and social futures. This orientation toward the future dates back to the beginnings of the Progressive Era conservation movement of the late 19th and early 20th centuries. The welfare of future generations was the root concern of George Perkins Marsh's monumental 1864 book "Man and Nature" (Lowenthal 2001), which has been called "the fountainhead of the conservation movement" in the United States (Mumford 1931: 35). In the 1960s, the modern environmental movement was spurred by an urgent desire to avoid the dystopian ecological future reflected in the title of Rachel Carson's "Silent Spring" (1962). The seminal Brundtland Commission report, "Our Common Future," sparked a worldwide and ongoing discussion about sustainable development, defined as ". . . development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Economic Development 1987: 43). Visions of environmental futures that have motivated generations of environmental stakeholders have often been dominated by neo-Malthusian warnings of environmental degradation, natural resource scarcity, food shortages, and overpopulation (e.g., Brown 1954, Meadows et al. 1972, Sears 1935), although other visions have portrayed a much brighter view of environmental futures (e.g., Glesinger 1949, Lomborg 2001, Simon 1981).

The pervasive orientation toward the future in conservation thinking has been institutionalized in environmental protection and natural resource management agencies over the past century, beginning with the founding legislation and mission statements of these agencies. For example, the "Organic Act" that created the U.S. National Park Service in 1916 states that the purpose of the National Parks is to " . . . conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (National Park Service Organic Act, 16 U.S.C.1., 1916). The mission of the U.S. Forest Service is to " . . . sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations" (U.S. Department of Agriculture, Forest Service 2008). Numerous additional examples of future-oriented missions could be given for national, state, and local environmental agencies around the world, as well as for nongovernmental environmental organizations and environmental policy think tanks.

Environmental agencies and organizations have often struggled to fulfill these future-oriented missions, however. Environmental agencies and scientists have devoted substantial effort to forecasting, but this work has been plagued by a host of shortcomings and the track record has been poor at best (Pilkey and Pilkey-Jarvis 2007, Sarewitz et al. 2000, Sherden 1998). Ecological forecasts are filled with irreducible uncertainties due to drivers beyond the scope of ecology (e.g., climate change, demographic change, and management interventions), unknown feedbacks in coupled social-ecological systems, and unpredictable human actions (Carpenter 2002). The complex interactions of people and ecosystems ensure that ecological forecasts are highly uncertain. Experience in the social sciences confirms that predictions of social phenomena are also notably inaccurate. Sociologist Seymour Martin Lipset reviewed the accuracy of forecasts in economics, demography, sociology, and political science, and concluded, "Social scientists are good historians. They are able to understand the processes in what has already happened. But they have not been good forecasters" (Lipset 1983: 157). Even the latest generation of economic forecasting models (Dynamic Stochastic General Equilibrium models), the product of a decade of intense research, fail dismally at forecasting basic economic variables, although they perform no worse than other economic forecasting methods (Edge and Gurkaynak 2010).

Despite the shortcomings of traditional approaches to social and ecological forecasting, the need for environmental foresight has increased in recent decades as the pace of change has accelerated and the frequency of surprise has increased. The Millennium Ecosystem Assessment (2005: 1) concluded that "over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel." Surprises are increasing along with the expanding scale of human impacts (Gunderson and Folke 2008). Hibbard et al. (2007) refer to the period following World War II as the "Great Acceleration," a time of significant increase in the scope, scale, and intensity of impacts on the social-ecological system. Global indicators of the Great Acceleration discussed by Hibbard and colleagues include rapid growth in human populations, atmospheric carbon dioxide concentrations, average global temperatures, use of nitrogenous fertilizers, percentage of marine fisheries fully exploited, and species extinctions. Add to these changes the rapid pace of technological change with the potential for sweeping environmental effects—such as genetic engineering and nanotechnologies—and it is clear that the need for environmental foresight has never been greater (Olson and Rejeski 2005).

## AN OVERVIEW OF FUTURES RESEARCH[1]

Futures research, also called futures studies, futures, and strategic foresight, has been defined as a "methodological-based form of inquiry into alternative futures in terms of what is possible, probable, and/or preferable with the goal of anticipating and possibly influencing those futures" (Kubik 2009: x). Bell (1997) further characterizes futures research as a transdisciplinary social science and an "action science" with an orientation to informing decisionmaking and action. Futures research is distinct from strategic planning, although there is a symbiosis and a widely recognized link between these two fields (Cole 2001). Both futures research and planning may identify preferable futures in terms of vision and goals. But where planning involves the development of a specific course of action to achieve stated goals, futures research provides a broader and longer-term perspective, explores a range of alternative futures, and provides essential context for planners' and policy makers' more specific concerns.

A central principle of futures research is the importance of exploring and preparing for multiple plausible futures, not just the one considered most likely, because the future is fundamentally uncertain (Bishop et al. 2007). As futurist Herman Kahn stated, "The most likely future isn't" (1982: 82). In other words, even what is considered the most likely future is a low-probability

[1]This section draws from Bengston et al. (2012).

event given the complex nature of social-ecological systems and the frequency of discontinuous change and surprise. The most disruptive type of discontinuous change involves events of low probability but high impact, which futurists often refer to as "wild cards" (Cornish 2004, Petersen 1997). Rather than attempting to predict the most likely future—the goal of traditional scientific forecasting—the goal of futures research is to explore a range of possible and plausible alternative futures, in addition to the most probable future or baseline forecast (Bishop 1998, Cornish 2004). The frequency of discontinuous change makes it vitally important that we think broadly about the future, to minimize the risk of being surprised and unprepared.

The origins of futures research are sometimes traced back to a long tradition of utopian writings exploring preferred futures, beginning with the publication of Thomas More's "Utopia" in 1516. Bell (1997), Strathern (2007), and others have examined the early roots and many diverse strands of futures research, which reveal the deep human need—rooted in survival—to anticipate and influence the future course of events. In the modern era, futures research is sometimes traced to the 1901 publication of H.G. Wells' "Anticipations of the Reaction of Mechanical and Scientific Progress upon Human Life and Thought," which proposed a science of the future (Wager 1991). In 1932, Wells discussed the need for "professors of foresight" and university departments of foresight to anticipate and prepare for the future (Wells 1987). Not until the post-World War II era, however, did futures research begin to take shape as a distinct field of study. Work on the future of military technology was carried out in the 1950s by RAND Corporation, a think tank that grew out of early operations research and systems analysis. RAND served as a training ground for many early futurists, including Herman Kahn, one of the pioneers of scenario analysis, and Olaf Helmer, who helped develop the Delphi method. The Defense Advanced Research Projects Agency—one of many U.S. Department of Defense units that include futures research—was established in 1958 as a response to a "wild card" event: the Soviet Union's launching of Sputnik.

The development of futures research accelerated during the turbulent 1960s and 1970s. Many futures organizations were founded at this time, including the U.S.-based World Future Society in 1966 and the more international World Futures Studies Federation in 1967. Best-selling futures books such as "Future Shock" (Toffler 1970), "Limits to Growth" (Meadows et al. 1972), and "Megatrends" (Naisbitt 1982) captured the public's imagination and elevated popular awareness of futures research.

In recent decades, futures research has developed into a well-established transdisciplinary field. Numerous academic and popular futures journals have appeared, including Foresight, Futures, Futures Research Quarterly, Futuribles (in French), Futurics, Journal of Futures Studies, On the Horizon, The Futurist, Technological Forecasting and Social Change, and World Future Review. Many business journals regularly publish futures research, such as International Journal of Forecasting, Long Range Planning, and Strategic Management Journal. Academic futures programs have also developed around the world, and the World Futures Studies Federation has compiled a list of the various tertiary futures educational programs, including graduate programs in futures studies and programs that incorporate futures studies, as well as single units, short courses, and online futures studies courses (World Futures Studies Federation 2012). The World Future Society's annual conference currently attracts about 1,000 attendees, and its "Futurist Directory" lists nearly 1,400 people professionally involved in the study of the future (World Future Society 2000). A major global futures research effort, the Millennium Project (Millennium Project 2012), was initiated in 1992 by the Smithsonian Institution, The Futures Group International, and the United Nations University. The Millennium Project is now an independent, non-profit futures research think tank with nodes in 40 countries around the world, and it produces an annual "State of the Future" report as well as many special studies.

Within futures research, a variety of distinct traditions have developed since the 1960s. Futurists hold many different views of what futures research is and how the study of the future should be approached (Inayatullah 1996). Gidley et al. (2009) identify five traditions, which they label predictive-empirical, critical-postmodern, cultural-interpretive, prospective-action (or participatory futures), and integrative-holistic. A detailed discussion of these traditions or other proposed typologies of futures research is beyond the scope of this paper, but each can generate useful insights depending on the decision context. Multiple traditions are often employed in futures research as a strategy for dealing with fundamental uncertainties.

In sum, futures research is now a mature field of study with a considerable body of literature, many specialized journals, professional organizations, and distinct methods and perspectives for studying possible, plausible, and preferable futures. The majority of futures research nonetheless remains invisible to the scholarly community and the public because it takes place in military units, intelligence agencies, and corporations around the world and is hence proprietary or confidential. In nearly all major corporations, applied futures research is quietly carried out either by a dedicated futures group or, more often, under rubrics such as strategic and long-range planning, technological forecasting, strategy development, and horizon scanning. Limited versions of this research are sometimes published (e.g., Chief of Force Development 2010, Central Intelligence Agency 2000, Royal Dutch/Shell Group 2005), but most is closely guarded and unpublished. Thus, due to the proprietary or confidential nature of most futures research, the published literature is the tip of a much larger iceberg (Bell 1997).

## FUTURES RESEARCH METHODS

As a transdisciplinary field of inquiry, futures research embraces methodological pluralism, the philosophy of science that claims multiple disciplinary approaches, frameworks of analysis, and ways of knowing are required to understand complex systems or phenomena (Norgaard 1989). Consequently, futurists have developed a wide range of methods and borrowed or adapted methods from many fields. A comprehensive futures project usually involves multiple methods to address different dimensions of the problem. Several leading futurists have provided comprehensive reviews of futures research methods (e.g., Bell 1997, Fowles 1978, Glenn and Gordon 2009, Helmer 1983). This section briefly reviews several of the main methods used in futures research: scanning, visioning, the Delphi method, and scenarios.

Scanning, also called horizon scanning or environmental scanning, refers to a wide range of processes for identifying and understanding significant emerging trends in the external environment of an organization (e.g., a government agency, corporation, or non-governmental organization) or an area of interest (e.g., biological diversity, wildfire, or ecosystem services). Ideally, scanning serves as an early warning system to identify potential threats and opportunities. The goal is to find early indications of future developments that may be important. Gordon and Glenn (2009: 4) characterize scanning as "the central input to futures research" because the emerging trends identified through scanning are often used in other futures research methods. Scanning was first used extensively during World War II and has long been standard practice in business as well as many government agencies (Cornish 2004). The digital age has transformed scanning and there are now hundreds of approaches tailored to specific decisionmaking contexts, all of which involve identifying and classifying trends or potential trends into categories. A key element of effective scanning systems is feedback from management to the scanning team, so the system can "learn" to produce the most germane information and improve performance (Gordon and Glenn 2009).

Visioning or preferred futures methods involve identifying and choosing a preferred image of the future, a vital step in most comprehensive futures research projects (Hines and Bishop 2007). A vision is a compelling statement of the future that a group or organization wants to create based on shared deep values and purpose (Bezold 2009), or an idealized state that conveys the possibility of future attainment (Huber 1978). Images of the future are important because they enhance options and possibilities in the present (Slaughter 1995). "Future workshops" to create visions of preferred futures were organized and conducted in Europe by writer and futurist Robert Jungk beginning in

1962 (Jungk and Mullert 1987). While Jungk and others were conducting future workshops in Europe, Americans Edward Lindaman and Ronald Lippitt created a similar method called Preferred Futuring. Various forms of Preferred Futuring have been used by tens of thousands of organizations (Lippitt 1998).

The Delphi method, named after the Greek oracle at Delphi, is a futures research technique that solicits and structures the opinions of a panel of experts over multiple rounds to develop assessments of alternative futures (Kubik 2009). This method was developed at the RAND Corporation in the early 1950s in a study of the likely effects of nuclear war (Linstone and Turoff 1975). Early applications of this method were dominated by forecasting advancements in science and technology, following the lead of the classic Delphi study by Gordon and Helmer (1964). The Delphi method, in its many forms, has been applied in thousands of studies internationally for a wide range of purposes (Gordon 2007).

Scenario development and analysis is the most widely used futures research tool for helping decisionmakers think creatively about possible and plausible futures in the context of a world of great uncertainties. Glenn and The Futures Group International (2009: 2) define a scenario as "… a story with plausible cause and effect links that connects a future condition with the present, while illustrating key decisions, events, and consequences throughout the narrative." The output of scenario analysis is a set of stories or narratives about plausible futures. The stories are not predictions, but represent a range of plausible futures intended to help decisionmakers and other stakeholders build adaptive capacity to make their systems more resilient. The scenario method was developed by Herman Kahn and others at RAND Corporation and was first brought to public attention by the publication of Kahn's influential books (e.g., Kahn 1962, Kahn and Weiner 1967). Scenario analysis has been widely used for many decades in military and business planning (Bradfield et al. 2005). More than two dozen specific techniques for developing scenarios have been identified, and Bishop et al. (2007) discuss eight broad types of scenario development methods. Unlike other futures research methods, scenario analysis has increasingly been applied to environmental issues. A growing number of large-scale environmental studies include or are based on scenario methods, such as the Intergovernmental Panel on Climate Change (IPCC) reports (Solomon et al. 2007), and the Millennium Ecosystem Assessment (Carpenter et al. 2005, Raskin 2005).

Many other futures research methods have been developed by futurists or adapted from other fields, each with unique advantages and disadvantages depending on the context. For example, the Millennium Project's "Futures Research Methodology—v.3.0" describes more than 30 individual methods, including the futures wheel, cross-impact analysis, technology sequence analysis, and relevance trees. Together, these methods constitute a diverse and powerful tool kit for examining alternative futures.

## CONCLUDING COMMENT

This paper has briefly introduced futures research as a vital but often overlooked dimension in environmental science and policy. Futures research explores a range of possible, plausible, and preferred futures, and examines their implications for planning, management, and policy. The methods of futures research have been widely and productively applied in business and military spheres over the past 50 years, yet are mostly unknown in environmental affairs, with the exception of the recent surge in the use of scenario analysis in global environmental assessments. These relatively recent applications of a core futures method are encouraging and have demonstrated the usefulness of futures research as an alternative to traditional forecasting methods in dealing with irreducible uncertainties and exploring alternative futures. Application of the full range of methods and perspectives of futures research to environmental policy, however, has been scattered and minimal. Consequently, futures research has contributed relatively little to environmental issues to date, despite the need to effectively explore alternative futures for sound policy and planning in a rapidly changing world. Futures research offers a valuable set of tools and perspectives, and has an important role in sustainability science and policy.

## LITERATURE CITED

Bell, W. 1997. **Foundations of futures studies, volume 1: History, purposes, and knowledge**. New Brunswick, NJ: Transaction Publishers. 365 p.

Bengston, D.N.; Kubik, G.H.; Bishop, P.C. 2012. **Strengthening environmental foresight: potential contributions of futures research**. Ecology and Society. 17(2): 10. Available at www:ecologyandsociety.org/vol17/iss2/art10. (Accessed 22 June 2012).

Bezold, C. 2009. **Using vision in futures planning**. In: Glenn, J.C.; Gordon, T.J., eds. Futures research methodology—version 3.0 (CD-ROM). Washington, DC: The Millennium Project.

Bishop, P. 1998. **Thinking like a futurist**. The Futurist. 32(5): 39-42.

Bishop, P.; Hines, A.; Collins, T. 2007. **The current state of scenario development: an overview of techniques**. Foresight. 9(1): 5-25.

Bradfield, R.; Wright, G.; Burt, G.; Cairns, G.; Van Der Heijden, K. 2005. **The origins and evolution of scenario techniques in long range business planning**. Futures. 37(8): 795-812.

Brown, H. 1954. **The challenge of man's future**. New York, NY: Viking Press. 290 p.

Carpenter, S.R. 2002. **Ecological futures: building an ecology of the long now**. Ecology. 83(8): 2069-2083.

Carpenter, S.R.; Pingali, P.L.; Bennett, E.M.; Zurek, M.B., eds. 2005. **Ecosystems and human well-being: scenarios - findings of the Scenarios Working Group.** Millennium Ecosystem Assessment Series. Washington, DC: Island Press. 560 p.

Carson, R. 1962. **Silent spring**. Boston, MA: Houghton Mifflin. 368 p.

Central Intelligence Agency. 2000**. Global trends 2015: a dialogue about the future with nongovernmental experts**. Available at http://www.dni.gov/nic/PDF_GIF_global/globaltrend2015.pdf (Accessed 22 June 2012).

Chief of Force Development. 2010. **The future of the security environment, 2008-2030. Part 1: Current and emerging trends**. Ottawa, ON: Chief of Force Development, National Defense Headquarters. Available at http://www.cfd-cdf.forces.gc.ca/sites/page-eng.asp?page=7241. (Accessed 22 June 2012).

Cole, S. 2001. **Dare to dream: bringing futures into planning**. Journal of the American Planning Association. 67(4): 372-383.

Cornish, E. 2004. **Futuring: the exploration of the future**. Bethesda, MD: World Future Society. 313 p.

Edge, R.; Gurkaynak, R.S. 2010. **How useful are estimated DSGE model forecasts for central bankers?** Brookings Papers on Economic Activity (BPEA), Fall 2010. Washington, DC: Brookings Institution. Available at http://www.brookings.edu/~/media/projects/bpea/fall 2010/2010b_bpea_edge.pdf. (Accessed 22 June 2012).

Fowles, J., ed. 1978. **Handbook of futures research**. Westport, CT: Greenwood Press. 822 p.

Gidley, J.M.; Fien, J.; Smith, J.A.; Thomsen, D.C.; Smith, T.F. 2009. **Participatory futures methods: towards adaptability and resilience in climate-vulnerable communities.** Environmental Policy and Governance. 19(6): 427-440.

Glenn, J.C.; The Futures Group International. 2009. **Scenarios.** In: Glenn, J.C.; Gordon, T.J., eds. Futures research methodology—version 3.0 (CD-ROM). Washington, DC: The Millennium Project.

Glenn, J.C.; Gordon, T.J., eds. 2009. **Futures research methodology—version 3.0 (CD-ROM).** Washington, DC: The Millennium Project. Available at http://www.millennium-project.org/millennium/FRM-V3.html#toc. (Accessed 22 June 2012).

Glesinger, E. 1949. **The coming age of wood.** New York, NY: Simon and Schuster. 279 p.

Gordon, T.J. 2007. **Energy forecasts using a "roundless" approach to running a Delphi study**. Foresight. 9(2): 27-35.

Gordon, T.J.; Glenn, J.C. 2009. **Environmental scanning**. In: Glenn, J.C.; Gordon, T.J., eds. Futures research methodology—version 3.0 (CD-ROM). Washington, DC: The Millennium Project.

Gordon, T.J.; Helmer, O. 1964. **Report on a long-range forecasting study**. RAND Paper P-2982. Santa Monica, CA: RAND Corporation.

Gunderson, L.; Folke, C. 2008. **A different future (editorial)**. Ecology and Society. 13(2): 57. Available at http://www.ecologyandsociety.org/vol13/iss2/art57/. (Accessed 22 June 2012).

Helmer, O. 1983. **Looking forward: a guide to futures research**. Beverly Hills, CA: Sage Publications. 376 p.

Hibbard, K.A.; Crutzen, P.J.; Lambin, E.F.; Liverman, D.M.; Mantua, N.J; McNeil, J.R.; Messerli, B.; Steffen, W. 2007. **Group report: decadal-scale interactions of humans and the environment**. In: Costanza, R.; Graumlich, L.J.; Steffen, W., eds. Sustainability or collapse? An integrated history and future of people on earth. Cambridge, MA: The MIT Press: 341-375.

Hines, A.; Bishop, P., eds. 2007. **Thinking about the future: guidelines for strategic foresight**. Washington, DC: Social Technologies. 242 p.

Huber, B.J. 1978. **Images of the future**. In: Fowles, J., ed. Handbook of futures research. Westport, CT: Greenwood Press: 179-224.

Inayatullah, S. 1996. **What futurists think**. Futures. 28(6/7): 509-692.

Jungk, R.; Müllert, N. 1987. **Future workshops: how to create desirable futures**. London, UK: Institute for Social Inventions. 126 p.

Kahn, H. 1962. **Thinking about the unthinkable**. New York, NY: Horizon Press. 254 p.

Kahn, H. 1982. **The coming boom: economic, political and social**. New York, NY: Simon and Schuster. 237 p.

Kahn, H.; Weiner, A.J. 1967. **The year 2000: a framework for speculation on the next thirty-three years**. New York, NY: MacMillan. 431 p.

Kubik, G.H. 2009. **Projected futures in competency development and applications: a Delphi study of the future of the wildlife biology profession**. Minneapolis, MN: University of Minnesota. Ph.D. dissertation. 519 p.

Linstone, H.A.; Turoff, M. 1975. **Introduction**. In: H.A. Linstone; Turoff, M., eds. The Delphi method: techniques and applications. Reading, MA: Addison Wesley Publishing: 3-12.

Lippitt, L.L. 1998. **Preferred futuring: envision the future you want and unleash the energy to get there**. San Francisco, CA: Berrett-Koehler. 230 p.

Lipset, S.M. 1983. **On the limits of social science**. In: Smith, R.B., ed. An introduction to social research: Volume I of handbook of social science methods. Cambridge, MA: Ballinger: 149-168.

Lomborg, B. 2001. **The skeptical environmentalist: measuring the real state of the world**. Cambridge, UK: Cambridge University Press. 515 p.

Lowenthal, D. 2001. **Marsh's <u>Man and Nature</u> in the 21st century**. Forest History Today. (Spring/Fall): 57-63. Available at http://www.foresthistory.org/publications/FHT/FHTSpringFall2001/lowenthal.pdf. (Accessed 22 June 2012).

Meadows, D.H.; Meadows, D.L.; Randers, J.; Behrens, W.W., III. 1972. **Limits to growth: a report for The Club of Rome's Project on the Predicament of Mankind**. New York, NY: Universe Books. 205 p.

Millennium Ecosystem Assessment. 2005. **Ecosystems and human well-being: synthesis**. Washington, DC: Island Press. 137 p.

Millennium Project. 2012. **The Millennium Project. On-going programs**. Available at www.millennium-project.org. (Accessed 26 June 2012).

Mumford, L. 1931. **The brown decades: a study of the arts in America, 1865-1895**. New York, NY: Harcourt, Brace and Co. 266 p.

Naisbitt, J. 1982. **Megatrends: ten new directions transforming our lives**. New York, NY: Warner Books. 290 p.

National Park Service Organic Act. 1916. Available at www.cr.nps.gov/local-law/FHPL_NPSOrganic1.pdf. (Accessed 26 June 2012).

Norgaard, R.B. 1989. **The case for methodological pluralism**. Ecological Economics. 1(1): 37-57.

Olson, R.; Rejeski, D., eds. 2005. **Environmentalism and the technologies of tomorrow: shaping the next industrial revolution**. Washington, DC: Island Press. 195 p.

Petersen, J.L. 1997. **Out of the blue: wild cards and other big future surprises—how to anticipate and respond to profound change**. Arlington, VA: Arlington Institute. 189 p.

Pilkey, O.H.; Pilkey-Jarvis, L. 2007. **Useless arithmetic: why environmental scientists can't predict the future**. New York, NY: Columbia University Press. 230 p.

Raskin, P.D. 2005. **Global scenarios: background review for the Millennium Ecosystem Assessment.** Ecosystems. 8(2): 133-142.

Royal Dutch/Shell Group. 2005. **Shell global scenarios to 2025**. London, UK: Shell International Limited. 220 p.

Sarewitz, D.; Pielke Jr., R.A.; Byerly Jr., R., eds. 2000. **Prediction: science, decision making, and the future of nature**. Washington, DC: Island Press. 405 p.

Sears, P. 1935. **Deserts on the march**. 1988 Conservation Classics edition. Washington, DC: Island Press. 256 p.

Sherden, W.A. 1998. **The fortune sellers: the big business of buying and selling predictions**. New York, NY: John Wiley. 308 p.

Simon, J. 1981. **The ultimate resource**. Princeton, NJ: Princeton University Press. 415 p.

Slaughter, R.A. 1995. **The foresight principle: cultural recovery in the 21st century**. Westport, CT: Praeger. 232 p.

Solomon, S.; Qin, D.; Manning, M.; [et al.], eds. 2007. **Summary for policymakers**. In: IPCC, Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. Available at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf . (Accessed 28 July 2010).

Strathern, O. 2007. **A brief history of the future**. London, UK: Robinson. 322 p.

Toffler, A. 1970. **Future shock**. New York, NY: Random House. 505 p.

U.S. Department of Agriculture, Forest Service 2008. **U.S. Forest Service—caring for the land and serving people.** Washington, DC: U.S. Department of Agriculture, Forest Service. Available at http://www.fs.fed.us/aboutus/mission.shtml. (Accessed 23 March 2012).

Wager, W.W. 1991. **The next three futures: paradigms of things to come**. New York, NY: Praeger. 165 p.

Wells, J.G. 1987 (1932). **Wanted—professors of foresight!** Futures Research Quarterly. 3(1): 89-91.

World Commission on Environment and Development. 1987. **Our common future.** Oxford, UK: Oxford University Press. 347 p.

World Future Society. 2000. **The futurist directory: a guide to individuals who write, speak, or consult about the future.** Bethesda, MD: World Future Society. 436 p.

World Futures Studies Federation. 2012. **World Futures Studies Federation.** Available at http://wfsf.org. (Accessed 26 June 2012).

# AN APPROACH TO THE FUTURE

*Peter C. Bishop*

**Abstract.** This paper describes the rudiments of an approach to the future that we should teach and practice in our personal and professional lives. It begins with a consideration of change. The future is about change. If there were no change, we would have no reason to pay attention to the future. The paper concludes with an approach to long-term forecasting that takes uncertainty seriously. The result is a set of plausible futures for which we must be ready; otherwise, we run the risk of being surprised—or worse.

## INTRODUCTION

My colleague, Draper Kauffman, created a set of aphorisms about systems thinking (Kauffman 1980: 39), one of which is "High morality depends on accurate prophecy." If we desire to do good and we define a good action as one that has good outcomes, then we must be able to tell what the outcome of an action is before we can judge whether it is good or not. So forecasting is not just a nice description of the future; it is knowledge that is essential to knowing what to do.

It is disappointing, therefore, that so few people teach about the future when, in fact, we will live the rest of our lives there. Almost everything we do is intended to understand or to influence the future. But where is the future in our educational systems? We study the past, which we should, but why not study an equal amount about the future?

There are two answers to that question – one professional and the other epistemological. The professional answer is that teachers do not teach what they do not know. Since they were never taught about the future, how can we expect them to teach their students about the future? The more important and deeper answer is that most people believe that the future is unknowable. You cannot teach things you cannot know. But that is a fallacy. The future is knowable in exactly the same way that next week's weather is knowable or next week's stock market or next week's ball scores. We can know them as a set of possibilities, as plausible alternative futures, any one of which has a significant chance of occurring. Granted, knowing a set of possibilities is not as satisfying as <u>really knowing</u> what will happen. But when really knowing is impossible, is it not better to know something about the future (its possibilities) than to ignore it and know little or nothing?

## CHANGE

The study of the future is the study of change. But everything does not change at the same time or at the same rate, so every future is some combination of constants and changes. Constants and changes form strata, where the top levels are changing faster compared to the constant or slower-changing lower levels. The ocean serves as an analogy: the waves are driven by the winds, but currents are driven by the moon and the rotation of the Earth.

Our personal and organizational futures are shaped by two sets of forces: change that happens to us (from the external world beyond our control, which we call "inbound" change) and change that we create ourselves (based on our decisions and actions, which we call "outbound" change). Therefore, the future is partially constrained by the forces of the world (i.e., we cannot get the exact future we want), but we are not totally constrained because we still have some discretion. People and groups have different proportions of constraint and discretion in different situations, and those proportions themselves can change over time. But some measure of both inbound and outbound change shapes the future all the time.

Change also occurs at two rates: continuous, incremental change, versus discontinuous, disruptive change. Discontinuous change reaches further down into the strata, and results in more fundamental changes. It may change so much that the world becomes unrecognizable.

Continuous and discontinuous change alternate to form a pattern of punctuated equilibrium as in the theory of biological evolution (Gould and Ethredge 1972). Punctuated equilibrium consists of eras, which are relatively long periods of stability and continuous change separated by shorter periods of instability and disruptive change. The change from one era to another is characterized by an S-curve with three periods: a run-up period in which change is slow and incremental, a period of explosive growth in which change is unexpected and chaotic, and a maturation period in which change slows and the characteristics of the new era emerge.

Every system matures over time—from individuals to the planet as a whole. In the process, systems get good at what they do—actions become more routine and more efficient; fewer mistakes are made. And the system will remain in that state as long as its environment lets it. The environment is usually changing, however, and sooner or later it puts new demands on the system that it is unable to meet or even recognize. A mature system reaches the law of diminishing returns because it is approaching its inherent capacity for performance. It cannot get much better short of radically changing how it does things. According to the old sayings, "If you keep doin' what you been doin', you'll keep gettin' what you been gettin'," or "The definition of insanity is doing the same thing over and over again and expecting different results." The law of diminishing returns means that simply adding more inputs (people, money, time, effort) will not improve performance much more. To create real change, one has to dismantle the current system (era), partially at least, and build a new one.

Understandably, most people do not want to usher in a new era because they are familiar with and good at what the old era requires. What is more, the transition between eras is always difficult. Would that it were not so, but transformational change always involves taking some steps backwards, in terms of reduced performance, heightened risk, more mistakes, and extra cost compared to remaining in the existing era. We pay that price and take those risks, however, in order to achieve breakthrough results. The costs and difficulties are actually investments that pay off when a successful transformation creates an increased capacity for performance of which the old system (era) was simply incapable.

Human systems also change at four levels simultaneously: individuals, groups or organizations, the group's immediate environment, and the global environment. Physicians and psychologists manage change at the individual level; managers, at the group level; and traditional forecasters and planners, at the level of the immediate environment. Once in a while, however, it is necessary to take a look at the global environment, the macro world out there, because many changes in the immediate environment come from there. Those changes in turn affect the organization and the individuals in that environment.

The global environment consists of domains—large domains of action and change. Different people use different categories to characterize these domains, but they are all based on a simple five-segment model called STEEP, the acronym of the segments: social, technological, economic, environmental, and political (Morrison 1992). Each of these domains is changing all the time and affecting the immediate environment of groups and individuals as it does so. And each domain affects every other domain. No matter what causal chain is considered—social structure affects the technologies that get invented and produced (technology), which affects how much money people make and the standard of living they enjoy (economy), which in turn impacts the biophysical world (environment), some of which is regulated by government (political). Any other sequences would also work.

The final attribute of change is the time horizon, how long it takes for some changes to have an effect. Most of what we do deals with the near-term, measured in hours or days. We also deal with the medium-term, measured in weeks or months. Rarely do we consider the long-term, sometimes called the strategic horizon, measured in years or even decades. And that oversight is unfortunate because some changes will have effects for decades or perhaps even centuries. Most of our time cannot be spent on the strategic horizon. Our enterprises would collapse and we would fail in the near- and medium-term. But spending no time on strategic matters is just as risky. If we do not invest our time (and our money) for some long-term return, the long-term future will be just what it is today or more likely worse.

So the four main attributes of change are:

- Source—Inbound and Outbound
- Rate—Continuous and Discontinuous
- Level—Individual, Group, Immediate environment, Global environment
- Time—Near-term, Medium-term, and Long-term (Strategic)

Would that we had learned even this little bit in school so we could understand and manage change with more intelligence and forethought.

## FORECASTING

Given these attributes of change, how can we know anything about changes and the effects that are yet to come? The answer is simple: exactly the way we know about anything that we cannot directly observe. We make inferences (call them judgments, estimates, interpretations, or conclusions) based on two types of information—evidence and assumptions (Toulmin 1958). We all know about evidence. Those are the facts that support the inference. Assumptions, however, are the shadowy partners of the evidence. We have been taught to "state your assumptions," but we do it poorly, casually, even haphazardly, more to just fill in that box and move on.

But assumptions are the key to the whole ballgame, even though they have gotten a bad rap in our scientific, fact-oriented culture. Everyone makes assumptions all the time. The light will come on when I flick the switch; the car will start when I turn the key. Professionals also make assumptions in science (the instrument is properly calibrated), in law enforcement (the fingerprint was left yesterday, not last year), in finance (gold will be a good hedge against inflation). Most importantly for our argument here, historians also make assumptions. The document or the photograph was not altered; the date on the building is accurate; people believed what they wrote in their diaries. Those are all excellent assumptions, by the way, and they are hard to challenge.

Forecasters use evidence and assumptions in exactly the same way. Evidence can be time series data, people's hopes and fears, an organization's statement about executing a new strategy. The difference, however, is that assumptions about the future are much easier to challenge. A trend that has gone on for 20 years might not go on for another 20, people may not get what they hope for, or organizations may not execute their strategy successfully. These are quite reasonable alternative assumptions, to be sure. Does that make the original assumption wrong? No, it's just not as solid as the historian's. Does it make the conclusion wrong? No, it just introduces a fair amount of uncertainty into the conclusion. Does it mean that we know nothing about the future when we make such assumptions? Finally and definitely, no! We know the expected future if we accept the original assumptions, and we know one or more alternative futures if we consider one or more of the alternative assumptions.

But do we not have to choose which assumptions we will use in making our forecast? Absolutely not! And that is the fallacy of traditional forecasting. Making assumptions resolves uncertainty. It literally makes it go away. As a result, I can state my conclusion with much more certainty than I should because, of course, I have stated my assumptions, haven't I? But stating assumptions does not resolve the uncertainties in the world—only in our heads and in our forecasts and in our plans. The big problem with traditional forecasting is not that people do not state their assumptions. Good forecasters do. It is that they do not challenge those assumptions with alternatives. Challenging an assumption does not mean that the original assumption is wrong or even less probable than an alternative assumption. We are not trying to disprove anything. We are merely raising the possibility that the original assumption might be wrong because there is an alternative assumption that might be true instead. Notice the emphasis on "might." We are not saying it is; we are just saying that it might be. In that statement, then, is the power of knowing the future as it really exists.

The presence of plausible alternative assumptions measures the amount of uncertainty in an argument. If there are none, the forecast is strong; if there are some or many, then the forecast is accordingly weaker. This distinction appears in courtrooms, in the United States at least, every day. Lawyers call it the difference between doubt and reasonable doubt (Diamond 1990). Anyone can doubt any conclusion. No conclusion about the world is true beyond doubt. Descartes taught us that. But reasonable doubt requires a reason. We must have some basis for doubting—not just the possibility that the conclusion is false, but some reason that it might be. In American jurisprudence, a jury that has reasons for its doubt about the guilt of the accused, not just the possibility that the defendant is innocent, must return a verdict of "not guilty." Notice that the verdict is not "innocent." Jurors do not know with certainty that the defendant did not commit the crime. They just know that the case against the defendant is weaker than it should be. Usually, that weakness comes from assumptions that the prosecution had to make that have reasonable and plausible alternatives.

Futurists take uncertainty seriously, perhaps because statements about the long-term future are less certain than statements about the near-term future. For the same reason, other forecasters often make no statements about the long-term future at all. They know that they cannot discount the presence of significant amounts of uncertainty. And that is why most people do not think about the long-term future either—because they cannot be sure.

Futurists take a different tack. Realizing that we ignore the long-term future at our peril, they find a way to talk about it in a rigorous yet meaningful way. Identifying plausible alternative assumptions suggests plausible alternative futures. It is actually that simple. The result is a future that is not a single state the way most people talk about it, but rather a set of alternative futures ("scenarios").

That is the way we should talk about the long-term future in all professional work—what <u>might</u> occur, not just what we think <u>will</u> occur. And that is what we should be teaching our students in general education, from high school on, and in all our professional schools. If the mission of a profession is to do good for some group of people in the future, then rigorous forecasting of that future should be an essential skill of every professional.

## CONCLUSION

A useful scheme for forecasting based on these premises (though one that is much simpler than what is actually used) identifies three types of drivers of the future.

> **Trend**—continuous, inbound change of some variable over time, often described by a mathematical function. Examples include the aging of society, economic growth, and increasing planetary temperature. Constants, trends, and plans lead to the expected or baseline future. The expected future is more probable than any of the other futures in the set, provided that the individual or group accepts the assumptions it requires, i.e., assuming nothing really surprising happens.
>
> **Event**—a sudden, inbound change in some condition, usually closing one era and opening a new one. Events are the surprises that the assumptions of the expected future assume will not occur. But they might. And if they do, they can create a future significantly different from what was expected. Examples would be the collapse of the Soviet Union, the introduction of Hyper Text Markup Language and creation of the World Wide Web, and the terrorist attacks on 9/11.
>
> **Choice**—outbound decisions and actions taken by ourselves and others for a particular purpose. Choice comprises the decisions and actions taken to influence the future. Examples would be President Franklin D. Roosevelt's decision to create Social Security and set 65 as the retirement age, IBM's decision to use Bill Gates' MS-DOS operating system for the personal computer, and the decision to ban chlorofluorocarbons in an effort to preserve the ozone layer.

Each of the three drivers creates a different type of future with its own characteristics and sets of futures research tools to deal with them:

Trends lead to an expected or baseline future, the future that would occur if all or most plausible assumptions turn out to be true.

Events lead to plausible futures, alternatives to the expected future. Scenarios based on plausible alternative assumptions are a common tool to explore plausible futures.

Choices lead to the preferred future, the result of visioning, planning, and action to move in the direction of the preferred future.

The three drivers combine to create the cone of plausibility (Taylor 1990), an image of the future consisting of a cone expanding through time. The baseline future is the center-line of the cone, the plausible futures are all the other regions of the cone, and the preferred future is one area of the cone selected as the vision or goal for an individual or a group. The purpose of traditional predictive forecasting is to establish the center of the cone, the purpose of scenario forecasting is to explore the other major regions of the cone (i.e., other plausible futures), and the purpose of visioning and goal-setting is to select a region to use as the guide for decision and action.

People can move toward their preferred future in two ways: outside-in, i.e., scanning and understanding their future and then deciding how to proceed through it, or inside-out, i.e., establishing a vision or a goal and taking the best path to it. Each approach uses the same sets of tools, but in different orders. The outside-in approach begins with research and forecasting, then goes to visioning and goal-setting, and finally ends with planning and action. The inside-out approach begins with visioning and goal-setting, then assesses the future environment through research and scanning, and finally ends with planning and action.

So can we know the future? No; as a singular condition, the future cannot be known. But can we know the futures? Absolutely, or we can know at least most of them. And that is how we should approach the future.

## LITERATURE CITED


Diamond, H.A. 1990. **Reasonable doubt: to define, or not to define**. Columbia Law Review. 90(6): 1716-1736.

Gould, S.J.; Eldredge, N. 1977. **Punctuated equilibria: the tempo and mode of evolution reconsidered**. Paleobiology. 3(2): 115-151.

Kauffman, D.L. 1980. **Systems One: an introduction to systems thinking**. Second edition. St. Paul, MN: Future Systems. 44 p.

Morrison, J.L. 1992. **Environmental scanning**. In: Whitely, M.A.; Porter, J.D.; Fenske, R.H., eds. A Primer for New Institutional Researchers. Tallahassee, FL: The Association for Institutional Research: 86-99.

Taylor, C.W. 1990. **Creating strategic visions**. Carlisle Barracks, PA: Strategic Studies Institute, U.S. Army War College. 21 p.

Toulmin, S.E. 1958. **The uses of argument**. Cambridge, UK: Cambridge University Press. 251 p.

# A FRAMEWORK FOR DEVELOPING FORESIGHT IN NATURAL RESOURCE MANAGEMENT

*Kay E. Strong*

**Abstract.** This paper describes a fundamental framework for anticipating and influencing the future that has been used to prepare professional futurists at the University of Houston for more than 35 years. The overview of the framework addresses how futures researchers organize information about changes in the world (e.g., by defining the domain, or scope, of the forecasting topic and identifying drivers of future change). Specific techniques to develop foresight, including environmental scanning and trend analysis, are discussed. The paper summarizes the three kinds of futures typically explored: the probable future, plausible alternatives, and preferable futures, whether centered on individuals, organizations, or society at large. Plausible futures are among many aspects of futures forecasting where scenarios can be used. Definitions and descriptions of scenarios are provided. The process of developing scenarios is illustrated, and their purpose in the forecasting framework is presented.

## INTRODUCTION

Writer William Gibson reportedly quipped, "The future is already here—it's just not evenly distributed."[1] Assuming Gibson is correct, how does one gain access to the knowledge about the future that is already here? Some disciplines rely on quantitative modeling to project the current and past state of the world environment forward in time. Because these models are driven by known data, their predictions about the future meet the standards of reliability and internal consistency, hallmarks of sound scientific research. Unfortunately, most of these predictions fall short of realization beyond a window of 2 or 3 years due to unanticipated factors. To better anticipate the future and manage its inevitable uncertainty, some have turned to the forecasting methodologies employed by futures research. The U.S. Environmental Protection Agency (EPA) defines futures research as "a platform to engage in strategic conversations to better understand uncertainty and shape a sustainable future" (U.S. EPA 2005: 1). Futures research relies more heavily on qualitative modeling to forecast what is probable, to anticipate possibilities, and to envision what is desired. Three principles differentiate futures research from traditional forecasting methodologies. Taking the long view means looking a decade or more into the future, thinking from the "outside-in" by placing emphasis on the uncontrollable external environment, and actively seeking a diversity of perspectives. Opening doors to new insights is a key objective of futures research.

Framework forecasting is a methodology taught at the University of Houston (Houston, TX) for conducting futures research. The framework itself is an organizing technique which directs the gathering and sorting of information on the topic of interest. Once completed, the information framework serves as the foundation for generating foresight about the long-term future. This paper provides a brief overview of the University of Houston's fundamental framework for anticipating the future. The framework differentiates among three futures: the probable, plausible alternatives, and the preferred. Finally, the process and purpose for scenario development are highlighted.

## FRAMEWORK OVERVIEW

Gaining access to knowledge about a future that is already here but not evenly distributed requires spending time trying to understand and give context to the changes occurring in today's world. The intelligence we gather is sorted into one of the following sections of the forecasting framework: (1) time horizon and domain definition, (2) current assessment, (3) drivers of future change, (4) uncertainties, (5) summary, and (6) information sources.

### Time Horizon and Domain Definition

Good futures research is most effective when used to make better decisions in the present about the future we are trying to pursue. It can help ensure that the strategies and goals for 2020, 2025, or 2030 are informed by insights into the world we are likely to inhabit. The time horizon establishes the depth of the forecast, that

[1]William Gibson, writer, National Public Radio, August 31, 1993.

is, how far into the future the forecast will illuminate. The domain definition defines the scope of the forecast topic: what will be included in the forecast, and what will not be included. To be clear on the purpose from the outset, it is important to identify the focal issue(s) and the key question(s) to be addressed given the selected time horizon. The more precise the definition, the more focused the information search. For example, what is the future of "symviability" (ecological-cultural symbioses and intercultural symbioses) in the United States (Boyd and Zeman 2010)? Speculative statements about what might or could happen in the future for the topic of interest should be avoided.

## Current Assessment

The current assessment is characterized as a snapshot highlighting essential facts, quantities, and structures about the domain, listing key players (stakeholders) who will be affected and have an interest in the possible outcomes, identifying their current interests and announced goals and plans for the future, and identifying the historical events that brought about the domain's current state. These events most likely occurred abruptly, disturbing life as we had known it. The emergence of the World Wide Web, the fall of the Berlin Wall, and the recent global recession are examples of game-changing, discontinuous events.

## Drivers of Future Change

Identifying "what is driving future change" (events, trends, issues, ideas, images, and actions) is central to understanding where the future of the domain is heading. Environmental scanning is a systematic and ongoing process for detecting early signs of "what is happening and what is likely to happen" in the external environment of the domain by reviewing and analyzing current literature, Web sites, and other sources to identify and monitor change. Long-time futurists Gordon and Glenn (1994: 1) remind us that "[n]o system will be able to eliminate all uncertainty; the objective of a scanning system is simply to find early indications of possibly important future developments to gain as much lead time as possible." The intelligence gathered by scanning can be used to generate new perspectives regarding future opportunities and risks as well as to challenge established assumptions and current wisdom about the domain.

An effective environmental scanning process has the potential to generate an overwhelming amount of information. Therefore, classification and analysis of this information are essential. Common mnemonic classification methods include STEEP (society, technology, economics, environment, politics), DEGEST (demography, economics, government, environment, society, technology), and EPISTLE (economic, political, informational, social, technological, legal, environmental). A well-rounded scanning process will endeavor to explore across all relevant macro-level categories as they pertain to the domain of interest, including:

- <u>Cultural factors</u> such as behavior, values, and institutions that enable a society or group to develop and maintain identity; language; ethics; religion; arts; aesthetics; and recreation;
- <u>Demographic dynamics</u> such as population size, rates of change, gender distribution, age structure, ethnicity, family composition, and migration;
- <u>Economic assumptions</u> (global-regional-local) such as growth rates, production, finance, distribution of resources (e.g., food, water, and energy) and products between regions and across sectors of society, and consumer behavior;
- <u>Ecological factors</u> as a source of inputs (i.e., air, water, land, energy, resources) and outputs (i.e., waste, pollution, climate change), ecosystems, and land-use planning;
- <u>Institutional assumptions</u> such as actions, processes, traditions, and institutions through which authority is exercised; conflict and governance; role of non-governmental organizations; and public policy;
- <u>Science and technology assumptions</u> such as rate of development; accessibility; role in transforming structure of production; nature of work; use of leisure time; advances in cyber-, nano-, bio-, and information/communication technologies; and transportation;

**Table 1.—U.S. Environmental Protection Agency's system for ranking the importance of environmental scanning hits**

| Ranking Criteria for Scans | Minimum Allowable Ranking Value | Maximum Allowable Ranking Value |
|---|---|---|
| Novelty | 1 = old hat | 5 = never been seen before |
| Scope | 1 = affects almost nobody | 5 = affects everybody |
| Severity | 1 = slight effect | 5 = human fatality, ecological disaster |
| Visibility | 1 = of little interest | 5 = of great interest |
| Timing | 1 = 20+ years into the future | 5 = imminent |
| Probability | 1 = little chance of happening | 5 = already an issue or certain to happen |
| Organizational Relevance | 1 = no authority to act | 5 = full authority to act |

- Social factors such as human development (i.e., such basic needs as health, education, security, identity, and freedom), lifestyles, and beliefs.

Following discovery and classification, scanning hits (information that indicates a possible or plausible change in the future) are graded or ranked according to their perceived importance and relevance. The highest ranking hits are coded into the framework; others are dismissed. Table 1 shows the ranking scheme devised by the EPA to grade a scanning hit across seven criteria of importance to this agency (U.S. EPA 2005).

Over time, drivers of future change may evolve or multiple drivers interact. When they do, trends take shape. A trend is a statement about the direction of change (i.e., more, less) in those forces shaping the future, usually gradual, long-term, or cumulative. A trend does not have to be dynamic, however; it can be stable and continuous through time (i.e., a constant) or it may oscillate in recognizable patterns (i.e., a cycle). Demographic and economic trends are particularly good candidates for extrapolation using basic mathematical projection techniques. EPA's futures handbook (U.S. EPA 2005: 12) offers the following advice for analyzing trends:

- Identify and state the trend. Give the trend a name and a verb. State the direction of change. For example, "The U.S. population grew by at least 10 percent during the 1990s."
- Document for credibility. Researchers must validate trends just as they must validate data in their scientific research, using numbers, graphs, and verifiable documentation.
- Explore potential countertrends. Identify countertrends that may reduce, reverse, or alter the course of the original trend. For example, if one trend states that the U.S. population is aging steadily, whereas another trend states that hundreds of thousands of young immigrants are moving to the United States each year, the first trend is weakened by the second.
- Generate implications. Identify the implications of the trend for the future of the environment. Will this trend affect the research being done now, or the research planned for later? To avoid bias, explore implications and actions in a group setting. Consider implications that are (a) obvious, (b) possible, and (c) speculative. Explore how different parts of an organization might be affected and how they could better prepare for potential implications.
- Determine options. Identify the research needs or how to develop more knowledge in a particular area. Once the researcher has adequate knowledge, identify what individuals or organizations can do now to avoid a bigger problem later. Describe the appropriate actions, the obstacles to achieving these actions, and the risks associated with inaction.

## Uncertainties

Uncertainties arise from non-trend drivers of future change such as potential events and actions, emerging issues, and new ideas and images. Uncertainties have the potential to hijack the expected future and are, therefore, the core around which alternative futures scenarios are woven. For example, the World Economic Forum's Global Risks Report 2011 identified six global uncertainties as high in both likelihood and potential impact: climate change, extreme energy price volatility, economic disparity, fiscal crises, geopolitical conflict, and global governance failure. These uncertainties are likely to be connected to and impact most domains.

### Information Sources

This section of the framework is a record of resources important to the researcher's domain, such as written and electronic publications, Internet sites, domain-specific organizations, and experts in that domain. To keep the forecasting framework up-to-date, the analyst will periodically return to these resources.

## WHAT FUTURE?

In futures research, a wide range of methods may be used to generate the probable future. This baseline forecast is primarily data-driven, describing the difference between the present and the expected or most likely future for the domain of interest. The baseline forecast is built upon a coherent and internally consistent set of assumptions about key driving forces and their relationships. It extrapolates current conditions, known trends, stakeholders' announced plans and goals, and experts' projections in the field forward to the selected time horizon. As an extension of the present, the baseline assumes no disruptions. Nevertheless, plausible alternative futures which are data-driven with a touch of imagination, embrace the reality of disruptions and uncertainties. Alternative futures scenarios are generated with at least one plausible uncertainty at their core. Preferred futures, the third kind of futures, are value-driven and used in action planning by individuals or organizations to bring about a desired future. Visioning and strategic planning are the tools used to influence the course of the future.

Even with the most rigorous approach, the forecast may miss the target. Why? Erica Orange, vice president of the futures consulting group Weiner, Edrich, Brown, says, "In order to learn new things and become truly objective about the future, you first have to begin forgetting—by discarding no longer useful information. Change gives information, knowledge, expertise a short shelf life" (quoted in Weeks 2010). Forecasts are improved by challenging underlying assumptions and by continuously updating the information framework through environment scanning.

## SCENARIO DEVELOPMENT

What are scenarios? The United Nations Environment Programme (2002: 320) definition states, "Scenarios are descriptions of journeys to possible futures. They reflect different assumptions about how current trends will unfold, how critical uncertainties will play out and what new factors will come into play in alternative environments." According to Zurek and Henrichs (2007), scenarios are not facts, predictions, forecasts, or speculation, but a means to create projections and to explore environments characterized by uncertainty and complexity. In "Environmental Futures," Alcamo (2008) lists six types of environmental scenarios, each with a distinct purpose:

- <u>Exploratory scenarios</u> start in the present, have a set of assumptions on policies, and identify key driving forces;
- <u>Anticipatory scenarios</u> start in the future with a prescribed vision (optimistic, pessimistic, or neutral) and work backward in time to visualize how that future could emerge;
- <u>Reference scenarios</u> describe the (default) future state in the absence of additional, new, and focused environmental policies;
- <u>Policy scenarios</u> describe a future state in the presence of additional, new, and focused environmental policies;
- <u>Qualitative scenarios</u> describe possible futures in primarily non-numeric formats; and
- <u>Quantitative scenarios</u> describe possible futures in primarily numeric formats (models).

Another distinction is between inquiry-driven and strategy-driven scenarios. In essence, inquiry-driven scenarios estimate and assess alternative future states of the environment, while strategy-driven scenarios focus on strategy development, evaluation, and planning to improve environmental quality and achieve a triple bottom line: ecological-social-economic sustainability.

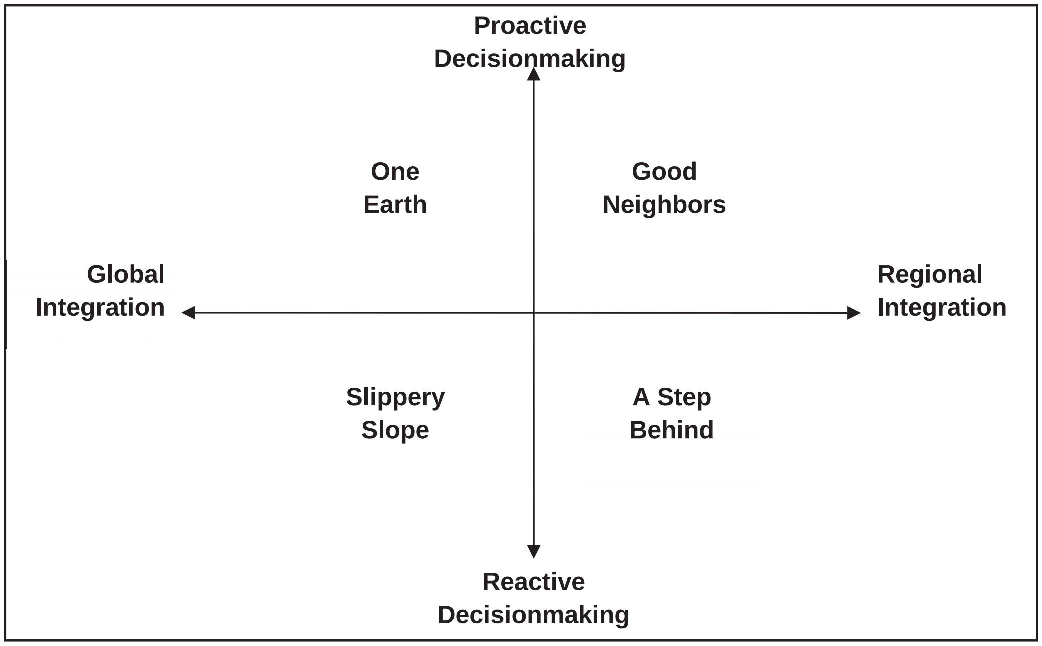


Figure 1.—2-by-2 scenario matrix.

Several international organizations have been active in developing global environmental futures scenarios. The Millennium Ecosystem Assessment, an interdisciplinary framework involving more than 1,360 experts worldwide, analyzed the conditions, trends, and services provided by the world's ecosystems as well as envisioning possible solutions to restore, conserve, or enhance the sustainable use of the ecosystems (Millennium Ecosystem Assessment 2005). The Intergovernmental Panel on Climate Change has used scenarios to illustrate how alternative policy pathways may or may not achieve an environmental target (Carter et al. 2007). The World Water Council, sponsor of the World Water Vision (Cosgrove and Rijsberman 2000), advocates development of a common strategic vision on water resources and management among all stakeholders with the support of strategic initiatives and activities.

The development of a scenario is a synthesis activity focused on conceiving, formulating, and elaborating a set of scenarios. The futures forecasting framework discussed earlier is an excellent approach to gathering and organizing information that can be used for generating scenarios. One popular approach to building scenarios was developed by Peter Schwartz (1991) and is used by the strategy consulting firm Global Business Network (GBN). The GBN scenario planning process begins by brainstorming a list of driving forces of future change (e.g., trends, uncertainties, surprises) which are both highly unpredictable and highly relevant to the focal issues and the key questions identified at the onset of the foresight project. Pre-determined forces, those easily extrapolated by standard forecasting techniques, are separated from the fundamental uncertainties. Linkages between the driving forces are identified. The remaining uncertainties are prioritized to facilitate identification of the two most critical. At least two extreme but plausible outcomes for each of the critical uncertainties are described. Finally, the scenario logic that integrates the two (or more) most important drivers into one future is constructed.

A GBN 2-by-2 scenario matrix subsequently can be created. One driver is mapped onto the horizontal axis with the extreme outcomes located at either end. Likewise, the second driver is mapped along the vertical axis. Each quadrant is a scenario logic representing a provocative yet plausible outcome of the two uncertainties. The scenario matrix offers four distinct future trajectories for the domain over the time horizon, which are given titles that capture the essence of the scenario logics. Figure 1 illustrates a typical 2-by-2 scenario matrix.

Believable plot lines for the scenario logics are written as if the observer is living at the selected time horizon, say 2030. The information gathered into the framework should be filtered back into the scenario where most appropriate. In a paragraph or two, how and why that "world" came into being are described. Embellishing the scenario script with interesting characters, specific facts, dates, events that occurred, and conflict or surprising developments deepens the reality. Scenarios should be written in a format that is convincing and sufficiently absorbing to draw the reader in. To give the scenario a deeper sense of future reality, scenarios are sometimes cast into an artifact of the times dated at the time horizon, such as an editorial blog, a letter addressed to a special-interest group, a news podcast, or a day-in-the-life video.

Recall that good futures research is most effective when used to make better decisions in the present about the future we are trying to pursue (or avoid). Forecasts of long-term futures are generated based on the information gathered into the framework. Scenarios are a means to summarize the main drivers, external conditions, and key uncertainties at play and to describe a set of plausible futures for a domain of interest. Scenarios are platforms for rehearsal. If decisionmakers assess the implications of each scenario based on the original focal issue and key questions, then the robustness of goals and strategies can be tested against the range of future possibilities. As a final step, decisionmakers need to develop a monitoring plan to identify specific leading (early warning) indicators that the future is, in fact, resolving itself toward one or another of the alternative futures. With sufficient advance warning, users of forecasts are well-positioned to side-step the obstacles and seize the opportunities that lie in the future.

## CONCLUDING COMMENT

A fundamental question for environmental planners, managers, and policy-makers is how they might benefit from futures research. Futures research offers a variety of techniques and tools for identifying and exploiting the uncertainties that underlie unpredictability in traditional forecasting. Since the objective is not to improve predictive power but rather to open doors to new insights, the methodologies long employed by futurists should be welcome additions to the toolkit of scientists concerned with environmental management and policy.

## LITERATURE CITED


Alcamo, J., ed. 2008. **Environmental futures: the practice of environmental scenario analysis.** Amsterdam, The Netherlands: Elsevier. 197 p.

Boyd, G.; Zeman, V. 2010. **Towards a global-systems steering vision that is simple enough, but not too simple: symviability.** Proceedings of the 54th Annual Meeting of the International Society for the System Sciences (ISSS). Available at http://journals.isss.org/index.php/proceedings54th/issue/view/10. (Accessed 6 July 2012).

Carter, T.R.; Jones, R.N.; Lu, X.; [et al.] 2007. **New assessment methods and the characterisation of future conditions.** In: Climate change 2007: impacts adaptation and vulnerability. Working Group II contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press: 133-171.

Cosgrove, W.J.; Rijsberman, F.R. 2000. **World Water Vision: making water everybody's business.** World Water Council. London, UK: Earthscan. 108 p.

Gordon, T.J.; Glenn, J.C. 1994. **Environmental scanning.** Available at http://crrm.u-3mrs.fr/web/IMG/pdf/environment_scan-2.pdf. (Accessed 6 July 2012).

Millennium Ecosystem Assessment. 2005. **Scenarios: findings of the Scenarios Working Group.** Washington, DC: Island Press. 560 p.

Schwartz, P. 1991. **The art of the long view: planning for the future in an uncertain world.** New York: Doubleday. 272 p.

United Nations Environment Programme. 2002. **GEO-3: Global environmental outlook.** Available at http://www.unep.org/geo/geo3/english/515.htm. (Accessed 6 July 2012).

U.S. Environmental Protection Agency. 2005. **Shaping our environmental future: foresight in the Office of Research and Development.** Washington, DC: U.S. Environmental Protection Agency.

Weeks, L. 2010. **2010 isn't what many futurists of the past imagined.** GPB News, Georgia Public Broadcasting, Mon., October 18, 2010. Available at http://www.gpb.org/news/2010/10/18/2010-isnt-what-many-futuristsof-the-pastimagined. (Accessed 6 July 2012).

World Economic Forum. 2011. **Global Risks 2011. Sixth edition. An initiative of the Risk Response Network.** Available at http://riskreport.weforum.org/#/1/8. (Accessed 6 July 2012).

Zurek, M.B.; Henrichs, T. 2007. **Linking scenarios across scales in international environmental scenarios.** Technological Forecasting and Social Change. 74: 1282-1295.

# GLOBAL MEGA FORCES: IMPLICATIONS FOR THE FUTURE OF NATURAL RESOURCES

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**Abstract.** The purpose of this paper is to provide an overview of leading global mega forces and their importance to the future of natural resource decisionmaking, policy development, and operation. Global mega forces are defined as a combination of major trends, preferences, and probabilities that come together to produce the potential for future high-impact outcomes. These forces are examined in terms of their possible, probable, and preferable future impacts on natural resources. The paper is presented in two stages. First, it identifies seven commonly cited categories of existing, emerging, and projected global mega forces for direction and implications. Next, two technological mega forces with potential for high impact—networked sensor-actuator technologies and electronic performanceware systems—are identified and examined in detail.

## INTRODUCTION

The intent of this paper is two-fold: First, to stimulate strategic thinking about the future of natural resources based on emerging mega forces, and second, to identify exemplars of the implications of these mega forces for the future of natural resources. These objectives are accomplished by identifying a series of major global forces, the factors that drive them, and their implications for natural resource futures. Global mega forces are defined as a combination of major trends, preferences, and probabilities that come together to produce the potential for high-impact outcomes in the future. The forces are outlined in terms of the emerging challenges and opportunities they present for policy makers, decisionmakers, and practitioners who will determine the future of natural resources.

The approach involves a description of the major forces likely to shape future events. It is not a prediction or prescription of which specific futures will actually occur. Rather, a limited number of forces are presented that can be anticipated to produce disproportionate influences on the future.

Why is the study of global mega forces important to the future of natural resources? Accelerating change and complexity are anticipated to dominate the global scene in future decades (Enriquez 2001, Micklethwait and Wooldridge 1996), placing escalating pressures on how social-ecological systems will operate and what they will become. In the midst of these interacting forces the role of anticipatory, future-savvy leaders and decisionmakers will be crucial to outcomes for society and natural resources. An understanding of futures thinking and global forces enhances organizations' and individuals' ability to think strategically and proactively about the future. Such strategic thinking is especially important in natural resource management. In addition, this approach helps to prepare organizations and individuals to respond more effectively to future alternatives—both foreseen and unforeseen. Thus, decisionmakers, policy formulators, and practitioners can all be expected to benefit from an increased understanding of global forces coupled with knowledge of futures studies.

In futures research, it is important to understand that the future is not predictable in detail. Throughout history there have been many attempts to predict the future, from the prophecies of ancient Egyptian priests and the Greek Oracles at the Temple of Delphi, to those of American economist Ben Bernanke, current chairman of the Federal Reserve. However, attempts at prediction have proven to be largely unsuccessful in the long term as science increasingly recognizes the limits to prediction and modeling in complex systems (Batty and Torrens 2001). According to Batty and Torrens, current scientific prediction is characteristically embedded in qualification. At the same time, science is becoming less oriented to prediction and more directed toward the development of understanding as a framework for structuring debate.

While some scientists assert that the future is rendered more predictable with the generation of greater information, other scientists are beginning to challenge this traditional assumption (Cunningham et al. 2002, Gell-Mann 1994). For example, recent studies in complexity theory have argued that the generation of additional data does not ensure improved outcomes, greater predictability, or risk reduction when dealing with chaotic or complex adaptive systems (Briggs and Peat 1999, Holling 1978). In these frameworks, bifurcations, emergent processes, and discontinuous events confound predictive efforts—despite information.

So what does this mean to the future of natural resources? With so many forces and variables at work, is it hopeless to try to anticipate the future? Proponents of futures research would typically respond to these questions by stating that, while we cannot predict the future, we can anticipate a range of possible, probable, and preferable future outcomes, and use that information to influence the future.

Let's examine this rationale. Futures research is premised on the basic principle of unpredictability: that is, the future is inherently unpredictable in detail, many alternative futures are possible, and specific future outcomes cannot be known with certainty. However, while futures research is not focused on predicting the future, it does assume that a disciplined futures research approach aids in shaping preferred future outcomes. Future outcomes can be positively influenced by improving forecasting and futures-oriented decisionmaking in the present. Further, knowledge of global forces and pertinent variables contributes to the robustness of the futuring process and its outcomes. The incorporation of a futures approach and a knowledge of global forces provides four distinct advantages to policy makers, decisionmakers, and practitioners: it increases the robustness of our forecasting ability in the natural sciences, amplifies our understanding of emerging phenomena in this area, better prepares us for working with uncertainty, and enhances our ability to create and communicate our visions of preferred futures.

Understanding the importance of global mega forces in terms of emerging natural resource futures requires an awareness of the changing nature of change. The accelerating generation of data, information, knowledge, and ideas is bringing about profound global changes in almost every area of life. Bits are replacing atoms, telecommunication is instantaneous, and digital technologies are everywhere. Information flows freely around the world 24 hours a day, every day—and the Internet forms a global communications network that is always on, offering electronic services on demand. No society, enterprise, or individual is immune to the cascading changes that are being produced by this development. It is in this milieu that societies and natural resource managers everywhere are being challenged to develop robust frameworks that will successfully guide them into the future.

Why are some forces and their impacts more important than others—and often, more difficult to identify? The culprit here is the increased dimensionality of the changes. Change is occurring along three dimensions—speed, complexity, and magnitude of impacts. Historically, we have experienced rapid change primarily across one dimension, or sometimes two. But rarely has rapid change occurred across all three of these dimensions at the same time.

Making this process more difficult is the nature of the interactions taking place among global forces and pertinent variables. Scientists are increasingly discovering that the relationships among these forces are characteristically non-linear and complex in nature; that is, they do not operate in direct proportion to each other (Briggs and Peat 1999). Similar to Newton's famous three-body problem in physics, the outcomes of these interacting forces are, in large part, not subject to easy projection or modeling using the conventional tools of science. Futures research aids us in: (1) understanding the non-linear relationships existing among global forces, (2) more effectively addressing global forces and uncertainties across all three dimensions of change, and (3) coping with increasing uncertainty in the future(s) of natural sciences.

## SEVEN GLOBAL MEGA FORCES

Many global forces are at work shaping the future. Some of these forces have been long recognized and typically include political, demographic, economic, socio-cultural, and technological dimensions. More recently, the list of categories of global forces has been expanded to include environmental, scientific, and information dimensions. Many other global mega forces are less widely recognized. Often, these forces are outside our traditional scanning focus, believed to exceed the scope of our mission, or considered to be beyond our ability to address in a scientific manner. Other forces and variables may be considered to be outside our ability to effectively intervene. In contravention to this theme, I assert that it is important to recognize that we influence, and are influenced by, the full spectrum of global factors. Without an awareness of the major forces at work, deciphering the future can seem like embarking on a road trip without a roadmap or a destination.

While many global mega forces and trends are present, we focus on seven easily recognizable mega forces: demographics, globalization, economics, work, digital networks, information, and digital technologies. For the most part these forces are already well known, but that knowledge may not be evenly distributed and the implications for natural resources not examined. In the following subsections, each mega force is briefly described and then possible implications for natural resources are outlined.

## 1. Demographics

Demographic mega forces typically encompass major changes in characteristics occurring among populations. Examples include age, gender, race, employment, and location. Demographic change is always a fundamental driver of long-term social change (Schwartz 2003). Two examples of mega forces in demographic change are presented here: population growth and urbanization.

### A. Population growth.

Population growth is a commonly cited demographic mega force. The current world population is approximately 7 billion people and increasing. However, population growth rates are unevenly distributed among nations and peoples. For example, Beazley (2009) has projected that China, Russia, and Japan will exhibit relatively low changes in population size during the period 2009 to 2050. During that same interval, Beazley has projected that the population of India will increase dramatically from 1.135 billion to 1.592 billion, Nigeria from 137 million to 258 million, Bangladesh from 147 million to 243 million, and Pakistan from 164 million to 305 million. In general, the population of Europe is expected to decline during that same period from 729 million to 517 million, while less developed countries are expected to account for 70 percent of global population growth by 2030 (Beazley 2009, McKinsey and Company 2010).

Continued world population growth will place growing pressures on the global land base and water resources. Differences in population growth rates among nations will result in accelerating conflicts over natural resources, and will be a major factor in influencing natural resource decisions and policies around the globe. Population growth and increasing affluence will amplify the need to conserve natural resources in the face of escalating demands for their consumptive use, such as agriculture and resource extraction (Hall et al. 2000, Organ and Fritzell 2000).

### B. Urbanization.

There is a continuous and substantive transition in populations from rural to urban among most nations around the globe (Beazley 2009). For the first time in history, more people are living in cities than in rural areas and their work and social preferences are changing. Rising urban populations are creating major changes in expectations regarding the sharing of global wealth, the right to meaningful work, and access to educational resources.

An increasing percentage of the world's population will be located in urban areas and demand new forms of access to natural resources. Urbanization will result in accelerated trends toward consumptive practices and increases in waste disposal, pollution, and toxic discharges. Urban populations will tend to be more highly educated and expect greater participation in natural resource decisionmaking and policy formulation around the globe.

## 2. Globalization

Globalization refers to the ongoing process by which regional economies, societies, and cultures are becoming increasingly integrated through a globe-spanning network of communication and trade (Friedman 2007).

Increased globalization will require adoption of a broader, more international view of natural resources by countries, enterprises, and individuals everywhere. Adoption of a global agenda for natural resources will be demanded as historical and locality-based natural resource agendas become increasingly irrelevant. Furthermore, an increasing percentage of the world's population will demand direct involvement in natural resource decisions and planning.

## 3. Economics

Major shifts are occurring in the economic leadership of the global economy. Maddison (2007) documented the peaking of the United States' share of world Gross Domestic Product (GDP) during the 1950s and contrasted it to Asia's rising share of GDP. According to the International Monetary Fund, GDP is the most commonly used single measure of a country's overall economic activity. It is especially notable that China and India have dominated world GDP during 14 of the last 16 centuries, while North America and Western Europe have enjoyed less than 200 years at the top of the world GDP list. At the same time, historical and geographical divisions of individual economies are becoming less relevant in the context of the rising and interconnected global market. As Friedman (2007) has noted, the world is flat—or at least becoming flatter.

Funding priorities for natural resources will begin to shift in unforeseen directions as a result of globalized economic interests in the environment and changes in the relative GDP standings of nations. Economic actions taken in one part of the world will no longer be viewed as localized or separate from the rest of the world.

## 4. Work

New generations of workers are increasingly mobile and educated, and always plugged-in. Work environments are characterized by accelerating change, anytime-anywhere connectedness, rapidly redefined roles and competencies, an explosion in open source innovation, greater involvement and collaboration, and unprecedented increases in complexity and uncertainty. Emerging work challenges are demanding new forms of enterprises that are capable of greater and faster organizational agility, resiliency, and fluidity, and better and faster decisionmaking (Hamel 2007, Rubinstein and Firstenberg 1999, Ulrich 2000).

As the nature of work quickly evolves and more workers are drawn into the global workforce, workers' expectations and priorities for leisure and recreation are also changing. Greater affluence for segments of the world's population is being accompanied by shifts in lifestyle preferences and leisure activities. In "The Rise of the Creative Class", Florida (2002) has argued that high-income individuals place an elevated value on active outdoor recreational activities exemplified by mountain biking, kayaking, trail running, snowboarding, and rock face climbing. Increases in these activities, and similar leisure vectors, can be expected to produce future shifts in environmental and natural resource orientations. Growing rejection of resource-consumptive and polluting industries will further impact the future of natural resource management decisions and planning.

## 5. Digital Networks

An explosion is occurring in the development, availability, and widespread use of digital networks in all areas of human activities (Tapscott 1996, Tapscott and Williams 2010). Digital networks are stimulating major transformations in the nature of work, learning, society, and leisure. The global Internet is exerting unforeseen impacts on every aspect of living and working around the globe.

The business world commonly uses three types of digital networks: the Global Area Network, which we identify as the Internet; Wide Area Networks; and Local Area Networks. Other types of networks are quickly emerging. Rapidly evolving personal networks include Personal Area Networks and Body Area Networks (Dertouzos 1997, Heinrich 2005). These networks provide personal connectivity for individuals and are projected to use fabric for circuitry and body movement for power generation (Starner 1996). Other developing network configurations involve System Area Networks, Home Area Networks, and Car Area Networks.

Vastly improved access to people, devices, and information is redefining work, leisure, learning, and social activities around the globe. Natural resource landscapes that were formerly remote from most of the world's population will come under increased scrutiny, monitoring, and review by globally networked individuals with access to vast arrays of natural resource information and networked sensors. Social media such as Facebook, Twitter, and YouTube will enhance the ability to disseminate opinions, videos, and information about natural resource activities everywhere. Internet forums, weblogs, social blogs, microblogging, wikis, and podcasts will increasingly impact natural resource decisionmakers, policy makers, and practitioners everywhere as greater percentages of the world's population become connected, networked, aware of natural resource issues, and demand to have their voices heard.

### 6. Information

In 1996 former President William J. Clinton stated, "When I took office, only high energy physicists had ever heard of what is called the World Wide Web . . . Now even my cat has its own page" (Ingenito 2010: 9). The number of Internet users is growing exponentially. The total number of Internet users worldwide has increased from 16 million Internet users (0.4 percent of the world's population) in 1995 to over 2.1 billion users (30.4 percent of the world's population) today (Internet World Stats 2011a). Asia currently accounts for 44.0 percent of the world's Internet users, while Europe accounts for 22.7 percent, and North American usage accounts for 13.0 percent (Internet World Stats 2011b). According to Internet World Stats (2011b), the Internet penetration rate is currently 78.3 percent for North America, 58.3 percent for Europe, and 23.8 percent for Asia.

Nearly every individual around the globe will have access to the Internet in the future. The Internet will be a ready source of information to increase awareness and understanding about natural resources and the decisions that affect them. Natural resource decisionmakers, policy planners, and practitioners will become increasingly accountable in ways and to degrees that are currently unforeseen. The result will be greater scrutiny of natural resource activities and increased demands for meaningful participation—from everywhere.

### 7. Digital Technologies

Digital technologies in the form of computers, telecommunications, sensors, and actuators are becoming ubiquitous and increasingly transparent in operation. As a result, an explosion of collected data, the generation of new information and knowledge, and unforeseen developments in scientific visualization, intelligent devices, and performance amplification and augmentation systems are occurring. Digital technologies are becoming faster, cheaper, smaller, networked, and capable of operating at all scales. They are increasingly blending into the backgrounds of built and natural environments. Emerging digital technologies are rapidly transforming every aspect of human life (Martin 1996, Tapscott 1996, Tapscott and Williams 2010).

Digital technologies increase our ability to monitor and learn about natural resources, communicate our opinions and priorities to others, and act on our decisions. One important outcome of this development is how we consider and interact with natural versus built environments. The growing presence of digital technologies can be expected to radically alter traditional definitions and distinctions between natural and built environments. It can be anticipated that future debates and exchanges concerning natural versus built or engineered environments will radically influence how we define and experience natural resources in the future (Kahn 2011).

## OTHER GLOBAL FORCES OF SPECIAL SIGNIFICANCE

There are obviously many other significant global forces at work that offer the potential to impact natural resources in the future. However, they are too numerous to list and individually address in this paper. A few illustrative global forces include emerging "new economics," changing societal values, political power shifts, biotechnology, greening movements, transgenic organisms,[1] alternative energy sources, and technologies for sustainability. Instead of expanding on these forces,

[1]Transgenic organisms are genetically modified or engineered organisms whose genetic material has been altered through the use of one or more technologies.

the remainder of this paper will address two specific mega forces that exhibit high potential to impact the future of societies and natural resources: networked sensor-actuator systems and Electronic Performance Enhancement Systems (EPES). Together, these mega forces are already beginning to demonstrate their ability to transform natural resources everywhere.

### Networked sensor-actuator systems

Sensors are devices designed to perceive environmental states, monitor changes in environmental conditions, and communicate the resulting data to interrogators or other nodes (Culler et al. 2004, Heinrich 2005). Sensors are built or grown to detect wide ranges of variables including temperature, altitude, light, chemical composition, weight, pressure, proximity, and acceleration. Specific functions include pattern recognition, environmental analysis, and monitoring. The development of sensor webs is of special importance to natural resources. Sensor webs were first described by NASA in 1997 in reference to networks of sensors that communicate wirelessly and self-organize in ways that permit individual sensor components to act and coordinate as a unit.

Actuators are the counterpart to sensors. They are cybernetic devices designed to control or regulate some aspect of the environment by physically acting on the environment to bring about a change in a predetermined condition or status. Actuators are important because they permit matter to become an active agent rather than an inert substance (Glenn 1989). Actuators can be used for a variety of purposes over a wide range of environments. Applications include fly-by-wire control of aircraft, regulation of automated machining tools on factory floors, remote release of chemicals to reduce insect populations, triggering of stomata to control transpiration rates in leaves, or the activation of fire suppression systems in response to significant increases in ambient temperature.

Networked sensors and actuators are already present in large numbers in our homes and businesses—and the natural environment. They are primarily used for monitoring, tracking, and controlling functions. Networked sensor-actuator systems are present in factory assembly lines, aircraft and vehicles, home thermostats, medical dosage regulators, agricultural fertilizer applicators, weather monitors, tracking collars for endangered species, and indicators for diseased trees in forests.

The rapid expansion of research, development, and application of networked sensors and actuators has been well documented over the last several decades. These efforts have resulted in an explosion in the number of networked instrumentation and activation systems that are embedded in natural and built environments around the planet. Illustrating this point, Kelly (1998) observed that the number of computer chips embedded in objects is increasing at a much faster rate than the number of computer chips located in computers.

It is notable that networked sensors and actuators are being generated at ever-decreasing scales. For example, the Defense Advanced Research Projects Agency is designing networked sensor-actuator systems (also known as “smart dust” or “smart mote” technologies) to be produced in extremely large numbers at the nanometer level. This scale is representative of a new class of nanotechnology machines operating at the molecular and sub-molecular levels, where one nanometer equals one billionth of a meter (Kurzweil 2005). Drexler (1986), Drexler and Peterson (1991), and Regis (1995) have forecast that these micro and nano-scale artifacts will become cheap enough, and small enough, to drift in the air, be embedded in buildings and appliances, become part of organisms, be plowed into the soil, and become infused in the water.

Advancements in the development of smart dust technologies represent a significant factor in the expanding field of networked sensor-actuator technology (Heinrich 2005, Kahn et al. 2000). Self-organizing networked sensor-actuator systems operating at this level are frequently termed swarm technologies. Swarm technologies require that each distinct component sensor and/or actuator in the network be mobile, self-powered, and able to dynamically re-configure its role and relationships to conform to changes in environment, group objectives, network relationships, and relative and absolute position (Kurzweil 2005).

The following paragraphs summarize some trends in the development of networked sensor-actuator systems.

*Connecting people, objects, and environments.* The emerging ability to connect people, objects, and environments requires ongoing developments in the density, scale, and intelligence of connectivity. A recent example is development of the 2011 Internet Protocol version 6 (IPv6) addressing standard. This standard was designed to replace the prior Internet Protocol version 4 (IPv4) that was first implemented in 1981. Adoption of the new IPv6 standard provides the ability to address many more devices in the present, and more importantly, in the future. How many devices could be connected? Davies (2012) has stated that the IPv6 Internet Protocol, also known as the Next Generation Internet Protocol or IPng, is capable of connecting approximately $3.402 \times 10^{38}$ addresses. This very large address space is capable of connecting $6.65 \times 10^{23}$ devices for every square meter of the earth's surface, or over a thousand devices for every atom on the surface of the earth (Davies 2012).

*Building networked sensors and actuators at nano-levels.* Another requirement for developing future sensor-actuator networks is the ability to design and build these devices at ever-decreasing scales—eventually approaching the nanometer level. Current developments in this area include devices being built at the scale of approximately 1 to 100 nanometers ($1\text{-}100 \times 10^{-9}$ meters). Kaku (2011) and in a seminal work Drexler (1986) have asserted that projections of nanotechnology futures suggest these machines will be sufficiently large in number and small in size as to eventually vanish from human awareness and perception.

Nanometer devices are initially expensive to design and prototype. However, the primary cost of these systems is incurred in the design and testing stages rather than production. Once designed and tested, sensor-actuator networks could be assembled (or grown) using highly automated reprogrammable assembly lines, or be designed for self-replication. Scientists such as Drexler (1986), Drexler and Peterson (1991), and von Neumann (Brown 2000) developed the concept of self-replicating automata as a means of future fabrication of devices such as networked sensors and actuators. Their approach suggests that future self-replicating devices of this nature would possess the capability of mass reproduction and be able to generate copies of themselves at geometrically increasing rates.

Everyone and everything becoming plugged-in. It is projected that sensor-actuator networks will become ubiquitous in future built and natural environments. This projection anticipates a world where individuals and environments are increasingly "plugged-in" to each other. In this future world everyone would have the capability to connect to everything else—in homes, businesses, and natural resources. Realization of this outcome will require the expanding development and application of smart networks operating at a variety of scales including Global Area Networks, Wide Area Networks, Local Area Networks, Personal Area Networks, and Body Area Networks. Future applications in the natural resource area could include smart Forest Area Networks, Ecosystem Area Networks, Tree Area Networks, Microagronomy Area Networks, or individual Critter Area Networks.

This view of the future holds the promise that everyone will have the option of being connected to everyone else, and to everything else, on the planet. As future smart sensor and actuator networks become ubiquitously embedded throughout the globe, these devices will hold the potential to connect to every blade of grass, every leaf, and every organism on the planet. Indeed, this will be the dawn of a connected planet.

Why is this connectedness important? As objects become smarter, networked, and capable of both sensing and acting on their environments, they radically expand and redefine the options available for natural resource managers. Networked ecologies of things that continuously monitor and act on their environments, and update data in real time, also provide alternatives to traditional concepts of labor-intensive data collection, static information systems, and legacy approaches to planning and decisionmaking.

Environmental processes infused with multitudes of networked sensors and actuators will increasingly enable natural resource environments to be monitored continuously, controlled more precisely, and acted on more quickly. Natural resource agencies that take advantage of these capabilities stand to be more proactive, anticipatory, and agile, rather than reactive or slow responding. An example of a next step in this projected evolution is the development of a smarter planet.

*A smarter planet.* IBM recently introduced a marketing campaign premised on building a smarter planet (Palmisano 2008). The company's assertion is that the planet is rapidly becoming more instrumented, interconnected, and intelligent. It has projected this concept across a wide spectrum of applications that thematically include buildings, businesses, cities, energy, education, healthcare, security, transportation, and water.

IBM's view of the future provides an interesting perspective. Its premise is that the world is becoming smaller, flatter, and smarter and the application of technology will facilitate this process through increased digital instrumentation, interconnection, and embedded intelligence. It proposes to accomplish this goal by embedding large numbers of networked sensors and actuators in our built and natural environments, and by creating increasingly smarter digital systems to coordinate their functions.

Some have taken this view of the future even further. American author, inventor, and futurist Raymond Kurzweil (2005) has forecast that humanity will eventually impart intelligence to every atom in the universe using smarter digital technologies. Perhaps Kurzweil's forecast will be realized someday. In the interim, this view suggests a greatly expanded role for smart, networked sensors and effectors in the future(s) of natural resources.

## Electronic Performance Enhancement Systems

The world is entering a new age characterized by demands for accelerating human performance. This new age demands faster work outputs that are of higher quality than their predecessors. Significantly, it also requires leading-edge knowledge, innovation, and idea workers at a time when these resources are only beginning to be understood as capital assets (Dickelman 1999, Stewart 1997).

It can be anticipated that the future of natural resources work will closely parallel demands for work performance made elsewhere in the economy. This view of the future suggests that decisionmaking, policy development, and associated natural resources work will continue to become more complex and demanding. It is also indicative of the need for future natural resource workers who will be capable of providing world-class performance on demand, anytime and anywhere.

To respond to this challenge, it is probable that future natural resources work will increasingly involve the application of networked smart technologies, tools, and environments. Projections of future smart tool technologies suggest that these devices will exhibit two notable characteristics: they will actively learn as they are used and continuously reprogram themselves in response to changing needs. Smart tools will also exist in the form of smart environments that contain embedded intelligence. Autonomous and semi-autonomous robots will be another example. Future projections suggest that these mind-tools will be capable of evolving independently of their initial design parameters and will demonstrate greater intelligence over time (Kaku 2011, Kurzweil 2005). They will also operate transparently in the background. The purpose of these smart tools and environments will be specific: to augment and amplify human ability to conduct work.

Electronic Performance Enhancement Systems constitute a major response to future performance challenges. EPES are a class of rapidly emerging technology-based systems designed to enhance human ability to learn and perform cognitive-based work. These performanceware systems are composed of hardware and software components that work together to fuse the processes of learning and doing among users, and provide this capability on demand (Rosenberg 2001).

EPES will enable future decisionmakers, policy formulators, and practitioners to immediately engage in leading-edge performance situations. Performanceware systems will also eliminate extensive periods of pre-training and education as prerequisites for performance. The overall intent is to amplify and augment both professionals and novices in any environments—physical or virtual—and to enable peak performance under any conditions. It can be projected that EPES will be a leading factor in 21st-century work and learning (Winslow and Bramer 1994).

EPES are an outgrowth of earlier computer-enhanced learning systems exemplified by Computer-Based Training, Intelligent Computer-Assisted Instruction, and Intelligent Tutoring Systems (Gery et al. 1999, Mandl and Lesgold 1988). These systems were based primarily on the application of expert systems and advances in Human-Computer Interface technologies. The business world in particular has developed and applied variants identified as Decision Support Systems, Executive Information Systems, Executive Support Systems, and Electronic Performance Support Systems.

These precursors to EPES were developed mainly by business, education, and military interests, and have been widely applied throughout these enterprises. Future development and application of EPES will continue to depend on the fusion of a variety of separately evolving technologies. These technologies include artificial intelligence, computers, expert systems, neural networks, and telecommunications.

Current design strategies for EPES outline several commonly shared building blocks. EPES, intelligent software agents, and smart systems (which include emerging classes of smart robots) are frequently characterized as anticipatory, interconnected, knowledgeable, trustworthy, networked, convenient, reliable, and helpful (Aarts et al. 2002, Kaku 2011). They provide assistance in response to user inquiries such as "help me," "explain to me," "orient me," "show me," and "do for me." They help close the otherwise widening gap between relatively slowly developing human competencies, abilities, and knowledge, and the exponential increases that characterize digitally based machine capabilities and information resources.

*Expertise on a chip*. Why is the escalating development and application of electronic performanceware systems important to the future of natural resources? Today, we observe the presence of performanceware systems largely in the form of expert systems made up of embedded subroutines. The purpose of these systems is largely to automate routine and repetitious tasks and off-load the functions into silicon. These systems reduce the cognitive workload of natural resource workers by handling recurring work. Examples include the Apple iPhone and similar devices that are revolutionizing how we communicate, learn, and conduct work (Kelly 2010, Tapscott and Williams 2010). These and similar devices are already impacting natural resource work by providing expertise-on-a-chip.

Projections indicate an escalating demand for improved work performance. This mega force will continue well into the future as we face the full impacts of the emerging 7 billion mind economy. One strategy is to embed smarter devices in our environments, tools, and bodies. Evolving performanceware systems in the form of EPES represent a major opportunity to augment and amplify our ability to continuously deliver world-class performance on behalf of natural resources. Earlier in this paper we noted that future generations of natural resource workers will be highly mobile, educated, and always plugged-in. The question is, "What will they be plugged into—and why?"

## CONCLUDING THOUGHTS

The purpose of this paper has been to address the subject of mega forces of change. Seven broad mega forces were identified and their implications for natural resources briefly touched upon. Limitations in the length of this paper precluded further description and detail. The paper also explored two leading mega forces in greater detail. These mega forces were identified as developments in networked sensor-actuator technologies and Electronic Performance Enhancement Systems. It was asserted that the future impact of these mega forces on natural resources would prove to be nothing less than revolutionary. Their potential impacts may even be compared to the combined historical impacts of the printing press and electricity.

We conclude with a key question: What difference might we be able to make by adding formalized futures thinking to our conceptual resources? We live in an increasingly interconnected world. It is a world where the distinctions between the built and natural environments are blurring. In this milieu, we generate ever more knowledge and information about our past, present, and possible futures. Our challenge is to use this knowledge and creativity in extraordinary ways. An understanding of futures thinking and global forces enhances the ability of organizations and individuals to think strategically and proactively about the future.

## LITERATURE CITED


Aarts, E.; Harwig, R.; Schuurmans, M. 2002. **Ambient intelligence**. In: Denning, P.J., ed. The invisible future: the seamless integration of technology into everyday life. New York, NY: McGraw-Hill: 235-250.

Batty, M.; Torrens, P.M. 2001. **Modeling complexity: the limits to prediction**. CASA Working Paper 36. London, UK: Centre for Advanced Spatial Analysis, University College London. Available at http://discovery.ucl.ac.uk/260/1/paper36.pdf. (Accessed 26 June 2012). 37 p.

Beazley, M. 2009. **Snapshot: the visual almanac for our world today**. New York, NY: Octopus Books. 224 p.

Briggs, J.; Peat, F.D. 1999. **Seven life lessons of chaos: timeless wisdom from the science of change**. New York, NY: HarperCollins Publishers. 207 p.

Brown, J. 2000. **Minds, machines, and the multiverse**. New York, NY: Simon & Schuster. 396 p.

Culler, D.; Estrin, D.; Srivastava, M. 2004. **Overview of sensor networks**. Computer. 37(8): 41-49.

Cunningham, J. B.; Gerrard, P.; Schoch, H.; Hong, C. L. 2002. **An entrepreneurial logic for the new economy**. Management Decision. 40(8): 734-744.

Davies, J. 2012. **Understanding IPv6: your essential guide to implementing IPv6 on Windows**. Redmond, WA: Microsoft Press. 716 p.

Dertouzos, M.L. 1997. **What will be: how the new world of information will change our lives**. New York, NY: HarperEdge. 336 p.

Dickelman, G.J. 1999. **Performance support: crossing the chasm from ideas to practice**. Performance Improvement. 38(7): 5.

Drexler, K.E. 1986. **Engines of creation**. Garden City, NY: Anchor Press/Doubleday. 298 p.

Drexler, K.E.; Peterson, C. 1991. **Unbounding the future: the nanotechnology revolution**. New York, NY: Quill William Morrow. 304 p.

Enriquez, J. 2001. **As the future catches you: how genomics & other forces are changing your life, work, health & wealth**. New York, NY: Crown Business. 259 p.

Florida, R. 2002. **The rise of the creative class: and how it's transforming work, leisure, community and everyday life**. New York, NY: Basic Books. 404 p.

Friedman, T.L. 2007. **The world is flat: a brief history of the twenty-first century**. New York, NY: Picador/Farrar, Straus and Giroux. 672 p.

Gell-Mann, M. 1994. **The quark and the jaguar: adventures in the simple and the complex**. New York, NY: W.H. Freeman and Company. 392 p.

Gery, G.; Malcolm, S.; Cichelli, J.; et al. 1999. **Performance support in internet time: the state of the practice**. Performance Improvement. 39(6): 7-17.

Glenn, J.C. 1989. **Future mind: artificial intelligence**. Washington, DC: Acropolis Books, Ltd. 307 p.

Hall, C.A.; Jones, P.W.; Donovan, T.M.; Gibbs, J.P. 2000. **The implications of mainstream economics**

**for wildlife conservation**. Wildlife Society Bulletin. 28(1): 16-25.

Hamel, G.; Breen, B. 2007. **The future of management**. Boston: Harvard Business School Press. 272 p.

Heinrich, C. 2005. **RFID and beyond: growing your business through real world awareness**. Indianapolis, IN: Wiley Publishing, Inc. 267 p.

Holling, C.S. 1978. **Adaptive environmental assessment and management**. New York: John Wiley & Sons. 377 p.

Ingenito, D. 2010. **Democracy in the 21st century: social media and politics—global village or cyber-Balkans?** Los Angeles: University of Southern California. 71 p. M.A. thesis.

Internet World Stats. 2011a. **Internet growth statistics**. Available at http://www.internetworldstats.com/emarketing.htm. (Accessed 6 August 2011).

Internet World Stats. 2011b. **Internet usage statistics**. Available at http://www.internetworldstats.com/stats.htm. (Accessed 6 August 2011).

Kahn, J.M.; Katz, R.H.; Pister, K.S. 2000. **Emerging challenges: mobile networking for 'smart dust.'** Journal of Communication and Networks. 2(3): 188-196.

Kahn, P.H. 2011. **Technological nature: adaptation and the future of human life**. Cambridge, MA: The MIT Press. 248 p.

Kaku, M. 2011. **Physics of the future: how science will shape human destiny and our daily lives by the year 2100**. New York, NY: Doubleday. 389 p.

Kelly, K. 1998. **New rules for the new economy: 10 radical strategies for a connected world**. New York, NY: Viking. 179 p.

Kelly, K. 2010. **What technology wants**. New York, NY: Viking. 406 p.

Kurzweil, R. 2005. **The singularity is near: when humans transcend biology**. New York, NY: Viking Penguin. 652 p.

Maddison, A. 2007. **Contours of the world economy 1-2030 AD: essays in macro-economic history**. Oxford, UK: Oxford University Press. 448 p.

Mandl, H.; Lesgold, A. 1988. **Learning issues for intelligent tutoring systems**. New York, NY: Springer-Verlag. 326 p.

Martin, J. 1996. **Cybercorp: the new business revolution**. New York, NY: AMACOM American Management Association. 326 p.

McKinsey and Company. 2010. **Global forces: how strategic trends affect your business**. Available at http://ww1.mckinsey.com/clientservice/strategy/pdf/Strategic_Trends.pdf. (Accessed 5 August 2011).

Micklethwait, J.; Wooldridge, A. 1996. **The witch doctors: making sense of the management gurus**. New York, NY: Times Books. 369 p.

Organ, J. F.; Fritzell, E.K. 2000. **Trends in consumptive recreation and the wildlife profession**. Wildlife Society Bulletin. 28(4): 780-787.

Palmisano, S. 2008. **A smarter planet: instrumented, interconnected, intelligent**. Available at http://www.ibm.com/ibm/ideasfromibm/us/smartplanet/20081117/sjp_speech.shtml. (Accessed 18 July 2012).

Regis, E. 1995. **Nano: The emerging science of nanotechnology: remaking the world—molecule by molecule**. Boston, MA: Little, Brown and Company. 325 p.

Rosenberg, M.J. 2001. **E-learning: strategies for delivering knowledge in the digital age**. New York, NY: McGraw-Hill. 343 p.

Rubinstein, M.F.; Firstenberg, I.R. 1999. **The minding organization: Bring the future to the present and**

**turn creative ideas into business solutions**. New York, NY: John Wiley & Sons, Inc. 206 p.

Schwartz, P. 2003. **Inevitable surprises: thinking ahead in a time of turbulence**. New York, NY: Gotham Books. 247 p.

Starner, T. 1996. **Human-powered wearable computing**. IBM Systems Journal. 35(3&4): 1-12.

Stewart, T. A. 1997. **Intellectual capital: the new wealth of organizations**. New York, NY: Doubleday/ Currency. 278 p.

Tapscott, D. 1996. **The digital economy: promise and peril in the age of networked intelligence**. New York, NY: McGraw-Hill. 342 p.

Tapscott, D.; Williams, A.D. 2010. **Macrowikinomics: rebooting business and the world**. New York, NY: Portfolio/Penguin. 424 p.

Ulrich, D. 2000. **Context, capability, and response**. In: Chowdhury, S., ed. Management 21C: Someday we'll all manage this way. Harlow, UK: Prentice Hall-Pearson Education Limited: 235-249.

Winslow, C.D.; Bramer, W.L. 1994. **Future work: putting knowledge to work in the knowledge economy**. New York, NY: The Free Press. 384 p.

# SCENARIOS AND DECISIONMAKING FOR COMPLEX ENVIRONMENTAL SYSTEMS

*Stephen R. Carpenter and Adena R. Rissman*

**Abstract.** Scenarios are used for expanding the scope of imaginable outcomes considered by assessments, planning exercises, or research projects on social-ecological systems. We discuss a global case study, the Millennium Ecosystem Assessment, and a regional project for an urbanizing agricultural watershed. Qualitative and quantitative aspects of scenarios are complementary. Scenarios can help address several of the currently recognized challenges of sustainability science.

## INTRODUCTION

Society faces unprecedented challenges due to the pace and magnitude of environmental change (Millennium Ecosystem Assessment 2005). Human actions are important drivers of environmental changes through effects on land use, biogeochemical cycles, species invasions, disease emergence, and climate. These actions have large and long-lasting consequences for provision of food and fresh water; regulation of floods, pests and diseases; and the other benefits that people receive from nature, which collectively are called ecosystem services. Changes in ecosystem services affect human food security, health, and access to resources for both current and future generations.

Future changes in systems of people and nature (social-ecological systems) are deeply uncertain. The high velocity and vast extent of current changes in Earth's systems have not occurred before in the history of our species. We cannot rely on historical analogs for guidance. Social-ecological dynamics are unpredictable for many reasons, including nonlinear processes, the propagation of shocks in an increasingly connected world, and the role of human volition. Controllability of social-ecological systems is equally uncertain. Our ability to predict the consequences of policy instruments and management interventions is limited. Actions intended to mitigate environmental problems often have unintended consequences, including the emergence of new and unexpected problems. Collectively, these uncertainties make it impossible to predict futures of social-ecological systems, or even compute probability distributions for social-ecological futures.

Despite these difficulties, the need to think about the future of social-ecological systems cannot be avoided. The definition of sustainability includes the notion of non-decreasing wealth: sustainable policies meet the needs of the present without undermining future generations' ability to meet their needs (Arrow et al. 2004). Inevitably, environmental actions affect future generations as well as the present. Therefore, present-day decisionmakers must think about long-term consequences of environmental actions.

In view of profound uncertainty, how can environmental decisions best be guided to meet current and future human needs? Tools are needed to organize vast amounts of information, and portray uncertainties that cannot be computed using the usual tools of decision theory. Decisions can at least use all of the information available when the decision is made, even if that information is incomplete. Scenarios are one of the tools for supporting decisions in this setting. Here we provide a brief summary of scenarios for complex environmental decisions.

## WHEN ARE SCENARIOS USEFUL?

The set of plausible and possible future trajectories for a social-ecological system occupies a vast and mostly unknown space (Fig. 1). Most of the space is in the realm of unasked questions—outcomes that are not imagined and therefore not subject to inquiry. Imaginable but non-computable outcomes occupy a smaller part of the total space. These are outcomes that are plausible, are potentially important, and should be considered in decisionmaking even though they are difficult to analyze. A still smaller space is occupied by the recognized uncertainties, unknowns which are subject to formal analysis with computable probabilities. What we know for certain occupies the smallest region of all.

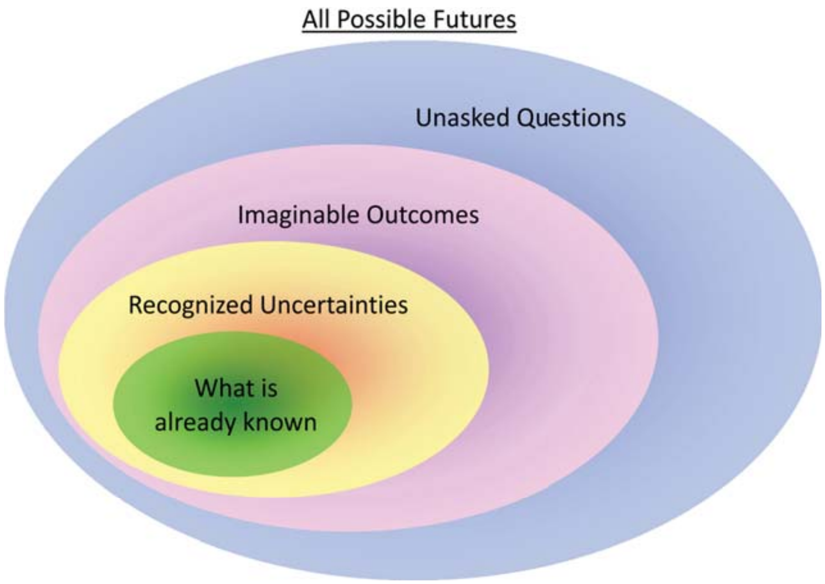



Figure 1.—The space of all possible future trajectories for a social-ecological system. Modified from Carpenter et al. (2006).

Decisionmaking under uncertainty is a lively discipline with many tools that are useful for environmental decisions (Polasky et al. 2011). Some established and effective tools, such as optimization of expected utility or related alternatives, are designed for the realm of recognized uncertainties (Polasky et al. 2011). In this realm, scenarios are not as effective as the more established tools. Scenarios are not especially useful if the set of potential outcomes is known, probabilities are computable for the outcomes, desirability (utility) of the outcomes is computable (or at least rankable), and the controllability of the social-ecological system is understood.

Scenarios are uniquely valuable for expanding the space of imaginable outcomes by prompting questions that have not yet been asked. Scenarios also organize and condense complex information in ways that improve communication and understanding. Thus, scenarios evoke broad conversations about the future while providing a framework to integrate diverse points of view about the future. Simulation modeling is not essential for scenarios, but in many cases scenarios and simulation models have been used in complementary ways within a single project. Examples of scenario projects are presented in the next two sections of the paper.

## MILLENNIUM ECOSYSTEM ASSESSMENT

The Millennium Ecosystem Assessment (MA) was conducted from 2000 to 2005 to assess the status and future of the world's ecosystem services and the implications for human well-being. Scenarios for global ecosystem services from 2000 to 2050 were developed as a part of the MA. The creators of the MA scenarios were able to learn from earlier efforts to build global environmental scenarios, notably the Global Scenarios Group of the Stockholm Environment Institute (Raskin 2005) and the Special Report on Emissions Scenarios of the Intergovernmental Panel on Climate Change (Nakicenovic and Swart 2000). Yet ecosystem services and their links to human well-being had never before been addressed by a global scenarios program (Bennett et al. 2003). The MA scenarios team had to consider nonlinear ecological feedbacks (Cumming et al. 2005) as well as relationships of ecosystem conditions to diverse aspects of human well-being (Butler et al. 2005). The challenges of addressing ecosystem services in the context of global change were reviewed in depth by the MA scenarios team in the early stages of the project (Chapters 2, 3, and 4 of Millennium Ecosystem Assessment 2005).

The overarching question for the MA Scenarios Working Group was: What will be the condition of the world's ecosystem services in 2050, and what changes will occur along the way? The process of building the MA scenarios began with a workshop to review the status of global scenarios and the particular challenges posed by ecosystem services. Shortly after this workshop, MA staff conducted a telephone survey of about 60 global thinkers to gather ideas about the vulnerability and resilience of the Earth's systems (Bennett et al. 2005). At about the same time, pilot projects were launched to "learn by doing" scenarios for several regions around the world.

Four storylines emerged from broad discussions following the synthesis of previous global scenarios and the interviews of global thinkers (Carpenter et al. 2006). In Global Orchestration, economic development and globalization accelerate. Environmental management is reactive, responding to crises as they arise. In Order From Strength, nations emphasize their own security, leading to a divided world with slower economic growth. Environmental management is reactive. Adapting Mosaic also envisions a less globalized world, in response to movement toward local and regional management of ecosystem services. Environmental management is proactive, emphasizing local knowledge, engagement of local people, and property rights to create incentives for more resilient stewardship of natural resources. In TechnoGarden, economies are globalized and technological innovation is booming. Environmental management is proactive due to implementation of large-scale innovative technological approaches for maintaining flows of ecosystem services. The four scenarios portray very different combinations of opportunities, risks, benefits, and costs. Outcomes are quite different across regions. Daily life for people would be very different in the four worlds of the scenarios.

Logical consequences of the four storylines were developed in both qualitative and quantitative form. Narratives emphasized the coherent and logical features of the storylines while attempting to explain what it would be like to live in each of the four worlds, in rich countries as well as poor ones (Cork et al. 2006). Quantitative analyses grounded in the logical structures of the storylines generated computable outcomes. This process required an analysis of drivers of change and their implications for ecosystem services (Nelson et al. 2006). Global models for macroeconomics, human demography, demand for food and fresh water, nitrogen emissions, climate, and biodiversity were run in parallel to compute changes in global land cover and land use, freshwater flows, freshwater quality, species diversity, and other outputs (Alcamo et al. 2005, van Vuuren et al. 2006). Harmonizing the qualitative and quantitative analyses, as well as the linkages among the various global models, was a major task for the Scenarios Working Group (Carpenter et al. 2006).

The MA exposed, and in some cases illuminated, several challenges of global scenarios for ecosystem services. These challenges include the problems of dealing with many different response variables (in contrast to climate-change scenarios that focus on only one response, greenhouse gas emission to the atmosphere), the challenges of harmonizing qualitative and quantitative scenarios, and the difficulty of integrating multiple global models. The MA also focused attention on the difficulty of analyzing and understanding the interactions of local- and global-scale processes (Biggs et al. 2007). Research on the integration of global and local scenarios has become an important frontier of scenarios research. We address one recently initiated case in the next section of this paper.

## WATER SUSTAINABILITY AND CLIMATE IN THE YAHARA WATERSHED, WISCONSIN

The Yahara Watershed includes the five lakes of Madison, WI. It drains 996 $km^2$ and is home to about 400,000 people. The watershed has been substantially altered by agricultural land use, urbanization, and climate change (Carpenter et al. 2007, Kucharik et al. 2010). Climate change, population growth, land-use change, and competing goals for the region place growing pressure on freshwater resources. Groups with competing water management goals include farmers, urban and suburban residents, developers, realtors, recreational lake users, neighborhood associations, environmental organizations, business organizations, and policy makers.

Water management in the region confronts many changes. Groundwater levels are declining in the deep aquifer that supplies drinking water, while runoff from road salt is increasing the salinity of surface water and shallow groundwater. Lake levels are becoming more variable over time, due to the increasing area of impermeable surface and more variable precipitation. Fluctuating lake levels trigger conflict over management of the locks that regulate discharge from the lakes. Some of the changes have come as surprises. In the late 1960s, Eurasian watermilfoil invaded the lakes and severely disrupted boating until the weed densities declined by about 1990. Diversion of sewage by 1971 did not cause the expected improvements in lake water quality. Instead, poor water quality and algae blooms were maintained by heavy runoff of nutrients from agricultural lands and construction sites (Carpenter et al. 2007). The recent invasion of spiny water flea is harming the native grazers in the lakes, and is likely to lead to more severe algae blooms. The lakes are vulnerable to invasion by zebra mussels in the future, which will litter beaches with sharp shells while promoting thick mats of decomposing algae along shorelines. Meanwhile climate change, urbanization, and intensive agriculture are likely to drive further changes in the hydrology and biogeochemistry of the lakes.

Scenarios of social-ecological change in the watershed from 2010 to 2060 will be developed as part of a new project that the authors have initiated with co-investigators Chris Kucharik, Steve Loheide, and Monica Turner. The overarching questions for the scenarios exercise are: (1) What will be the future condition of the natural capital and ecosystem services of the region between the present and 2060? and (2) What human actions will make the region more resilient (or vulnerable) to climate change?

The principal goal of the scenarios is to expand basic knowledge about sustainability and change in social-ecological systems (Table 1). Scenarios can be used to address many of the pressing questions of sustainability science (Kates et al. 2001, Swart et al. 2004). Qualitative narratives will be developed, based on in-person interviews and participatory workshops. Quantitative implications for land use, land cover, hydrology, and water quality will be modeled. The primary goal of this National Science Foundation-funded project is research, but outreach and public education are also important objectives. The scenarios will provide an arena for conversation about the future. Because the time horizon is significantly longer than the time frame of local politics, discussions can encourage a context of collaborative learning rather than conflict. Broad collaborative thinking may reveal new ways of improving the resilience of the region that are not known at present. In the long run, collaborative learning may help change the ways that people think about the region.

## EVALUATING SCENARIO PLANNING

Scenarios have been widely used by businesses, nonprofit organizations, researchers, and policy-makers, but relatively few evaluations of scenario planning have been conducted (Chermack et al. 2001). Improved understanding of the value of scenario planning could enhance its application in diverse contexts. Scenario planning engages groups to imagine plausible future alternatives, articulate previously unasked questions, and consider trajectories of change with unknowable outcomes. Evaluations may examine whether the theoretical advantages of scenario planning were realized, such as creating plausible alternative futures, encouraging creativity and collaboration, enhancing causal and story-based thinking, and changing mental models (Harries 2003). In addition, evaluations could address outcomes in terms of improved decisionmaking, changed behavior, or enhanced performance (Bartholomew and Ewing 2009). Since scenarios are not forecasts, it would be unreasonable to evaluate scenarios on the basis of whether they accurately predict future conditions. Yet some organizations highlight the success of scenarios in helping decisionmakers anticipate future changes in an increasingly interlinked world, although these self-reported success stories are not representative (Harries 2003).

Scenario planning for social-ecological change in the Yahara Watershed in Wisconsin will incorporate an evaluative component. The evaluation process will examine the role of scenario planning in enhancing participants' understanding of complex and dynamic social-ecological relationships, perceptions of utopian and dystopian futures, and perceived mechanisms and

**Table 1.—Research challenges to be addressed using scenarios in the Yahara Watershed project. Research challenges of sustainability science are based on Kates et al. (2001) and Swart et al. (2004).**

| Research Challenge | Key Aspects of the Challenge | Contribution of Scenarios |
|---|---|---|
| Spanning spatial scales | Local, regional, and global processes interact. | Identifying cross-scale feedbacks and their potential consequences |
| Spanning response times | Societal decisions about long-term change must be made in the short term. | Linking long-term goals to short-term decisions |
| Recognizing wide range of outlooks | Values and preferences for the future differ among people. | Accounting for perspectives that are recognized through outreach activities, surveys, etc. |
| Reflecting critical thresholds, surprise, and uncertainties | Unprecedented changes cannot be calibrated in models, and nonlinear thresholds are hard to measure. | Creative "what if" scenarios suggesting novel analyses and model simulations |
| Accounting for human volition | Human behaviors have strong effects yet are hard to forecast. | Normatively distinct viewpoints of desired or undesired futures being cast as scenarios for analysis and model simulation |
| Combining qualitative and quantitative thinking | Values, culture, and institutions have as much impact on sustainability as do quantifiable aspects of social, economic, and biophysical change. | Combining narrative scenarios with quantitative model simulations |
| Engaging stakeholders | Stakeholders have deep local knowledge of the system. Engaging them widens the knowledge base, helps address normative aspects of sustainability, and increases learning by all participants. | Providing a framework for synthesis and communication among researchers and stakeholders |

pathways of change. It will also examine the role of scenarios in changing the discourse in regional media and policy-making contexts on adaptive strategies for increasing resilience and decreasing vulnerability in the face of climatic, water resource, and human population change.

## CONCLUSIONS

Scenarios can increase the scope of environmental assessments by asking new questions and expanding the domain of uncertainties to be considered. Both qualitative and quantitative scenarios are useful. Qualitative narratives can be accessible to non-technical participants and thereby expand the diversity of people who participate in the scenario process (Carpenter et al. 2009). Qualitative scenarios are also useful for thinking about rare unpredictable events that are difficult to compute. Qualitative scenarios can help frame the social-ecological context for quantitative scenarios. Quantitative analyses enrich scenarios by providing details about computable aspects of environmental change, including important ecosystem services such as provision of food and fresh water. In addition, quantitative analyses provide a useful check on the plausibility of assumptions that are made when constructing qualitative scenarios.

Beyond playing a role in assessment, scenarios can help address basic research challenges in sustainability science (Table 1). Scenarios have also been used as a teaching device in university courses dealing with social-ecological systems (Biggs et al. 2010).

Use of scenarios in environmental assessment, management, and research seems to be expanding rapidly, based on the number of citations apparent in Google Scholar and Web of Knowledge. This brief article has only scratched the surface of an extensive and growing literature. We hope, at least, to have exposed some of the opportunities and challenges of scenarios for addressing change in social-ecological systems.

## LITERATURE CITED

Alcamo, J. D.; van Vuuren, D. P.; Ringler, C.; Cramer, W.; Masui, T.; Alder, J.; Schulze, K. 2005. **Changes in nature's balance sheet: model-based estimates of future worldwide ecosystem services**. Ecology and Society. 10(2): 19. Available at http://www.ecologyandsociety.org/vol10/iss2/art19/. (Accessed 6 July 2012).

Arrow, K.; Dasgupta, P.; Goulder, L.; Daily, G.; Ehrlich, P.; Heal, G.; Simon, L.; Mäler, K.-G.; Schneider, S.; Starrett, D.; Walker, B. 2004. **Are we consuming too much?** The Journal of Economic Perspectives. 18: 147-172.

Bartholomew, K.; Ewing, R. 2009. **Land use—transportation scenarios and future vehicle travel and land consumption: a meta-analysis**. Journal of the American Planning Association. 75: 13-27.

Bennett, E.; Carpenter, S.; Peterson, G.; Cumming, G.; Zurek, M.; Pingali, P. 2003. **Why global scenarios need ecology**. Frontiers in Ecology and the Environment. 1: 322-329.

Bennett, E. M.; Peterson,G.D.; Levitt, E. A. 2005. **Looking to the future of ecosystem services**. Ecosystems. 8: 125-132.

Biggs, R.; Diebel, M.W.; Gilroy, D.; Kamarainen, A.M.; Kornis, M.S.; Preston, N.D.; Schmitz, J.E.; Uejio, C.K.; Van De Bogert, M.C.; Weidel, B.C.; West, P.C.; Zaks, D.P.; Carpenter, S.R. 2010. **Preparing for the future: teaching scenario planning at the graduate level**. Frontiers in Ecology and the Environment. 8: 267-273.

Biggs, R.; Raudsepp-Hearne, C.; Atkinson-Palombo, C.; Bohensky, E.; Boyd, E.; Cundill, G.; Fox, H.; Ingram, S.; Kok, K.; Spehar, S.; Tengo, M.; Timmer, D.; Zurek, M. 2007. **Linking futures across scales: a dialog on multiscale scenarios**. Ecology and Society. 12(1): 17. Available at http://www.ecologyandsociety.org/vol12/iss1/art17/ (Accessed 6 July 2012).

Butler, C.D.; Corvalan, C.F.; Koren, H.S. 2005. H**uman health, well-being, and global ecological scenarios**. Ecosystems. 8: 153-162.

Carpenter, S.R.; Bennett, E.M.; Peterson, G.D. 2006. **Scenarios for ecosystem services: an overview**. Ecology and Society. 11(1):29. Available at http://www.ecologyandsociety.org/vol11/iss1/art29/. (Accessed 6 July 2012).

Carpenter, S.R.; Benson, B.J.; Biggs, R.; Chipman, J.W.; Foley, J.A.; Golding, S.A.; Hammer, R.B.; Hanson, P.C.; Johnson, P.T.J.; Kamarainen, A.M.; Kratz, T. K.; Lathrop, R.C.; McMahon, K.D.; Provencher, B.; Rusak, J.A.; Solomon, C.T.; Stanley, E.H.; Turner, M.G.; Vander Zanden, M.J.; Wu, C.-H.; Yuan, H. 2007. **Understanding regional change: a comparison of two lake districts**. Bioscience. 57: 323-335.

Carpenter, S. R.; Folke, C.; Scheffer, M.; Westley, F. 2009. **Resilience: accounting for the noncomputable**. Ecology and Society. 14(1):13. Available at http://www.ecologyandsociety.org/vol14/iss1/art13/ (Accessed 6 July 2012).

Chermack, T. J.; Lynham, S.A.; Ruona, W.E. A. 2001. **A review of scenario planning literature**. Futures Research Quarterly. 17: 7-32.

Cork, S. J.; Peterson, G.D.; Bennett, E.M.; Petschel-Held, G.; Zurek, M. 2006. S**ynthesis of the storylines**. Ecology and Society. 11(2): 11. Available at http://www.ecologyandsociety.org/vol11/iss2/art11/. (Accessed 6 July 2012).

Cumming, G. S.; Alcamo, J.; Sala, O.; Swart, R.; Bennett, E.M.; Zurek, M. 2005. **Are existing global scenarios consistent with ecological feedbacks?** Ecosystems. 8: 143-152.

Harries, C. 2003. **Correspondence to what? Coherence to what? What is good scenario-based decision making?** Technological Forecasting and Social Change. 70: 797-817.

Kates, R.W.; Clark, W.C.; Corell, R.; Hall, J.M. Hall; Jaeger, C.C.; Lowe, I.; McCarthy, J.J.; Schellnhuber, H.J.; Bolin, B.; Dickson, N.M.; Faucheux, S.; Gallopin, G.C.; Grübler, A.; Huntley, B; Jäger, J.; Jodha, N.S.; Kasperson, R.E.; Mabogunje, A.; Matson, P.; Mooney, H.; Moore, B.; O'Riordan, T.Svedin, U. 2001. **Sustainability science**. Science. 292: 641-642.

Kucharik, C.; Serbin, S; Vavrus, S.; Hopkins, E.; Motew, M. 2010. **Patterns of climate change across Wisconsin from 1950 to 2006.** Physical Geography. 31: 1-28.

Millennium Ecosystem Assessment. 2005. **Ecosystems and human well-being: scenarios**. Washington, DC: Millennium Ecosystem Assessment. Available at www.maweb.org/en/SYNTHESIS.aspx. (Accessed 7 July 2012).

Nakicenovic, N.; Swart, R.J., eds. 2000. **Special report on emissions scenarios**. Cambridge, UK: Cambridge University Press.

Nelson, G.C.; Bennett, E.M.; Berhe, A.A.; Cassman, K.; DeFries, R.; Dietz, T.; Dobermann, A.; Dobson, A. Dobson, Janetos, A.; Levy, M.; Marco, D.; Nakicenovic, N.; O'Neill, B.; Norgaard, R.; Petschel-Held, G.; Ojima, D.; Pingali, P.; Watson, R.; Zurek, M. 2006. **Anthropogenic drivers of ecosystem change: an overview**. Ecology and Society. 11(2): 29. Available at http://www.ecologyandsociety.org/vol11/iss2/art29/. (Accessed 7 July 2012).

Polasky, S.; Carpenter, S.R.; Folke, C.; Keeler, B. 2011. D**ecision-making under great uncertainty: environmental management in an era of global change**. Trends in Ecology & Evolution. 26(8): 398-404.

Raskin, P.D. 2005. **Global scenarios: background review for the Millennium Ecosystem Assessment**. Ecosystems. 8: 133-142.

Swart, R.J.; Raskin, P.; Robinson, J. 2004. **The problem of the future: sustainability science and scenario analysis**. Global Environmental Change Part A. 14: 137-146.

van Vuuren, D.P.; Sala, O.E.; Pereira, H.M. 2006. **The future of vascular plant diversity under four global scenarios**. Ecology and Society. 11(2): 25. Available at http://www.ecologyandsociety.org/vol11/iss2/art25/. (Accessed 7 July 2012).

# THE NORTHERN FOREST FUTURES PROJECT: A FORWARD LOOK AT FOREST CONDITIONS IN THE NORTHERN UNITED STATES

*W. Keith Moser and Stephen R. Shifley*

**Abstract.** Forests and forest ecosystems provide a critical array of benefits, from clean air and water to commercial products to open space. The forests and their ability to provide desired benefits constantly change in response to natural forces, human decisions, and human needs. The complexity and rate of change demand a rigorous evaluation of existing and emerging natural and anthropogenic forces, analysis of potential impacts of those forces, and consideration of how our response to them affects future forest sustainability. Nowhere is the apparent need for analysis of these challenges more critical than in the Upper Midwest and Northeast because this quadrant of the United States has both the greatest population density and the greatest percentage of forest cover.

The Northern Forest Futures Project is intended to be a window on tomorrow's forests, revealing how trends evident today and choices today and tomorrow can change the future landscape of the Northeast and Midwest. The project is a cooperative effort of the U.S. Forest Service, the Northeastern Area Association of State Foresters, and the academic community. This effort began with existing assessments and inventories and identification of trends and public issues. Current research is evaluating alternative future forest conditions based on scenarios from the Intergovernmental Panel on Climate Change, coupled with selected global circulation models and interpreted in the context of the latest ecological and social science. The results will provide a better understanding of the range of outcomes that may affect the North's 172 million acres of forest and the lives of the 124 million people who live near them. This information will be the basis for educational outreach that allows individuals, organizations, and resource managers to directly assess how differences that result from alternative social and economic choices about resource use, development, policy, and management affect the well-being of their communities and forests. Ultimately, the Northern Forest Futures Project provides the information needed for making wise decisions about the sustainable management of public and private forests in the northern United States.

## INTRODUCTION

The 20-state region from Maine to Maryland to Missouri to Minnesota, referred to as the North, has a higher proportion of forest cover (42 percent) and a greater share of the U.S. population (41 percent) than the other three quadrants of the United States (Fig. 1).

Today, forest conditions in the North reflect the human activities of many decades or centuries ago. The large-scale harvesting of old-growth timber that was common in the $19^{th}$ and early $20^{th}$ centuries was followed by forest fires, forest species succession, and most destructively by agricultural and urban land clearing. Forest-based cultures were replaced by farming, land development, or open-range grazing as settlers followed the loggers across the landscape (Williams 1989). Over time, however, marginal farm and pasture lands were gradually abandoned in many areas, allowing millions of acres of former agricultural land to revert naturally to forest cover. As a consequence, forest land in the North increased from 134 to 172 million acres (28 percent) from 1907 to 2007, while total U.S. forest land area showed little change (Smith et al. 2009). This increase in forest area in the North is remarkable because over that same period population in the quadrant increased from 52 to 124 million people (138 percent) and total U.S. population increased from 87 to 300 million (245 percent) (Shifley et al. 2012, U.S. Census Bureau 2012).

Future forest conditions in the North will be influenced by contemporary land use decisions and forest management activity, as well as population change and many other factors. For example, the increase in forest area appears to have nearly peaked as expanding urban areas in the North now subsume 4 million acres per decade, of which 1.5 million acres was formerly forest land (Nowak and Walton 2005, Shifley et al. 2012, Smith et al. 2009). How will forest resources and ecosystem services change in proximity to expanding

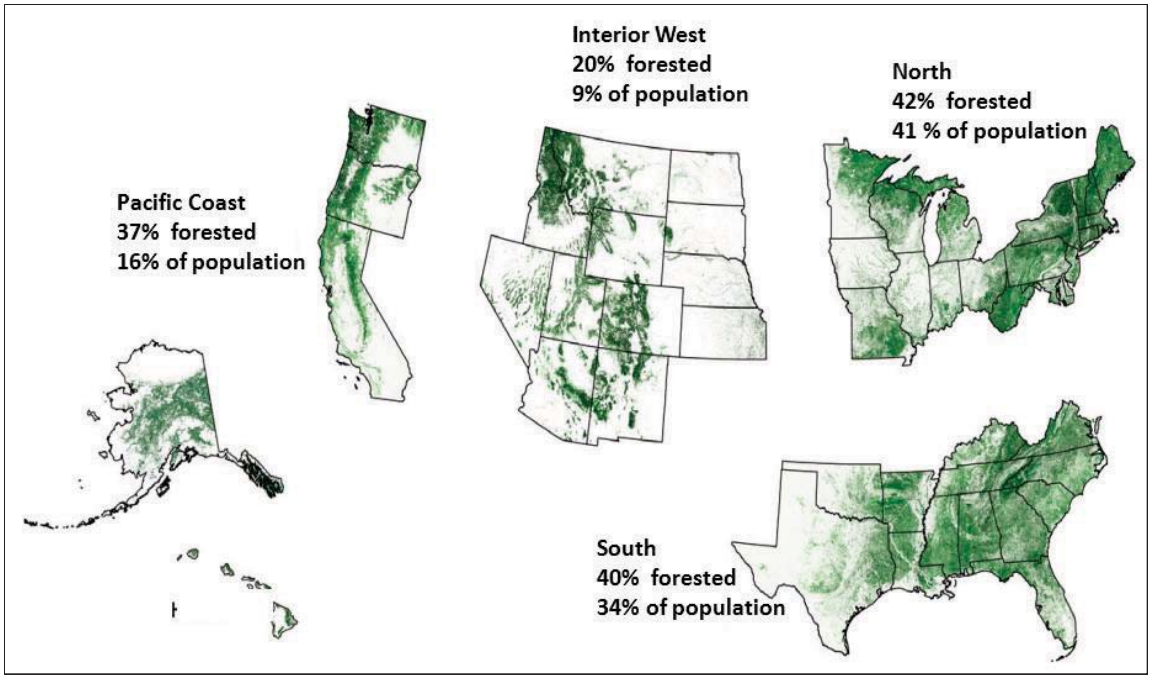



Figure 1.—Distribution of forests and people in the United States (Homer et al. 2004, Shifley et al. 2012, Smith et al. 2009, U.S. Census Bureau 2012). Shading shows forest land.

urban areas that house 80 percent of the North's population? The age distribution of the North's forest stands is concentrated in the 40- to 80-year-old age classes, rather than evenly balanced across a broader range of age classes. How is this age-class imbalance likely to affect forest biodiversity in coming decades, and how are management activities likely to affect future forest age-class distributions? The North's forests are being afflicted by new or expanding invasive insects and diseases. How are invasive species likely to affect the future condition of northern forests? How will the overarching effects of climate change over the next 50 years affect these patterns and trends? These and related questions have spurred research under the Northern Forest Futures Project.

Although the tradition of reporting forest statistics dates back to the 19th century, information on today's forests is more detailed and more complete than ever before. National assessments such as the Resources Planning Act (RPA) (USDA Forest Service 2012b), the 2010 National Report on Sustainable Forests (USDA Forest Service 2011a), and the billion-ton biomass report (Oak Ridge National Laboratory 2011, Perlack et al. 2005) highlight national trends and forecast national changes. Recently completed forest action plans for each state examine forest resource issues and proposed activities to address the most pressing of them (USDA Forest Service and Northeastern Area Association of State Foresters 2011). The Northern Forest Futures Project operates at a scale between states and the nation to examine issues, current conditions, trends, and projections of forest conditions, applying a consistent methodology to the 20 states within the North, individually and collectively. The methodology is linked to the Forest Inventory and Analysis (FIA) forest resource inventories and is intended to bring new forest resource projection capabilities to state and regional inventory data. Key projection methodologies and assumptions were developed from the methods applied for national RPA projections (USDA Forest Service 2012b) as well as the Southern Forest Futures Project (USDA Forest Service 2012c).

The Northern Forest Futures Project includes three components: (1) scoping contemporary issues and problems facing northern forests, (2) an assessment of current forest conditions and recent trends for a wide range of forest attributes, and (3) projections of future forest conditions for a range of alternative harvest, climate, and socioeconomic scenarios. The first and second components have been completed. Dietzman et al. (2011) analyzed hundreds of sources to produce a prioritized summary of issues and concerns recently expressed about the current condition of northern forests, which is supplemented by a summary of the issues raised in the forest action plans recently developed by each of the 20 states in the North (USDA Forest Service and Northeastern Area Association of State Foresters 2011). These products identify issues that can benefit from (or in some cases require) collaboration among states to address effectively. Examples include controlling invasive species, sustaining forest biodiversity, protecting water quality through watershed-scale management, and sustaining a viable wood products industry. The second component assessment is addressed by the recent publication of an assessment of 36 indicators of forest conditions in the North (Shifley et al. 2012). It provides a collective analysis of forest conditions and trends with comparative data at state and regional scales for many indicators of forest condition. In the remainder of this paper, we concentrate on the third component—development of forest projection capabilities.

## METHODS FOR FORECASTING CHANGE IN THE NORTHERN FOREST

### Overview

The projection component of the Northern Forest Futures Project seeks to estimate forest area, size, structure, and species composition under alternative scenarios for 2010 to 2060 across the 20-state North. In most cases these projections will be made for individual states and aggregated for regionwide estimates of change over time. Influencing these projections will be large-scale estimates of land use change, forest harvesting, and climate change over the time period. Fortunately, the Northern Forest Futures Project is able to utilize regional land use change and forest harvesting estimates developed as part of the 2010 Resources Planning Act assessment that includes national projections of forest change (USDA Forest Service 2012b, 2012c; Wear 2011). Climate change scenarios examined under the Northern Forest Futures Project are tied to climate projection models from the Intergovernmental Panel on Climate Change (IPCC) (Nakicenovic et al. 2000). State-scale forest resource projection methods follow those developed for the Southern Forest Futures Project (Wear and Greis in press), except the projected harvest levels were adjusted to match as closely as possible the RPA timber market scenarios and the forecasts of forest conditions (pers. comm., David Wear, USFS, May 2012). To maximize compatibility among projections for the North and the South, projection models for the North were implemented by the Southern Forest Futures Project team (Huggett et al., in press) and converted by Pat Miles into a Microsoft Access database that can be readily summarized and analyzed using his FIA EVALIDATOR program (Miles 2012).

The Northern Forest Futures Project projections will focus on a core subset of future scenarios that reflect high, medium, and low levels of climate change. The projection system accesses inputs of other models, quantifies scenario assumptions, and applies them to current forest inventory data (i.e., FIA plots), transforms these inventory data using calculated relationships, outputs the projected forest inventory data, and summarizes the projected data into a cohesive assessment of conditions under each scenario (Wear et al., in press).

There are two major benefits of this design. First, it largely mirrors the structure of the information flows of the RPA and the Southern Forest Futures Project, so the Northern Forest Futures Project can take advantage of existing algorithms, software, and expertise. Because those methods have already undergone peer review (Polyakov and Wear 2010, Wear et al., in press), so we can concentrate on understanding the implications of expected changes in northern forests rather than on developing projection methodology. Second, the future (projected) forest inventory database possesses the same data elements and structure as the current FIA inventory database. Within the constraints of usable data in this future dataset, the same analyses applicable to current FIA data will work for the future data. This provides substantial efficiencies in summarizing projection results and making direct comparisons to past and current forest conditions.

**Table 1.—Overview of IPCC storylines used in the 4th RPA asessment; Source: Nakicenovic et al. (2000) and Ince et al. (2011a)**

| Storyline Characteristics | Storyline A1B | Storyline A2 | Storyline B2 |
|---|---|---|---|
| General Description | Globalization, Economic Convergence | Heterogenic Regionalism, Less Trade | Localized Solutions, Slow Change |
| Global Real GDP Growth | Very High (6.2x) | Medium (3.2x) | Medium (3.5x) |
| U.S. GDP Growth | Medium (3.3x) | Low (2.6x) | Low (2.2x) |
| Global Energy Use | Very High | High | Medium |
| Oil & Gas Availability | High | Low | Medium |
| Technological Pace & Direction | Rapid; Gas, Biomass & Other Renewables | Slow; Coal & Gas | Medium; Gas, Oil & Biomass |
| Global Population Growth | Medium (1.3x) | High (1.7x) | Medium (1.4x) |
| U.S. Population Growth | Medium (1.5x) | High (1.7x) | Medium (1.3x) |
| General Development Themes | Economic growth; Introduction of New & More Efficient Technologies; Capacity Building | Self-reliance, Preservation of Local Identities | Sustainable Development, Diversified Technology |
| Global Expansion of Primary Biomass Energy Production (2010-2060) | High (Highest for USA) | Medium | Medium (lowest for USA) |

## Estimating Future Climate Change

The IPCC has evaluated alternative future climate scenarios based on selected atmospheric, economic, technological, and population variables (IPCC 2007). Future increases in greenhouse gas emissions are estimated based on four IPPC storylines. These storylines have differing assumptions about future economic, social, and technology changes that will influence future greenhouse gas emissions. The three IPCC storylines used in the Northern Forest Futures Project projections are summarized in Table 1. These storylines, which are also used in the RPA and Southern Forest Futures Project, can be summarized as follows:

- A1B—a future where the rest of the world approaches the United States in terms of per capita wealth, technology use, and population growth
- A2—a future where the world is not converging on the U.S. experience, but rather is much more regionally focused
- B2—a future of global sustainable development, with some regional economic convergence

The scenarios are categorized as very high, high, and medium global energy use for storylines A1B, A2, and B2, respectively (Table 1). Each storyline incorporates corresponding estimates of land use change and future greenhouse gas emissions. At least seven global circulation models (competing hypotheses) predict and map future temperature and precipitation based on estimates of future greenhouse gas emissions. To limit the total number of alternatives examined, we paired each of the three selected IPPC storylines (Table 1) with one of the midrange coupled global circulation models (CGCM) published by the Canadian Centre for Climate Modeling and Analysis (2012a, b). To define three Northern Forest Futures scenarios that represent high, medium, and low relative levels of future climate change, we modeled climate change using CGCM3.1 for IPCC storylines A1B and A2, and we used CGCM2 with IPCC storyline B2. The CGCM models chosen for the Northern Forest Futures Project analyses are intended to be consistent with the climate models used by the RPA and the Southern Forest Futures Project.

## Modeling Forest Change Under a Changing Climate

A version of the forest dynamics model (Wear et al. in press) is used to estimate change in northern forest conditions in response to projected land use change and the projected change in climate conditions outlined above. The model starts with a set of current FIA inventory plots that represent initial forest conditions for a given state and then operates on that inventory list to estimate change in FIA plot characteristics over a 50-year scenario. By summarizing the estimated future conditions of plots for the entire state (or any subset), it is possible to estimate the cumulative change in forest conditions over time.

In practice, the modeling process is complex and incorporates data from numerous sources. However, the core modeling technique is based on an imputation process that in its simplest form is intuitive. For example, begin with a list of all FIA plots for a given state. Then, for the next 5-year interval, stochastically estimate which plots will be harvested and replace each of those with a duplicate copy of a recently harvested FIA plot drawn from a pool of plots with matching ecological conditions. Harvest probability estimates are based on empirical models of historical harvest choices for each forest-type group; these probabilities are adjusted by a common scalar to simulate the level of harvest used for the RPA Scenario's harvest projection alternatives (pers. comm., David Wear, May 2012). Then, estimate which plots will be largely undisturbed and stochastically replace each of those with a copy of a plot that is 5 years older but otherwise of the same forest type and found on similar site conditions.

The next step is to use results from an external model of land use change (Wear 2011) to estimate increases or decreases in forest area for the projection period; model the change in forest area by proportionally increasing or decreasing the area that each FIA plot represents on the forest landscape (i.e., adjust the plot area expansion factor). Forest changes resulting from climate change are modeled by modifying the general methodology to replace plots representing forest growing under one historical climate regime with corresponding plots representing forest growing under a different historical climate regime (e.g., slightly warmer and wetter) that reflects the mapped changes in climate for future decades from a specific Coupled Global Climate Model.

The forest dynamics model has three submodels: partitioning, transition, and imputation. These submodels facilitate estimation of transition probabilities used to classify FIA plots, summarize detailed inventory data, and estimate change over time. The partitioning submodel groups similar FIA plots by identifying attributes such as age, density, precipitation, temperature, and live timber volume to develop groups (buckets) of similar plots. The transition submodel estimates the probabilities that a given plot will transition from one status (bucket) to another based on historical transition rates observed from re-measured FIA plots. Two separate versions of the transition submodel have been developed for (1) unharvested and partially harvested plots and (2) harvested plots that will be replaced by a plot representing new forest regeneration. These transition probabilities are used by the imputation submodel to predict a future condition for each inventory plot for the next time interval by stochastically drawing a replacement plot from the most appropriate partition group (bucket) as developed in the partition process. For example, if the transition probabilities state that a 40-year-old oak-pine plot will become a 45-year-old oak-pine plot (instead of an oak-hickory plot or some other forest-type group), then the model imputes what this 40-year-old plot will look like in 5 years by randomly picking an oak-pine plot from the bucket of existing 45-year-old plots that have similar ecological characteristics. This plot then becomes the new base plot for the next 5-year time step.

The completed simulation summarizes the results of these transitions for future decades by summarizing plot conditions for a projected future date in the same way that one would summarize forest conditions for any current or past forest inventory (Miles 2012). The forest condition forecasts are modified to account for projected land use change from an external land use model. Removals of wood products from timberland are derived from a separate model and summarized by hardwoods and softwoods.

## DISCUSSION

## Limitations of the Modeling Framework

### Model resolution

The partition submodel used to define groups of similar plots for the imputation process operates at the forest-type group level of aggregation, which is necessary to ensure sufficient sample sizes for imputation. For example, the oak-hickory forest-type group is an aggregation that includes 17 distinct forest types (e.g., white oak, red oak, bur oak, yellow-poplar/white oak/red oak, sweetgum/yellow-poplar, red maple/oak, southern scrub oak) and dozens of oak species. During the projection, the partition submodel aggregates more than 100 forest types into 10 or fewer forest-type groups that are carried forward in the projection. Projections of future forest species composition can be reported only by forest-type group, not by forest type or individual species. Thus, even though the projection system carries complete individual FIA plots forward in time, there are limits on the suite of variables that can be realistically summarized for future decades. The primary variables available for characterizing future forest inventories include forest-type group, area, age, site quality, size class, number of trees, volume, and biomass. Likewise, the methodology limits the spatial scale of results reporting to inventory units, entire states, or groups of states.

### Verification and validation

The forest dynamics model has been verified for U.S. forests by determining that the model is working as expected: the computer algorithms are correctly implementing the statistical models and the external assumptions about land use change and harvest are correctly applied to the projected forest conditions. The model projections have been validated in two ways. First, before the model was applied for the 2010 RPA projections, past FIA inventories for selected states were projected forward in time with the calibrated model and compared to observed present-day FIA inventories. Results were judged satisfactory by the model developers (pers. comm., David Wear, USFS, May 2012), and the subsequent RPA regional and national projections of forest change for 2010 to 2060 based on the model have undergone internal and external review. Second, the initial round of state-scale projections of forest change from 2020 to 2060 for the Northern Forest Futures Project were reviewed by the Forest Service FIA analysts working in the North and by state foresters and planners from northern states. Those evaluations, based on expert knowledge of forest conditions and past trends at the state scale, resulted in some modifications to model calibration for individual states, particularly with respect to estimated changes in forest area. More rigorous statistical validation of model projection accuracy and bias for individual northern states will occur over time with ongoing FIA state inventories. Present-day model projections from 2010 to 2060 serve as provisional hypotheses of forest change, and FIA statewide forest inventories completed in the coming decades will determine the accuracy of those projections in a de facto validation process.

In general, we anticipate that the longer the projection periods are, the lower the accuracy of the projection will be. For this application the imputation model uses the trends observed in the 2003 to 2008 forest inventories and other inputs, such as climate models, to build transition matrices. Consequently, trends occurring in that time span determine the future rates and patterns of forest change for the entire projection period. This may downplay the influence of some longer term trends, especially if those trends vary greatly from year to year. For example, mortality rates inherent in the model structure are based on those observed from 2003 through 2008 and may not reflect longer term or episodic cycles of forest pest attacks.

### Complexity

The imputation model is a custom product developed by the U.S. Forest Service, Southern Research Station's Forest Economics and Policy project (Wear et al., in press). Calibration and application require specialized knowledge and programming skills, which limits model implementation to a group of specialists. However, after a scenario is modeled the results will be readily accessible using a simple Web-based interface (Miles 2012).

**Table 2.—Northern Forest Futures Project research topics aligned under natural resource, human, or interaction categories (USDA, Forest Service 2011b).**

| Natural Resources | Human Systems | Natural Resource—Human Interactions |
|---|---|---|
| Wildlife habitat and biodiversity | Wood products | Insects and diseases |
| Forest area, species composition, and size structure | Environmental literacy | Stewardship and forest management |
| Water | Urban forest dynamics and management | Invasive plant species |
| Recreation | | Forest fragmentation and parcelization |
| Biomass and bioenergy | | |

## Strengths of the Modeling Framework

### Linkage to FIA data

There are many practical advantages to this modeling framework. Foremost, it can be calibrated and applied using existing FIA data that systematically sample all forest conditions in the United States. Consequently, it can be applied to all states in the North. Moreover, the same methodology has been applied to forecast nationwide changes in forest conditions as part of the RPA Assessment (USDA 2012b). Projections for the 20-state North use the same methods to provide state forecasts. Because the projection model input and output are databases of standard FIA plots, data summaries over time can be created using standard Web-based tools used to summarize current and historical FIA field inventory data (Miles 2012). This provides an efficient mechanism for summarizing projected changes over time in forest area, number of trees, age, size class, volume, and biomass in the same manner that present and past FIA data can be summarized.

### Linkages to other forest characteristics

Use of the FIA forest inventory plots as the basis for projecting forest conditions in future decades provides opportunities to link projected changes in forest conditions to estimates of other ecosystem services. Many forest attributes that can be estimated using a contemporary FIA inventory also can be estimated using projected inventory conditions (Table 2). Four principal investigative themes are outlined below.

#### 1. Invasive species

The Northern Forest Futures baseline assessment (Shifley et al. 2012) summarizes invasive insects and diseases that are likely to negatively impact northern forests in coming decades. These include (but are not limited to) emerald ash borer (*Agrilus planipennis*), gypsy moth (*Lymantria dispar*), Asian long-horned beetle (*Anoplophora glabripennis*), sirex wood wasp (*Sirex noctilio*), hemlock wooly adelgid (*Adelges tsugae*), and thousand cankers disease of black walnut.

Potential impacts of the emerald ash borer are well suited to examination with the Northern Forest Futures modeling framework. As it spreads, the emerald ash borer exclusively attacks ash trees (*Fraxinus* spp.) and kills virtually all of them. Consequently, it is relatively easy to model emerald ash borer impact on forest structure and composition by systematically removing ash trees from the imputed plots as the borer moves across the region. Other invasive species present greater modeling challenges within this projection system. The impact of the gypsy moth, which infests multiple species and kills only a portion of all infested trees, is much more difficult to model within the projection system and must be analyzed externally (e.g., USDA Forest Service 2012d).

#### 2. Forest biodiversity

Projections of forest age class through time can be used to examine broad change in forest age-class diversity. Age class is one of the simplest indicators of forest structural diversity (e.g., seedling, sapling, poletimber, saw log, and old-growth forest conditions) and associated wildlife habitat diversity (Tirpak et al. 2009). The current age-class distribution in the North is clustered in the 40- to 80-year-old range (Shifley et al. 2012). This has strong implications for current habitat diversity (Greenberg et al. 2011). The projection system allows exploration of anticipated changes in forest age class and structural diversity both spatially and temporally.

Gross changes in forest species composition can also be explored through the scenario projections of the Northern Forest Futures Project. As noted above, the assumptions underlying the projection process limit analyses of species composition to the aggregated forest-type group. Nevertheless, change in the relative proportion of oak-hickory vs. maple-beech-birch forest-type groups is sufficient to examine issues such as the rate of mesification of northern hardwood forests (Nowacki and Abrams 2008) and the associated loss of oak forest cover.

### 3. Wood volume and biomass

Because the modeling system operates on FIA plots as the basic unit indicating forest conditions, it is possible to summarize estimates of future wood volume and biomass over time for individual states or groups of states in exactly the same way as for current volume and biomass. Volume and biomass typically increase with increasing stand age. Consequently, the imbalanced age-class distribution of existing northern forests will be reflected in changes in wood volume and biomass under alternative future scenarios. Under most IPCC storylines, woody biomass is projected to supply an increasing proportion of the nation's energy needs (Ince et al. 2011b). This will affect energy portfolios, forest management opportunities, income opportunities for landowners, future forest age-class distribution, and associated forest biodiversity.

### 4. Ownership and urban-rural forest distribution

The FIA definition of forest is based on composition, structure, and function. Yet forest land is owned and managed for a variety of reasons. Five acres of suburban forest in New Canaan, Connecticut, may well be owned for different reasons than 5 acres of forest in Aroostook County, Maine. One consideration influencing different attitudes and management practices on forest land can be the proximity to the cultural and economic influences of major metropolitan areas. In the North, 80 percent of the population lives in urban areas that cover 6 percent of the land area. Consequently, forests near urban areas have the potential to provide ecosystem services such as aesthetics, recreation, water quality, air quality, and wildlife benefits to a large number of people. Anticipated demographic changes over the next 50 years are expected to exert a strong influence on forest conditions in proximity to urban areas. Specific research on the expected human influences on forest management and valuation in urban as well as rural environments helps us understand the special values of forests near urban areas (Butler et al. 2010, Nowak et al. 2010).

## SUMMARY

The Northern Forest Futures Project is intended to provide a view of what the region's forests are today and what they might become over the next 50 years. Comprising three components—scoping, assessment, and projection—the project uses projections of future economic, demographic, technological, and climate scenarios to produce future scenarios of forest land cover, composition, and structure. These future scenarios provide a quantitative basis from which to examine future forest threats, biodiversity characteristics, biomass production and utilization, ecosystem services, and landowner attitudes and influences. The project has already completed the issue identification or scoping phase (Dietzman et al. 2011) and the initial assessment (Shifley et al. 2012). Collaborating scientists are now completing the projection phase and expect to produce an assessment of alternative future northern forest conditions within the next year. The Northern Forest Futures Project can help refine expectations about future forest conditions and assist policy makers and forest managers in defining future priorities.

## ACKNOWLEDGMENTS

The authors thank Dave Wear, Bobby Huggett, and Ruhong Li, Southern Research Station, for their work in developing the USF$^A$S model and projecting Northern Forest Futures Project data; Pat Miles of Northern Research Station FIA for translating the results of the USF$^A$S model into FIA database format; the Forest Service's Region 9, the Northern Research Station, and Northeastern Area State and Private Forestry for financial and other support; and the many collaborators who made this project possible. The authors especially thank Dave Bengston for inviting us to present our paper at the ISSRM meeting in Madison, Wisconsin, in 2011.

## LITERATURE CITED

Butler, B.J.; Miles, P.D.; Hansen, M.H. 2010. **National Woodland Owner Survey table maker** [Web application]. Version 1.0. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. http://fiatools.fs.fed.us/NWOS/tablemaker.jsp. (27 July 2011).

Canadian Centre for Climate Modelling and Analysis. 2012a. CGCM3.1 - Coupled Global Climate Model (CGCM3), Medium Resolution (T47). http://www.cccma.bc.ec.gc.ca/models/cgcm3.shtml

Canadian Centre for Climate Modelling and Analysis. 2012b. CGCM2 - Coupled Global Climate Model, Medium Resolution (T47). http://www.cccma.bc.ec.gc.ca/models/cgcm2.shtml

Dietzman, D.; LaJeunesse, K.; Wormstead, S. 2011. **Northern Forest Futures Project: scoping of issues in the forests of the Northeast and Midwest of the United States.** Version 3.0. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 42 p.

Greenberg, C.H.; Collins, B.S.; Thompson, F.R. III. 2011. **Sustaining young forest communities: ecology and management of early successional habitats in the Central Hardwood region, USA.** New York: Springer 318 p.

Homer, C.; Huang, C.; Yang, L.; Wylie, B.; Coan, M. 2004. **Development of a 2001 national land-cover database for the United States.** Photogrammetric Engineering and Remote Sensing. 70(7): 829-840. Data from Multi-resolution Land Characteristics Consortium. www.mrlc.gov. (14 August 2008).

Huggett, R.; Wear, D.N., et al. In press. **Forest forecasts.** In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-XXX. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. xxx p.

Ince, P.J.; Kramp, A.D.; Skog, K.E.; Spelter, H.N.; Wear, D.N. 2011a. **U.S. forest products module : a technical document supporting the Forest Service 2010 RPA Assessment.** Res. Pap. FPL-RP-662. Madison, WI : U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 61 p.

Ince, P.J.; Kramp, A.D.; Skog, K.E.; Yoo, D.; Sample, V.A. 2011b. **Modeling future U.S. forest sector market and trade impacts of expansion in wood energy consumption.** Journal of Forest Economics. 17(2): 142-156.

IPCC Intergovernmental Panel on Climate Change. 2007. **Climate Change 2007: synthesis report**. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 p.

Miles, P.D. 2012. **Forest Inventory EVALIDator web-application version 1.5.00.** St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. [Available only on internet: http://apps.fs.fed.us/Evalidator/tmattribute.jsp]. (12 March 2012).

Nakicenovic, N. et al. 2000. **Special report on emissions scenarios: a special report of Working Group III of the Intergovernmental Panel on**

**Climate Change**.Cambridge, UK: Cambridge University Press. 599 p. Available online at: http://www.grida.no/climate/ipcc/emission/index.htm.

Nowacki, G.J.; Abrams M.D. 2008. **Demise of fire and mesophication of eastern U.S. forests.** BioScience. 58: 123-138.

Nowak, D.J.; Walton, J.T. 2005. **Projected urban growth (2000-2050) and its estimated impact on the U.S. forest resource. Journal of Forestry**. 103(08): 383-389.

Nowak, D.J.; Walton, J.T.; Dwyer, J.F.; Kaya, L.G.; Myeong, S. 2005. **The increasing influence of urban environments on U.S. forest management.** Journal of Forestry. 103(8): 377-382.

Nowak, D.J.; Stein, S.M.; Randler, P.B.; Greenfield, E.J.; Comas, S.J.; Carr, M.A.; Alig, R.J. 2010. **Sustaining America's urban trees and forests: a Forests on the Edge report**. Gen. Tech. Rep. NRS-62. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 27 p.

Oak Ridge National Laboratory. 2011. U.S. **billion-ton update: biomass supply for a bioenergy and bioproducts industry.** Oak Ridge, TN. 194 p.

Perlack, R.D.; Wright, L.L.; Turhollow, A.; Graham, R.L.; Stokes, B.; Erbach, D.C. 2005.**Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply**. DOE/GO-102995-2135 or ORNL/TM- 2005/66. Oak Ridge, TN: Oak Ridge National Laboratory. 60 p.

Polyakov, M.; Wear, D.N. 2010. **Harvest choice and timber supply models for forest forecasting.** Forest Science. 56(4):344-355.

Shifley, S.R.; Aguilar, F.X.; Song, N.; Stewart, S.I.; Nowak, D.J.; Gormanson, D.D.; Moser, W.K.; Wormstead, S.; Greenfield, E.J. 2012. **Forests of the northern United States.** Gen. Tech. Rep. NRS-90. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 202 p.

Smith, W.B.; Miles, P.D.; Perry, C.H.; Pugh, S.A. 2009. **Forest resources of the United States, 2007.** Gen. Tech. Rep. WO-78. Washington, DC: U.S. Department of Agriculture, Forest Service. 336 p.

Tirpak, J.M.; Jones-Farrand, D.T.; Thompson, F.R., III; Twedt D.J. 2009. **Multi-scale habitat suitability index models for priority landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas bird conservation regions.** Gen. Tech. Rep. NRS-49. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 195 p.

U.S. Census Bureau. 2012. **Population estimates.** Washington, DC: U.S. Department of Commerce. http://www.census.gov/popest/estimates.html. (23 May 2012).

U.S. Department of Agriculture, Forest Service. 2011a. **National report on sustainable forests – 2010.** FS-979. Washington, DC: U.S. Department of Agriculture, Forest Service. 212 p. http://www.fs.fed.us/research/sustain/2010SustainabilityReport/. (11 June 2011).

U.S. Department of Agriculture, Forest Service. 2011b. **Northern Forest Futures Project - Issues and Influences.** Newtown Square, PA: Northern Research Station. http://nrs.fs.fed.us/futures/issues_influences/ (20 March 2012).

U.S. Department of Agriculture, Forest Service. 2012a. **Future scenarios: a technical document supporting the Forest Service 2010 RPA Assessment.** Gen. Tech. Rep. RMRS-GTR-272. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 34 p.

U.S. Department of Agriculture, Forest Service. 2012b. **Research & Development - RPA Assessment.** Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.fs.fed.us/research/rpa/ (13 March 2012).

U.S. Department of Agriculture, Forest Service. 2012c. **Southern Forest Futures Project.** Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.srs.fs.usda.gov/futures/ (13 March 2012).

U.S. Department of Agriculture, Forest Service. 2012d. **Gypsy moth digest—maps and charts.** Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.na.fs.fed.us/fhp/gm/maps_charts/index.shtml (22 May 2012).

U.S. Department of Agriculture, Forest Service; Northeastern Area Association of State Foresters. 2011. **2010 Statewide forest resource assessments and strategies in the Northeast and Midwest: a regional summary.** Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 51 p. http://www.forestactionplans.org/regions/northeastern-region (12 August 2011).

Wear, D.N. 2011. **Forecasts of county-level land uses under three future scenarios: a technical document supporting the Forest Service 2010 RPA Assessment.** Gen. Tech. Rep. SRS-141. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 41 p.

Wear, D.N.; Greis, J.G. eds. In press. **The Southern Forest Futures Project: technical report.** Gen. Tech. Rep. SRS-XXX. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. xxx p.

Wear, D.N.; Huggett, R.; Li, R.; Perryman, B.; Liu, S. In press. **Forecasts of forest conditions in regions of the United States under future scenarios: a technical document supporting the Forest Service 2010 RPA Assessment.** Gen. Tech. Rep. SRS-xxx. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. xx p.

Williams, M. 1989. **Americans and their forests.** Cambridge, UK: Cambridge University Press. 599 p.

# LINKING GLOBAL SCENARIOS TO NATIONAL ASSESSMENTS: EXPERIENCES FROM THE RESOURCES PLANNING ACT (RPA) ASSESSMENT

*Linda L. Langner and Peter J. Ince*

**Abstract.** The Resources Planning Act (RPA) Assessment provides a nationally consistent analysis of the status and trends of the Nation's renewable forest resources. A global scenario approach was taken for the 2010 RPA Assessment to provide a shared world view of potential futures. The RPA Assessment scenarios were linked to the global scenarios and climate projections used in the Third and Fourth Intergovernmental Panel on Climate Change Assessments to recognize the influence of global forces on domestic resource conditions and trends. This paper reviews the challenges encountered, approaches taken to address these challenges, and the lessons learned.

## INTRODUCTION

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) (P.L. 93-378, 88 Stat. 475, as amended) mandates a periodic assessment of the condition and trends of the Nation's renewable resources on forests and rangelands. Known as the RPA Assessment, it provides a snapshot of current U.S. forest and rangeland conditions and trends on all ownerships, identifies drivers of change, and projects 50 years into the future. A team of U.S. Forest Service (USFS) scientists and their cooperators analyzes trends in outdoor recreation, fish and wildlife, biological diversity, wilderness, forests, range, water, urban forests, landscape patterns, and the potential effects of climate change on these resources.

## FRAMEWORK FOR THE 2010 RPA ASSESSMENT

The framing of the RPA Assessment has evolved over time to respond to changes in natural resource issues and management. The original legislation focused primarily on an economic evaluation of whether resource supplies could meet consumer demand. As public expectations about the role of natural resources broadened to include both ecological and socioeconomic values, the RPA Assessment analyses also broadened in recognition of the interrelationships between ecological and socioeconomic conditions in meeting the needs of the American public.

The 2010 RPA Assessment framework was designed to:

- incorporate global interactions that affect domestic resource conditions and trends;
- improve analyses of interactions among resources;
- extend our analytical capability to evaluate the potential effects of climate change across the resources; and
- describe more clearly the complexity and uncertainty associated with projecting future conditions and trends.

Global conditions and trends increasingly affect the conditions and trends in domestic natural resources. The 2010 RPA Assessment is framed around a set of future scenarios tied to a global set of scenarios that provide a coherent interdependent future for global population dynamics, socioeconomic factors, and climate change for more than 50 years into the future. These scenarios provided both quantitative and qualitative connections for the domestic resource analyses that project resource conditions and trends.

Using global scenarios to frame the 2010 analyses provided a coherent framework for evaluating outcomes across resource analyses. Socioeconomic and climate variables were all linked through these global scenarios. Scenarios were not assigned likelihoods, nor were any scenarios intended to be "most accurate" *per se*. Rather, these constructed scenarios provide a means of qualitatively and quantitatively understanding how different socioeconomic processes interacted to create different possible greenhouse gas (GHG) emissions pathways, how these emissions pathways drove global climate models to project different potential future climates, and how natural resources would respond to alternative futures. Each link in this chain of models is subject to uncertainty from a number of sources ranging from deliberate modeling assumptions (e.g., the global population growth rate selected for a given scenario), to stochastic processes in the global climate, economic, and

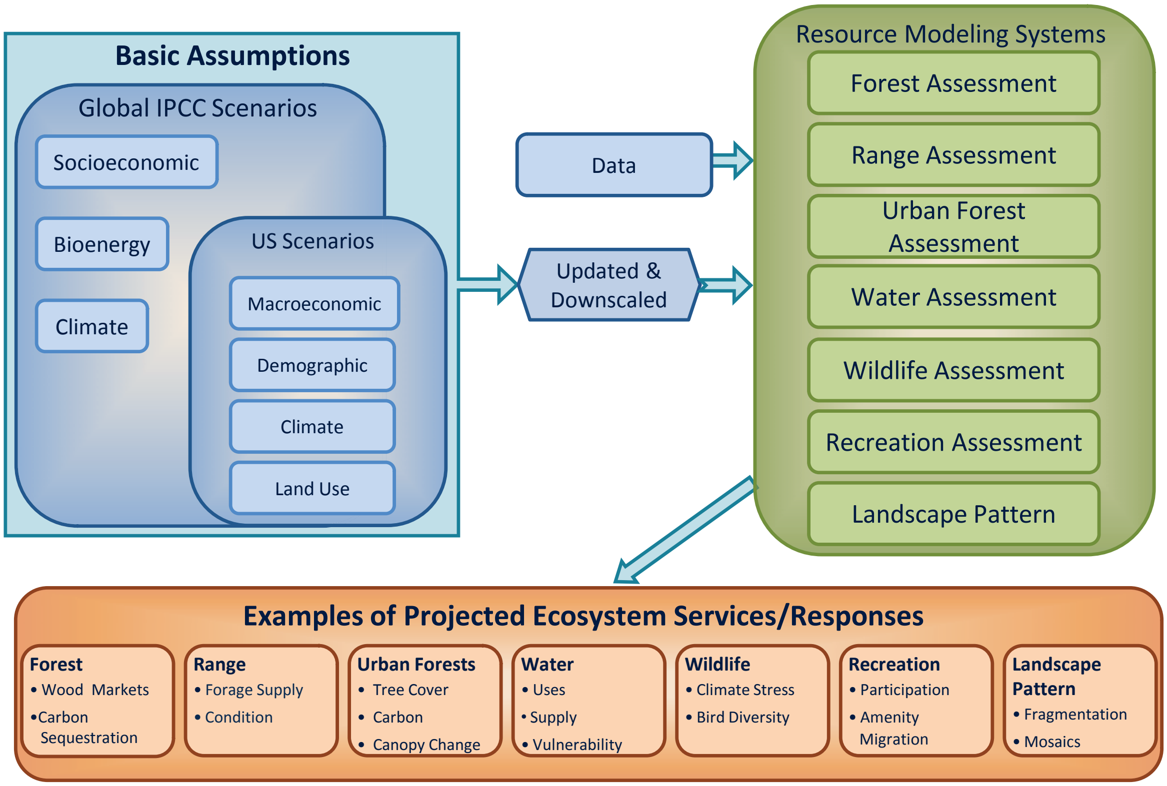



Figure 1.—RPA Assessment scenario analysis and modeling systems.

biological systems themselves. The scenarios help explore a consistent range of possible futures across resource analyses rather than intending to predict future resource conditions. Figure 1 presents a schematic that illustrates how global scenarios were linked to U.S. data that feed the various resource analyses.

## SCENARIO APPROACH IN THE 2010 RPA ASSESSMENT

Scenarios are used to explore alternative futures and are intended to serve as a counterfactual framework for objectively evaluating a plausible range of future resource outcomes. This approach is particularly useful when there is considerable uncertainty about the trajectory of the driving forces behind political, economic, social, and ecological changes (Alcamo et al. 2003, Intergovernmental Panel on Climate Change [IPCC] 2007). Scenario methods can use both qualitative and quantitative approaches in visualizing alternative futures using different socioeconomic or institutional assumptions for the United States. Carpenter et al. (2005) and Nakicenovic et al. (2000) reviewed examples and uses of scenarios in other applications.

The challenge of incorporating global interactions into the 2010 RPA Assessment led to the search for a set of comprehensive global scenarios to serve as anchors for the RPA Assessment analyses. These scenarios would provide the global context and quantitative linkages between national and global trends. We identified several criteria for evaluating and selecting global scenarios:

- Scenarios must be globally consistent in their underlying assumptions.
- Scenarios must be from a source that is scientifically credible and well-documented.
- Scenarios must include assumptions about key driving forces of resource change:
    - Population and economic growth
    - Land use change
    - Climate change
    - Energy use
- Globally consistent data must be available to link to U.S.-scale analyses.

A number of scenario-based approaches were reviewed as potential anchors for the 2010 RPA Assessment, including the Millennium Ecosystem Assessment

**Table 1.—Key characteristics of IPCC scenarios used to develop the RPA scenarios[a]**

| Characteristics | Scenario A1B | Scenario A2 | Scenario B2 |
|---|---|---|---|
| General global description | Globalization, economic convergence | Regionalism, less trade | Slow change, localized solutions |
| Global real GDP growth (2010-2060) | High (6.2X) | Low (3.2X) | Medium (3.5X) |
| Global population growth (2010-2060) | Medium (1.3X) | High (1.7X) | Medium (1.4X) |
| U.S. GDP growth (2006-2060) | High (3.3X) | Low (2.6X) | Low (2.2X) |
| U.S. population growth (2006-2060) | Medium (1.5X) | High (1.7X) | Low (1.3X) |
| Global expansion of primary biomass energy production | High | Medium | Medium |

[a] Numbers in parentheses (e.g., 6.2X) are the factors of change in the projection period. For example, global GDP increases by a factor of 6.2 times between 2010 and 2060 for scenario A1B.

(Alcamo et al. 2003, Carpenter et al. 2005), the IPCC (Nakicenovic et al. 2000), the "Mapping the Global Future" project (National Intelligence Council 2004), and the United Nations Environmental Program's Global Environmental Outlook (United Nations Environmental Program 2002, 2007). Although these studies exhibited wide variations in approach and objectives, all focused on a similar set of driving forces that shape the global future.

Scenarios used in both the IPCC third and fourth Assessment Reports (known as TAR and AR4, respectively) were selected to provide the global scenarios for the 2010 RPA Assessment. The Special Report on Emissions Scenarios from the TAR (Nakicenovic et al. 2000) provides detailed documentation of these scenarios that were used in both the TAR and AR4. The advantage of using IPCC scenarios as the basis for the 2010 RPA Assessment was the level of scientific rigor and acceptance surrounding their development, the degree of documentation, and the facilitated access to the data. The availability of both socioeconomic and climate data at global, regional, and country scales was also a critical decision factor. The range of scenarios considered in the IPCC Assessments provided a broad spectrum of potential futures from which a subset of the most relevant to evaluating potential U.S. future resource conditions and trends could be selected. In addition to their focus on climate change, the IPCC scenarios also incorporated detailed analyses of global energy trends, featuring alternative levels of growth in renewable energy and biomass energy production in the context of anticipated peaking of global petroleum production in the decades ahead.

None of the IPCC scenarios was considered to be the "most likely" or "business as usual" future. The IPCC deliberately avoided judging the likelihood of future scenarios. Although covering a wide range of alternative futures, the scenarios also deliberately excluded global disaster scenarios. Scenarios simply provide a tool to explore a range of future outcomes without judgment about the desirability of the outcomes (Nakicenovic et al. 2000).

## Selecting the Scenarios for the 2010 RPA Assessment

The variation across the IPCC scenarios in projections of world population, U.S. population, world and U.S. GDP, energy futures, and climate was evaluated. There was no pre-determined test of what constitutes "sufficient" variation in any of the variables, so the basic test was whether a subset of the IPCC scenarios would cover the range of possibilities that were likely to drive the greatest variation in resource effects in the United States. Three IPCC scenarios were chosen as the basis for the RPA scenarios. We retained the IPCC labels for continuity: A1B, A2, and B2. Table 1 lists some of the key characteristics of the IPCC scenarios chosen to be the basis for developing national scenarios for the 2010 RPA Assessment.

**Table 2.—IPCC U.S. population projections and updated RPA U.S. population projections, 2000-2060 (millions of people)**

| | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|
| **IPCC** | | | | | | | |
| A1B | 277 | 300 | 324 | 347 | 367 | 383 | 396 |
| A2 | 278 | 306 | 334 | 363 | 390 | 417 | 447 |
| B2 | 278 | 299 | 322 | 337 | 343 | 348 | 351 |
| **RPA** | | | | | | | |
| A1 B | 282 | 309 | 336 | 364 | 392 | 420 | 447 |
| A2 | 282 | 315 | 346 | 380 | 416 | 457 | 505 |
| B2 | 282 | 308 | 334 | 353 | 366 | 381 | 397 |

Each IPCC scenario had multiple associated climate projections. The climate projections vary across scenarios in response to the associated levels of energy production and GHG emissions, but they also vary within a scenario because the general circulation models (GCM) differ in their approaches to modeling climate dynamics. Therefore, we selected three GCMs for each of the three scenarios in order to capture a range of future climates.

## Scaling and Updating IPCC Data to U.S. and Sub-national Scales

The IPCC scenarios in combination with the climate projections from the GCMs provided the global demographic, macroeconomic, and climate assumptions for the various component resource analyses in the 2010 RPA Assessment. The next step was to develop national and sub-national projections of population, GDP, income, bioenergy use, and climate for the United States that are linked to the IPCC projections.

The IPCC scenario-based projections provided large-scale data, primarily at the global and macro-region scale. Country-level data for projections of population and GDP were also available. The IPCC projections of U.S. population and GDP were updated with more recent U.S. data. In doing so, the trends and cross-scenario relationships of IPCC scenarios were maintained. The updated estimates were then disaggregated to obtain U.S. county-level income and population data for the RPA scenarios.

Projecting U.S. population and economic information at the county level involved a number of simplifying assumptions. Accounting for all the various state and local events that govern the change and development of towns and counties is impossible. As a result, the RPA county-level projections should not be taken as statistically reliable projections of possible economic or demographic futures for specific counties. Rather, the overall spatial pattern of change in response to alternative scenarios is more important in our analyses, displaying the heterogeneity that would not be evident if projections were made only at the RPA regional or national levels.

### U.S. Population Projections

The U.S. population projection for the IPCC A1B scenario was based on the 1990 Census. We updated the RPA A1B population projections to align with the 2004 Census population series for 2000-2050 (U.S. Department of Commerce, Bureau of the Census 2004), with an extrapolation to 2060. The population projections for A2 and B2 were updated to begin at the same starting point in year 2000, and then follow a projection path that maintained the same proportional relationship to A1B as in the IPCC projections. Table 2 shows the IPCC U.S. population projections and the updated U.S. population projections for the 2010 RPA Assessment. Figure 2 illustrates the population projections for the three RPA scenarios relative to historical population trends in the United States. County-level population projections were developed for the three RPA scenarios (Zarnoch et al. 2010).

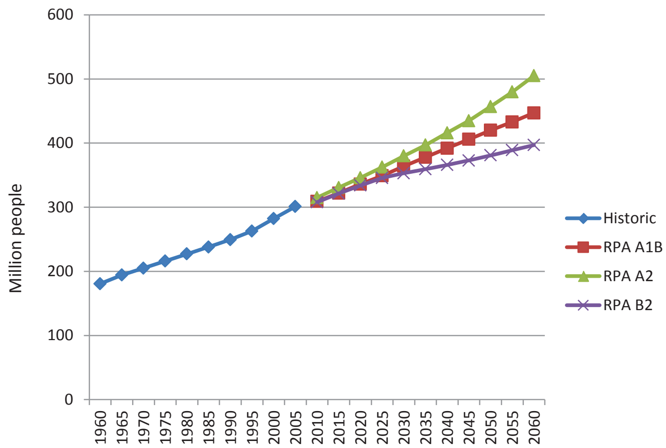



Figure 2.—Historic U.S. population and projected U.S. population to 2060 by RPA scenario.

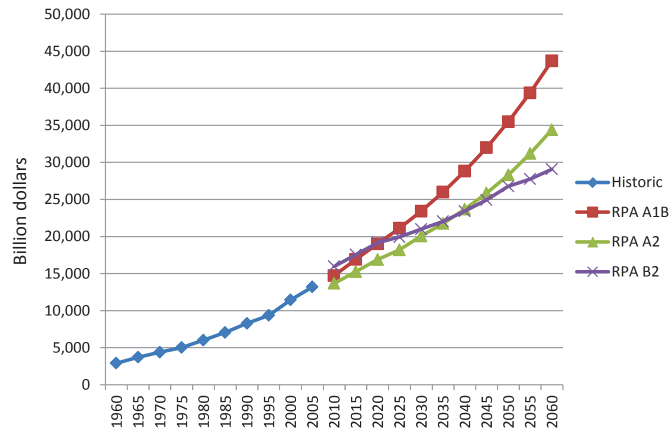



Figure 3.—Historic U.S. GDP and projected U.S. GDP to 2060 by RPA scenario.

## U.S. Economic Projections

Macroeconomic trends (e.g., trends in GDP, disposable personal income, and labor productivity) have a critical influence on the supply of and demand for renewable resources. The IPCC data were based on economic data from the early 1990s, so the GDP projections were updated to start with the official U.S. GDP value for 2006 for all three RPA scenarios (U.S. Department of Commerce, Bureau of Economic Analysis 2008a).

We applied GDP growth rates (U.S. Department of Agriculture, Forest Service 2012) to develop an adjusted projection of GDP for the A1B scenario. We revised the A2 and B2 GDP projections to maintain the same proportional relationship between the three RPA scenarios as defined by the IPCC U.S. GDP projections. Table 3 shows the differences between the IPCC projections for U.S. GDP and the updated RPA GDP figures. Figure 3 shows the differences among the three RPA scenario projections for updated GDP in comparison to historical U.S. GDP.

Projections of personal income and disposable personal income were also developed for RPA scenarios. The official U.S. 2006 statistics for personal income (PI) and disposable personal income (DPI) were used to start the updated projection for the A1B scenario (U.S. Department of Commerce, Bureau of Economic Analysis 2008b). We calculated the A2 and B2 projections for PI and DPI to maintain the same proportional relationship across RPA scenarios that were used in calculating the trajectories for U.S. GDP. The national DPI and PI projections were disaggregated to the county level (U.S. Department of Agriculture, Forest Service 2012).

**Table 3.—IPCC U.S. GDP projections and updated RPA U.S. GDP projections, 2000-2060 (billion 2006 USD)**

| | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|
| **IPCC-U.S GDP** | | | | | | | |
| A1B | 10,654 | 13,456 | 16,888 | 21,093 | 26,112 | 31,117 | 38,524 |
| A2 | 10,282 | 12,484 | 14,986 | 18,061 | 21,436 | 24,825 | 30,330 |
| B2 | 11,297 | 14,586 | 17,017 | 18,905 | 21,193 | 23,466 | 25,640 |
| **RPA – U.S. GDP** | | | | | | | |
| A1B | 13,195 | 14,736 | 19,029 | 23,424 | 28,835 | 35,496 | 43,696 |
| A2 | 13,195 | 13,679 | 16,890 | 20,057 | 23,683 | 28,313 | 34,401 |
| B2 | 13,195 | 15,974 | 19,164 | 20,990 | 23,416 | 26,778 | 29,084 |

Population, GDP, and income are important variables in determining GHG emissions levels. Although the U.S. population accounts for a small proportion of the world population, the U.S. contribution to emissions is much higher than its percentage of world population because of relatively high energy consumption. Therefore, updating the U.S. population and GDP projections (raising them modestly as we did) could lead to slightly higher global emissions than projected in the IPCC scenarios, or could lead to higher energy efficiency that would offset emissions. Regardless, we considered re-aligning the IPCC U.S.-level economic and population data with more recent data to be critical for projecting national resource effects within the RPA resource modeling systems. By not adjusting GHG emissions we have implicitly adopted the same variations in climate change across scenarios as projected by IPCC.

It can be noted also that the original IPCC emissions scenarios and the adjusted U.S. projections for the 2010 RPA scenarios were completed before the 2008-2009 global economic downturn. We chose 2006 as the base year for the U.S. economic variables because they were the most recent data available when the RPA scenarios were constructed. The U.S. GDP projection trend line from 2006 to 2010 does not account for the downturn in GDP and other economic variables through 2010, creating some discontinuity in the early years of the projection period. However, RPA long-term projections are not intended to predict temporary ups and downs, meaning that recessions are not part of projected 50-year trends. The recent global recession was quite severe, but the scenarios included in this Assessment have varying rates of economic growth, both for the United States and globally, that provide a robust set of projections across the range of potential futures.[1]

[1] In fact, two of the scenarios (B2 and A2) have lower U.S. GDP growth over the next 50 years than projected by a lognormal regression equation based on historical U.S. GDP growth data through 2010 (taking into account the effects of the recent recession), and the GDP growth of the A1B scenario closely matches the 50-year projection of the lognormal equation, indicating that the RPA GDP growth assumptions are at least as low as or lower than would be expected based on a time series regression analysis of historical GDP growth through 2010.

## U.S. Bioenergy Projections

Assumptions about the role of biomass in bioenergy projections were linked to the IPCC scenarios as was done with other RPA Assessment assumptions discussed in this document. The assumptions for bioenergy projections were incorporated into the RPA Forest Assessment Modeling System that includes the Global Forest Products Model (GFPM) and the U.S. Forest Products Module (USFPM). The approach accounted for relevant regional land use projections as well as regional biomass energy projections provided by IPCC scenarios and their supporting database (Nakicenovic et al. 2000). For a detailed explanation of the RPA Assessment bioenergy assumptions, see Ince et al. (2011).

In all three RPA scenarios, expansion of biomass energy plantation area projected in the IPCC macro-regions was directly correlated with projected regional expansion in primary biomass energy production. Comparing across scenarios, A1B had the largest regional expansion in the area of biomass energy plantations and also biomass energy production, while expansions of biomass energy plantation area and biomass energy production were both smaller in the A2 and B2 scenarios.

Because the United States maintains a large share of global GDP in all three scenarios and energy consumption is correlated with GDP, and because biomass energy replaces the declining output of petroleum-based energy, the U.S. projections of expansion in wood energy consumption are prodigious in all RPA scenarios. The expansion is by far the highest in the A1B scenario, followed by the A2 scenario, and lowest in the B2 scenario (Fig. 4). In the A1B scenario, for example, U.S. wood fuel feedstock consumption climbs to levels that dwarf U.S. consumption of wood for all other end uses (about five times higher by 2060 than all other wood uses), while in the B2 scenario U.S. wood fuel feedstock consumption climbs to a level just slightly higher than all other commercial uses.

## U.S. Land-Use Projections

Land-use change analyses provide a critical link to other models that analyze resource changes, such as wildlife habitat and timber availability. The IPCC provided

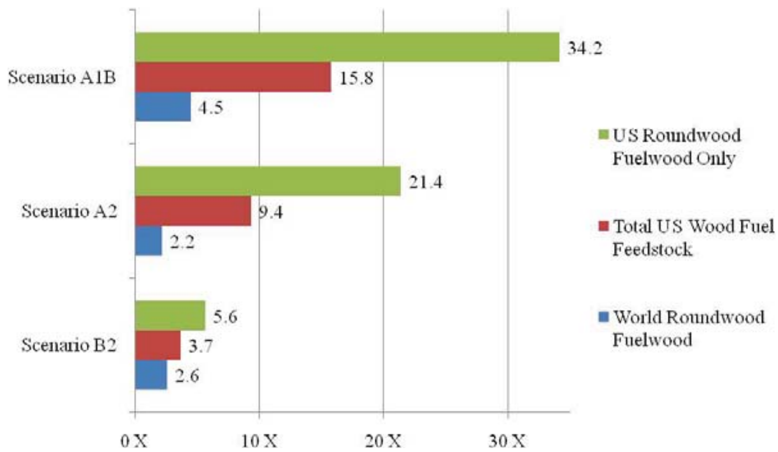



Figure 4.—Projected expansion from 2006 to 2060 in the volumes of wood consumed for energy by RPA scenario, including total U.S. wood fuel feedstock consumption, U.S. roundwood fuelwood consumption, and world roundwood fuelwood consumption.

global land-use projections by macro region that we used to deduce global wood energy consumption by region, but separate RPA land-use area projections were developed that were not tied to the IPCC land-use projections. However, the U.S. land-use projections are indirectly linked to the IPCC projections because the RPA land-use model includes both population and income variables that came from the county-level population and income projections described earlier. The land-use projections are documented in more detail in Wear (2011).

## U.S. Climate Projections

We selected AR4 climate model projections for A1B and A2 from the PCMDI Climate Model Intercomparison Project 3 (CMIP3) Web site, and the TAR climate model projections for B2 from the IPCC Date Distribution Centre (DDC). Three GCMs were chosen for each scenario based on the availability of the projections in the CMIP3 database at the time this study started and the variables needed for the RPA Assessment and assessments being done in Canada (Price et al. 2011). For the TAR climate models, a suite of climate models projecting the B2 scenario had been downscaled using the same procedure used for the 2010 RPA Assessment, and had been used to assess the impact of climate effects on vegetation (Price et al. 2004). Hence, these models were selected. The projections from this suite of GCMs capture a range of future climates.

The resolution of GCM projections stored in either the IPCC DDC or at the CMIP3 Web site range from 250 to 600 km on the side of the grid, far coarser than that typically used in many impact assessments, including the RPA Assessments. Many of the resource analyses in the RPA Assessment are conducted at the county level, which in turn necessitated climate projection data at that spatial scale. The IPCC climate projections were first downscaled to the approximately 10-km scale, and then aggregated to the county scale. More detailed documentation of the development of the RPA climate scenario-based projections and downscaling process can be found in Joyce et al. (in prep).

For the 2010 RPA Assessment projection period, the A1B scenario mean represents the warmest and driest scenario at the scale of the United States (Fig. 5). The A2

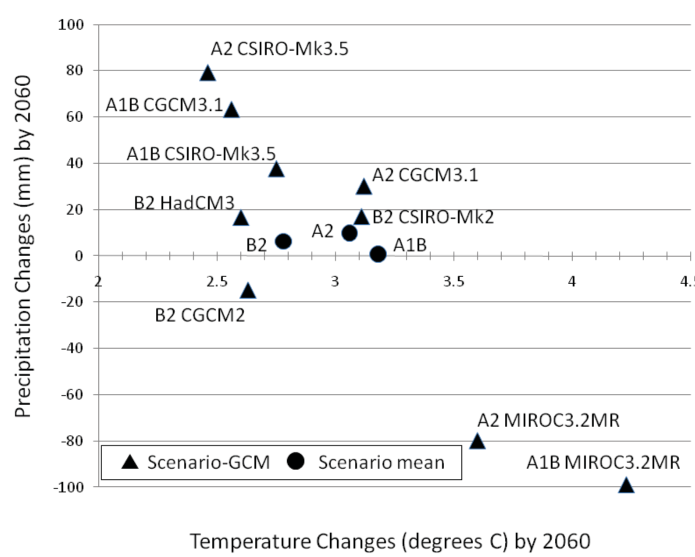



Figure 5.—U.S. temperature and precipitation changes from the historical period (1961-1990) to the decade surrounding the year 2060 (2055-2064) for scenario means and scenario-GCM combinations.

scenario becomes the wettest although the precipitation changes at the scale of the United States are small at 2060. Regional differences in precipitation projections vary greatly (Joyce et al. in prep). The B2 scenario projects the least warming of these three scenarios. The individual model projections vary across the individual scenario. For example, within the A2 scenario, the CGCM model projects the least warming and the MIROC model projects the greatest warming within this scenario. While the IPCC climate projections extend to 2100, the RPA Assessment resource analyses stop at 2060.

## LESSONS LEARNED

Developing a global scenario-based approach for the 2010 RPA Assessment was a learning process because previous RPA assessments had not employed global scenarios. Using common scenario assumptions was not new for the RPA process, but using assumptions nested within global scenarios was a departure from the past. It provided a more coherent framework, even though not all resource analyses could use all of the variables in the common assumptions.

The RPA Assessment is not a climate assessment, but rather it is a U.S. renewable resource assessment that takes global change into account. The RPA analyses consider climate as one more variable among many to consider in evaluating future resource conditions. Using the IPCC scenarios as our global anchor raised a concern that we would be seen as climate-focused. But the rationale for selecting the IPCC scenarios was based on the breadth of the variables they used in their analyses as well as the availability of the underlying data. For example, apart from climate projections, the scenarios also incorporate wide variation in wood energy projections linked to the IPCC projections of overall global energy production by source in the context of peaking oil production. As mentioned previously, the driving forces of change tend to be very similar in large-scale assessments, regardless of the objective of the assessment. Other global assessments, for example, point similarly toward anticipated large shifts in energy production toward expanded renewable energy and biomass energy production.

Although the IPCC scenarios provided a good linkage for the RPA scenarios, the major downside was the "freshness" of the IPCC socioeconomic data. Even though considerable work was done to update GCMs between the third and fourth IPCC assessments, no updates were done to the underlying scenario assumptions, so that the population and economic data were somewhat dated. As a result, compromises had to be made between staying true to the IPCC scenarios and updating to more recent data (as we did for U.S. GDP and population projections). For the 2010 RPA Assessment, updating the U.S. population and economic data was considered more important than maintaining strict conformity to the IPCC scenarios because population growth and economic factors are important drivers of resource change.

Developing the data for the United States, especially at the sub-national level, was time consuming and complex and also required a number of compromises. Even at the national level, there are limited sources for 50-year projections of population and income. At the time the projections were developed, the Census Bureau population projections stopped at 2050, ten years short of the RPA projection period. No comparable official U.S. estimate for GDP or other economic variables extends 50 years. Disaggregating the data to smaller scales is even more fraught with difficulties, particularly with limited resources to undertake complex analyses. Climate downscaling also presents myriad challenges—once an approach is decided upon, it is time consuming to conduct the downscaling and subsequently all of the associated data quality checks once the downscaling is completed. As long-term analyses become more common in large-scale assessments, cooperation across agencies to develop sets of U.S. scenarios that could be used in a variety of analyses would be extremely useful.

Assumptions at the scale of broad global regions (such as IPCC "macro" regions) are not always easy to translate to corresponding assumptions for a particular country. The United States is part of an IPCC macro region (OECD90) that includes all of the developed countries of Europe, plus Japan, Canada, Australia, and New Zealand. However, U.S. trends do not always move in concert with the OECD90 regional trend. One of the most obvious examples is in population—population growth is higher in the United States than in most developed countries. Another example of the complexity of translating IPCC scenarios to the United States was the treatment of bioenergy. To be consistent with the role of biomass energy in the IPCC scenarios, it was necessary to require large increases in U.S. consumption of woody biomass that are outside historic patterns of wood energy use, but are consistent with the IPCC view that petroleum-based energy will peak and be displaced in part by renewable energy and biomass energy during the projection period.

Regardless of when scenarios are constructed, some event is likely to create havoc with the assumptions when the project is on a multi-year timeline. The global recession began in 2007, right after the 2010 RPA scenarios and downscaling were completed. By the time the seriousness of the downturn was evident in 2009, it was not feasible to re-create the scenarios because of time and resource constraints. The important role of the housing sector in the economic downturn was also problematic for the RPA Assessment, since dramatic impacts on parts of the forest sector (e.g., reduced demand for lumber and wood panel products) are unlikely to be reversed in the near future.

Communicating the sometimes complex results from scenarios is also challenging. Providing a range of potential future outcomes is realistic given the many uncertainties associated with long-term projections. But there is a danger that users will conclude the information is of little use because of the uncertainty or because the volume of information can be overwhelming. Identifying commonalities and differences across scenario results and the underlying causes of variation across results can help users sort through these complexities. Presenting the results of the 2010 RPA Assessment will be another learning process as we develop communication strategies for various user groups.

## SUMMARY

We chose to take a global scenario approach for the 2010 RPA Assessment to provide a shared world view of potential futures. We linked our scenarios to the global scenarios A1B, A2, and B2 developed in the Third and Fourth IPCC Assessments. The use of global scenarios enriched the RPA analyses, but also created many challenges. Large-scale assessments are multi-year projects. Therefore, linking to a set of scenarios for a completed assessment tends to create issues about the timeliness of the source data, which in turn require decisions about updating and otherwise altering the source data, and the potential consequences of those alterations. Global assumptions and data, even at smaller regional scales, are not always easy to translate to national assumptions, especially if the regional trend is not consistent with the individual country trend.

Large-scale assessments such as the RPA Assessment are time- and resource-intensive. Linking to global assessments can actually save some time and resources, as it is unnecessary to develop those assumptions, and provides a starting place for the national assumptions. However, cooperation across agencies for development of national assumptions would be even more effective than individual agencies' developing unique sets of national assumptions. As more large-scale, long-term analyses are undertaken, this type of cooperation will become increasingly important.

## LITERATURE CITED

Alcamo, J.; Ash, N.J.; Butler, C.D.; et al. 2003. **Ecosystems and human well-being: a framework for assessment.** Washington, DC: Island Press. 245 p.

Carpenter, S.R.; Pingali, P.L.; Bennett, E.M.; Zurek, M.B., eds. 2005. **Ecosystems and human well-being: scenarios, volume 2. Findings of the Scenarios Working Group of the Millennium Ecosystem Assessment**. Washington, DC: Island Press. 560 p.

Ince, P.J.; Kramp, A.D.; Skog, K.E.; Spelter, H.N.; Wear, D.N. 2011. **U.S. forest products module.**

**A technical document supporting the Forest Service 2010 Resources Planning Act Assessment**. Res. Pap. RP-662. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 80 p.

Intergovernmental Panel on Climate Change [IPCC]. 2007. **Climate change 2007, the fourth IPCC Assessment Report**. Available at http://www.ipcc.ch/publications_and_data/publications_and_data.shtml#.T_spqZHhdIE. (Accessed 9 July 2012).

Joyce, L.A.; Price, D.T.; Coulson, D.P.; McKenney, D.W.; Siltanen, R.M.; Papadopol, P.; Lawrence, K. In preparation. **Climate change scenarios for the United States: a technical document supporting the Forest Service 2010 RPA Assessment**. Gen. Tech. Rep. RMRS--XXX. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Nakicenovic, N.; Alcamo, J; Davis, G. et al. 2000. **Special report on emissions scenarios: a special report of Working Group III of the Intergovernmental Panel on Climate Change**. Cambridge, UK: Cambridge University Press. 599 p. Available at http://www.grida.no/climate/ipcc/emission/index.htm (Accessed 9 July 2012).

National Intelligence Council. 2004. **Mapping the global future: report of the National Intelligence Council's 2020 Project**. Available at http://www.dni.gov/nic/NIC_globaltrend2020.html. (Accessed 9 July 2012).

Price, D.T.; McKenney, D.W.; Papadopol, P.; Logan, T.; Hutchinson, M.F. 2004. **High resolution future scenario climate data for North America**. In: Proceedings of the American Meteorological Society's 26th conference on agricultural and forest meteorology, 23–26 August 2004, Vancouver, BC. Boston, MA: American Meteorological Society: 7.7.1-7.7.13. Available at https://ams.confex.com/ams/AFAPURBBIO/techprogram/paper_78202.htm. (Accessed 17 July 2012).

Price, D.T.; McKenney, D.W.; Siltanen, R.M.; Papadopol, P.; Lawrence, K.; Joyce, L.A.; Coulson, D.P. 2011. **High resolution interpolation of climate scenario change factors for the conterminous USA derived from AR4 General Circulation Model simulations**. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Available at http://dx.doi.org/10.2737/RDS-2011-0023. (Accessed 17 July 2012).

United Nations Environment Program. 2002. **Global environment outlook 3**. London, UK: Earthscan Publications Ltd. 460 p.

United Nations Environment Program. 2007. **Global environment outlook 4**. Valletta, Malta: Progress Press Ltd. 572 p.

U.S. Department of Agriculture, Forest Service. 2012. **Future scenarios: a technical document supporting the Forest Service 2010 RPA Assessment**. Gen. Tech. Rep. RMRS-272. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 34 p.

U.S. Department of Commerce, Bureau of Economic Analysis. 2008a. **National and income product accounts table 1.15. Gross domestic product**. Version January 30, 2008.

U.S. Department of Commerce, Bureau of Economic Analysis. 2008b. **National and income product accounts table 2.1. Personal income and its disposition**. Version January 30, 2008.

U.S. Department of Commerce, Bureau of the Census. 2004. **US interim projections by age, sex, race and Hispanic origin**. Internet release March 18, 2004. Available at http://www.census.gov/population/www/projections/usinterimproj/natprojtab01a.pdf. (Accessed 17 July 2012).

Wear, D.N. 2011. **Forecasts of county-level land uses under three future scenarios: technical document supporting the Forest Service 2010 RPA**

**Assessment**. Gen. Tech. Rep. SRS-141. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 41 p.

Zarnoch, S.J; Cordell, H.K.; Betz, C.J; Langner, L.L. 2010. **Projecting county-level populations under three future scenarios: a technical document supporting the Forest Service 2010 RPA Assessment**. e-Gen. Tech. Rep. SRS-128. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 8 p.

# ENVIRONMENTAL FUTURES RESEARCH AT THE U.S. ENVIRONMENTAL PROTECTION AGENCY

*Robert L. Olson*

**Abstract.** Relatively little research on environmental futures has been carried out in the United States. An exception is the long-running futures research that the U.S. Environmental Protection Agency (EPA) has been conducting since the 1970s. This paper reviews past and current efforts toward developing a capacity for environmental foresight within the EPA, and discusses some lessons for other agencies and institutions concerned with the future of the environment.

## INTRODUCTION

The U.S. Environmental Protection Agency (EPA) was born in 1970 facing backwards towards the past. Its major challenge over the past 40 years has been dealing with the damages caused by the revolutions in industrial production that occurred earlier in the 19th and 20th centuries. This job, ranging from the cleanup of abandoned waste sites to the regulation of toxic chemicals, will still take decades to finish.

Today, however, we are at a critical point where technical changes even larger than those that produced the earlier revolutions in industry are converging. We are in the early stages of multiple revolutions in production, information and communications, logistics, and the interaction of new technologies such as nano- and biotechnology. These revolutions could pose a host of new environmental problems, but they also offer the possibility of creating a more environmentally advanced technological infrastructure based on highly efficient use of energy and materials, clean sources of energy, a "greening" of the chemical industry, and a new generation of industrial technologies in which pollution is viewed as a design failure, not an inevitable by-product of production.

Imagine, if you can, what might have happened if a powerful and well-organized environmental movement, strong environmental legislation, and a well-functioning government agency for environmental protection had emerged in the period between the 1850s and 1880s when science first began to strongly interact with technological development and major new industries began to arise. How many of today's environmental problems could have been avoided if environmental concerns had been integrated into the decisions of business leaders, government officials, and citizens from that time onward?

That opportunity was, of course, missed. The understanding, political will, and legal mechanisms needed for that to happen were not yet in place. Now, however, with new technological revolutions beginning to unfold, we have another opportunity to properly perceive the changes that are underway, integrate environmental concerns into our decisionmaking, head off potentially serious environmental damages, and shape emerging technologies for both economic success and the health of the planet. To be successful, one of the changes that urgently needs to occur is for the EPA to face forward toward the future and devote more of its attention to the environmental challenges and opportunities posed by emerging technologies.

In a 1995 report, "Beyond the Horizon" (U.S. EPA 1995), the EPA's Science Advisory Board issued a call for improving the Agency's capacity for exactly this kind of environmental foresight. It challenged the EPA "to begin to anticipate future environmental problems, and then take steps to avoid them, not just respond to them after the fact." It urged the EPA to change its priorities over time so that eventually, "as much attention should be given to avoiding future environmental problems as to controlling current ones."

How well has the EPA done in moving in this direction? A review of foresight-related efforts over time in the Agency shows that the shift in direction has begun but still has a long way to go.

## EARLY FORESIGHT EFFORTS

Almost from EPA's inception, there have been scattered and sporadic efforts within the Agency to explore the use of scanning, scenarios, modeling, and visioning exercises for environmental foresight. The best of the early initiatives was in 1975 when EPA's Office of Pesticide Programs commissioned the Center for the Study of Social Policy at SRI International to prepare a report on "Alternative Futures for Environmental Policy Planning: 1975 - 2000." In retrospect, this study pioneered important new methods and images of the future, but it is unclear whether it had any direct impact on policy and planning within the pesticides program (U.S. EPA 1975).

The largest single foresight initiative was the establishment in the early 1990s of a formal Futures Studies Unit in the Office of Policy, Planning and Evaluation. Innovative EPA programs such as Energy Star were born from the groundbreaking work of the futures unit. It helped organize greater intergovernmental cooperation to promote environmentally advanced technologies, and supported the Science Advisory Board's Environmental Futures Committee in producing the "Beyond the Horizon" report in 1995. But the futures unit was isolated within the Agency, and many of its forecasting efforts produced "bad news" that others inside and outside the Agency did not really want to hear. The Unit's director, David Rejeski, left EPA for the White House Office of Science and Technology Policy, where he felt he could have more influence, and in 2001, when the Bush Administration came in, the entire Office of Policy, Planning and Evaluation was eliminated.

The "Beyond the Horizon" report gave foresight efforts greater legitimacy within the Agency. During the latter part of the 1990s, a variety of foresight projects were undertaken by different offices within the Agency, including the Office of Radiation and Indoor Air, the Office of Research and Development, the Office of Human Resources, the Office of Emergency and Remedial Response, and the Office of International Activities (National Advisory Council for Environmental Policy and Technology 2002). Although these efforts produced credible results, they were all sharply limited. They were "one-shot" activities rather than part of an ongoing, systematic foresight process. They occurred in isolation from each other, with little sharing of results or lessons of experience. They had only minor impacts on the senior agency executives' priorities, and no discernable impact on the Agency's strategic planning.

## THE "FUTURES NETWORK" STRATEGY

In September 1999, Anita Street and Michael Brody in the Office of the Chief Financial Officer (OCFO), which coordinates the Agency's strategic planning process, launched an effort to create an Agency-wide Futures Network. OCFO contacted senior career executives in different parts of the Agency and asked them to appoint program and regional staff who have planning responsibilities or a particular interest in futures analysis to work within the Futures Network to promote environmental foresight.

The success of the effort hinged on the Network members' ability to serve as legitimate ambassadors from their offices to the Network, and from the Network back to senior career executives and colleagues within their offices. The hope was that the Network could help overcome some of the limits of past efforts by stimulating futures analysis throughout the Agency, promoting capacity-building, helping people share information across organizational boundaries, and keeping the Agency's senior career executives aware of and involved in foresight activities.

After establishing the Futures Network, the OCFO team decided that basic training in "building scenarios" would be a good way to familiarize Network members with futures methods and to lay the foundation for a consistent approach to futures analysis. OCFO allied with the Office of Research and Development (ORD) to sponsor 30 members of the Network for 3 days of intensive training provided by the Global Business Network, a leader in the field of corporate scenario planning. The following spring, OCFO organized a follow-on 1-day workshop for Network members run by the Institute for Alternative Futures (IAF), a leader in scenario planning with public and nonprofit organizations.

The strategy the OCFO team and IAF developed was to use Network members to interview Agency senior executives on their assumptions about the future of the environment and the Agency's evolving role in environmental protection. The goal was to identify topics Agency leaders believed worth exploring further through the use of scenarios. Network members used a standard form developed by IAF to conduct 34 interviews with senior executives representing nine headquarters and nine regional offices. The results of these interviews were presented back to senior managers at a Futures session preceding the Agency's Annual Planning Meeting. Many participants in this meeting were surprised to find that their personal views about the need for extensive change in the Agency were more widely shared than they had realized.

Following this session, the OCFO, IAF, and a scenario team made up of several Futures Network members used the views gathered in the interviews to construct four scenarios of the period between 2000 and 2020. The scenarios and the process used to develop them are described in detail in Appendix 1. Below is a simplified description of the four images of the future.

- Full Speed Ahead
  - Global "long boom" – rapid globalization
  - Low social cohesion
  - Moderate energy prices
  - Huge increases in use of energy, materials, and water

- A Darker Age
  - Stock market crash, lingering recession, economic strains worsening as Baby Boomers retire
  - Sharply rising oil and food prices, poor nations hurt worst
  - International terrorism
  - Polarized politics, growing intolerance, loss of community

- Soft Landing
  - Economic slowdown in late 2000s, continuing into 2020s
  - Global oil production reaching peak in 2010s and slowly declining
  - By 2020, growing realization a slowdown is inevitable and has a positive side (e.g., forces efficiency and reduces pollution)
  - Painful adjustments but growing social cohesion and community

- Eco-Efficiency Revolution
  - During 2010s, "mini-crises" and rising energy costs changing the character of economic growth
  - Rapid innovation in efficient energy, resource, and water use
  - Rapid development of energy sources such as wind, solar, batteries, hydrogen
  - "Greening" of the private sector
  - Advanced green technology applications of bio- and nanotechnology

In conjunction with a meeting of the Agency's Reinvention Action Council, EPA senior career executives met to engage in a "strategic conversation" based on these scenarios (Olson and Street 2002). The primary goal of the meeting was to encourage an open, honest exchange of ideas and opinions about possible future scenarios and to examine the Agency's current directions in the light of these potential futures. No budgets were at stake, and no decisions were needed. The whole point was to set aside pressing business and talk together about issues and aspirations that may be important over the generation ahead.

To prepare for the meeting, each participant was asked to cast a ballot allocating points (totaling 100) to reflect his or her assessment of the desirability, the likelihood of occurrence, and the relative severity of environmental impacts of each scenario (Table 1). The balloting results were reported to the group, which then discussed the challenges the Agency may face in the future and changes in the Agency's current directions that may be necessary to meet those challenges.

The Full Speed Ahead scenario was seen as most likely, largely because it came closest to reflecting current trends as well as the underlying assumptions and preferences of most leaders in business and government. Many in the group were surprised to find, however, that their collective assessment was that even though this is an appealing scenario in the short run, it is a destructive and

**Table 1.—Results of EPA senior executives' balloting**

| Scenario | Desirability | Likelihood | Severity |
|---|---|---|---|
| Eco-Efficiency Revolution | 60% | 23% | 17% |
| Full Speed Ahead | 6% | 45% | 32% |
| Soft Landing | 32% | 17% | 13% |
| A Darker Age | 2% | 15% | 38% |

negative scenario in the long run, with impacts nearly as severe as the gloomiest future, A Darker Age. The majority clearly favored the Eco-Efficiency Revolution scenario, and the Soft Landing scenario was actually viewed as having the lowest environmental impacts. Group members were therefore confronted with a disturbing conclusion from their own assessment of the scenarios: what they believe to be the most likely future, and the future that many government policies are geared toward promoting, is very different from what they believe is the preferred future that they would like to help create.

The discussion of how to bridge this gap between the scenarios seen as most likely and most preferable revealed a wide range of ideas about changes that may be needed in EPA's strategic direction. Some of the potential changes discussed by the group are summarized in the list below and the associated participant quotations taken from the meeting notes.

1) Dispense with day-to-day activities that others can do in order to focus EPA attention on higher priorities.
   *"The scenarios make you realize that things we do today (like permitting) should go to the states, so that EPA can elevate its attention to higher priorities."*

2) Take on a stronger role in promoting environmental technologies.
   *"We need to stimulate heavy investment in environmental technology now, 'while things are good'."*

3) Increase EPA's global involvement and international leadership.
   *"We need to achieve greater domestic consensus, elevate the Agency's international leadership . . . and help create incentives for the private sector to help developing countries adopt environmentally superior technologies."*

4) Expand information and outreach activities.
   *"Connect what we do—EPA's programs—to people . . . Localize global issues for people so they can understand and respond."*

5) Emphasize the importance of research for EPA's overall effectiveness.
   *"The biggest threat to EPA is our limited ability to measure impacts and articulate risks. Unless we can do this better, people won't invest in environmental protection."*

6) Coordinate environmental solutions across institutions.
   *"Solutions to environmental problems require more coordinated action across government departments. EPA should take the lead in defining coordination needs . . . State and federal roles need to be better integrated . . . Make more use of partnerships to achieve goals."*

7) Working with Congress, move toward multi-media, whole-system approaches to environmental protection.
   *"Establish greater legislative flexibility for dealing with environmental problems."*

At the meeting's end, one of the participants said,

> *"We've been meeting for years and this is the first time we've had a truly strategic conversation."*

## LOSS OF MOMENTUM

At this point, with a Futures Network in place and senior executives engaged in the process, it looked like environmental foresight was on its way to being a significantly larger focus of Agency attention. An EPA citizen advisory committee reporting to the EPA Administrator, the National Advisory Council on Environmental Policy and Technology (NACEPT), attempted to reinforce this direction of change with its 2002 report, "The Environmental Future:

Emerging Challenges and Opportunities for EPA" (NACEPT 2002). The report identified a wide range of emerging environmental issues and made three major recommendations in line with the recommendations the Agency's Science Advisory Board had made 7 years earlier:

1) Create a comprehensive, continuous, and institutional futures scanning process to identify emerging trends and issues.
2) Support the ongoing work of EPA's Futures Network and provide additional training on forecasting methods.
3) Incorporate futures analysis into EPA's strategic planning.

Unfortunately, the Futures Network initiative began to lose momentum over the next several years. Several factors were at work. The largest was the shift from the Clinton to the Bush Administration. The senior executives who worked with the scenarios had rated climate change as the top priority issue for EPA, but that and several other issues they rated as high priorities were not priorities for the new Administration. None of the changes they believed would improve the functioning of EPA were things the new Administration favored.

In retrospect, it is also clear that the Agency had not set itself up well for maintaining the effort. No full-time staff was responsible for foresight activities. The people leading the effort had other major responsibilities that had first call on most of their time. Not enough activity was generated for the Futures Network to keep its members engaged. And all the normal resistances that bureaucracies have to doing foresight came into play.

In 2002, David Rejeski, who had led the EPA Futures Studies Unit and was now at the Woodrow Wilson International Center for Scholars, and Bob Olson from IAF, who was continuing to work with the OCFO group in EPA, organized a workshop sponsored by the National Aeronautics and Space Administration that brought together people from several government agencies who had been involved in foresight efforts to discuss long-term (50-year) goals for society and the challenge of stimulating government agencies to think 50 years out (Rejeski and Wobig 2002). In a brainstorming and electronic voting process, participants highlighted the following reasons for resistance to foresight and long-term thinking:

- Lack of political will
- Leadership failure—lack of vision
- Organizational structure
- Fear of controversy or failure
- Annual budget process
- Tyranny of the inbox
- Insufficient methodology/training

## CONTINUING EFFORTS

Despite the loss of momentum from the peak in 1999-2000, the Agency, and especially OCFO, has maintained a continuous foresight effort. OCFO provided contract support to help develop a Foresight and Governance Project in the Woodrow Wilson International Center for Scholars (now called the Science and Technology Innovation Program). This program went on, with major foundation funding, to do some of the best work anywhere on environmental and social issues around emerging areas like nanotechnology, genomics, and systems biology. OCFO supported NACEPT's work in developing its report on "The Environmental Future: Emerging Challenges and Opportunities for EPA." It also supported a writing project that led to a book, "Environmentalism and the Technologies of Tomorrow," that dealt with emerging developments in a wide range of areas including energy and resource productivity; nanotechnology; genomics; ecological sensing and computing; geoengineering; the future of manufacturing; and economic, corporate, and governance changes for moving toward a sustainable society (Olson and Rejeski 2005).

For a time in the mid-2000s, the Agency's ORD ran a regular environmental scan and produced a handbook of foresight methods. Although work in OCFO was the first to call attention to the importance of emerging developments in nanotechnology and genomics, ORD coordinated the cross-Agency efforts involved in creating a Nanotechnology White Paper and Genomics White Paper that gave those areas much greater visibility.

Toward the end of the decade, the OCFO futures team succeeded for the first time in getting a foresight component into the revision of the Agency's strategic plan. The plan was organized around five long-term goals, with a different team of people working on each goal. A "futures workshop" was held with each of these five goal teams. In the plan revision, each goal section had an "Emerging Issues" section that set out the key issues that arose in each workshop and in follow-on research. Progress in environmental sensor technology emerged as an important topic in nearly all these workshops, and OCFO and IAF produced a white paper on emerging sensor capabilities for widespread circulation in the Agency. Publication of the white paper led to a field trial with Web-linked real-time nitrate sensors and other experiments in the Agency.

Over the past several years, OCFO has sponsored a small but ongoing scanning project to identify emerging technologies that may pose serious environmental problems or could provide new environmental solutions. The Futures Network (now called the Futures Community of Practice) has been called into action around a number of topics, such as evaluating the importance to the Agency of different emerging technologies and issues, and advising the NACEPT Council and the Administrator on hiring needs to insure that EPA has the competencies it needs to meet tomorrow's challenges. Other initiatives include foresight workshops with other agencies, workshops with state officials, and a foresight competition in which winning proposals for foresight projects were offered small amounts of funding or research support.

## LESSONS OF EXPERIENCE

Finally, several lessons have emerged from EPA's experience with environmental foresight that may be useful for other organizations concerned with the environment or with improving their foresight capabilities.

- The strategy of developing a Futures Network that reaches throughout the organization and has links to its senior career executives is highly worthwhile. It is a strategy that can be pursued in other government agencies and institutions.
- Develop some kind of "legitimizing process" where high-level people in the organization become involved and identified with the effort without putting many demands on their time. The Futures Network was one approach, but many other approaches are possible.
- Where possible, have a high-level champion or champions who will support and protect the foresight function over time.
- Avoid becoming an isolated unit; develop ties to other parts of the organization; connect to decisionmakers as closely as possible and try to understand where foresight can meet their needs.
- Frame efforts around stimulating thoughtful conversations and making better decisions today, not "knowing the future."
- Have a dedicated staff and a line-item budget to support the foresight function.
- Make an ongoing scanning/early warning system an integral activity.
- Utilize at least one formal method that is credible and understandable to all involved.
- Whenever possible, present the results of futures analysis to relevant decisionmakers in some form of interactive session that gives time for participants to integrate ideas into their thinking in a group setting.

## CONCLUSION

The record of EPA's experience with environmental foresight shows that real progress has been made toward developing a capacity for better environmental foresight. However, this progress is still incomplete and fragile and could easily be lost. Environmental foresight is not yet institutionalized in a way that assures it will continue after its strongest current proponents retire. The Agency is still far from the goal stated in "Beyond the Horizon" of giving as much attention to avoiding future environmental problems as to controlling current ones. Proponents of environmental foresight in the Agency need to work more closely with senior leadership to gain their support and appreciation for the value of futures thinking, strive to secure sufficient resources for the Agency to seriously engage in futures work, and promote the development of a culture of incentives and consequences to encourage foresight in planning.

## ACKNOWLEDGMENTS

The author would like to acknowledge and thank Michael Brody (at EPA), Anita Street (formerly at EPA, now at the U.S. Department of Energy), and David Rejeski (formerly at EPA, now at the Woodrow Wilson Center) for their efforts over many years to help build capacity for environmental foresight within EPA. Parts of this paper are drawn from an earlier paper written with Anita Street and published in 2002 (Olson and Street).

## LITERATURE CITED

National Advisory Council for Environmental Policy and Technology (NACEPT). 2002. **The environmental future: emerging challenges and opportunities for EPA.** Washington, DC: U.S. Environmental Protection Agency. 71 p.

Olson, B.; Street, A. 2002. **Foresight: the U.S. Environmental Protection Agency.** Scenario & Strategy Planning. 3(6): 14-19.

Olson, R.; Rejeski, D., eds. 2005. **Environmentalism and the technologies of tomorrow: shaping the next Industrial Revolution.** Washington, DC: Island Press. 195 p.

Rejeski, D.;Wobig, C. 2002. **Long-term goals for governments.** Foresight. 4(6): 14-22.

U.S. Environmental Protection Agency. 1975. **Alternative futures for environmental policy planning: 1975-2000.** Washington, DC: U.S. Environmental Protection Agency, Office of Pesticides Programs. 286 p.

U.S. Environmental Protection Agency. 1995. **Beyond the horizon: using foresight to protect the environmental future.** Washington, DC: Science Advisory Board. 34 p.

## APPENDIX: THE OCFO SCENARIO DEVELOPMENT EFFORT

In July 2000, OCFO formed a Scenario Development Team, a subgroup of the existing Futures Network. OCFO solicited volunteers to conduct research and define the axes around which to build the scenarios. After carefully considering the issues of concern raised by senior managers during interviews, the Team identified several topics for further research:

- climate change
- aquifer depletion/water quality
- urban sprawl (including non-point source pollution and biodiversity loss);
- biotechnology and nanotechnology
- chemicals in the environment (specifically, chemicals or sets of chemicals for which associations between exposure and effects are difficult to ascertain, and where there may be synergistic and cumulative effects of low exposures)
- existing persistent environmental problems that may surprise EPA as a result of changes in societal drivers; for example, an aging population may lead to mass migrations, so areas currently in compliance might be in violation of national air quality standards in the future.

The Scenario Development Team thought it important to choose a mix of topic areas that included issues that are global in scale, issues that were not on EPA's "radar screen," and some conventional persistent problems that are steadily worsening. An issue paper was developed on each of these topic areas. Each issue paper included an overview describing the general nature of the problem, trend data, the range of views on how the problem might change between now and 2020, and environmental and human health implications. The most important findings, or "nuggets," fed into the scenarios.

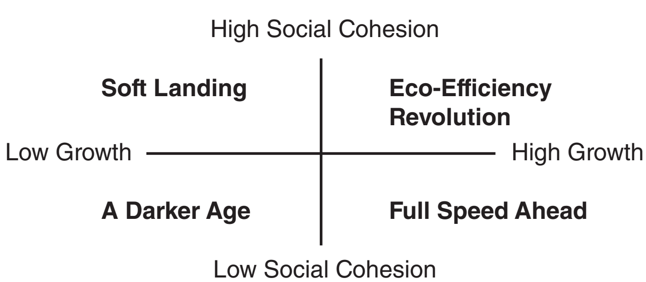
The scenario team then set out to select two axes to serve as a framework for building the scenarios. The chosen axes, economic growth and social cohesion, were selected to highlight social dynamics that have a profound effect on the environment but are often not considered in EPA policies and decisionmaking.

The economy axis was defined in terms of growth or decline in the total production and consumption of goods and services. These quantities are what Gross Domestic Product (GDP) measures in national economies and what Gross World Product (GWP) measures at the level of the world economy. At one end of the economy axis there is high growth in both U.S. GDP and GWP. Toward the other end of the axis, growth rates slow or even become negative.

The social cohesion axis was defined in terms of the extent of shared values, mutual trust, inclusiveness of participation, and willingness to face common challenges and cooperate in meeting them. Cohesion also requires a shared commitment to fairness, because extreme gaps between rich and poor and other forms of social injustice undermine mutual trust.

At one end of the social cohesion axis, most individuals, communities, and organizations are aligned around shared environmental values and committed to the importance of environmental protection. The different actors within society are willing to cooperate with each other and support government action to meet widely recognized environmental challenges. Toward the other end of the axis, society is increasingly fractionalized. Many people are indifferent or hostile to environmental values or refuse to recognize the seriousness of environmental challenges. Economic inequities, social conflicts, and practices that exclude people from participation create distrust and limit society's ability to cooperate in meeting challenges.

These two axes intersect to create four quadrants representing four possible alternative futures or scenarios that were entitled Eco-Efficiency Revolution, Full Speed Ahead, Soft Landing, and A Darker Age.




To flesh out the scenarios, the team engaged in an exercise using interconnected computers and groupware that allowed everyone to brainstorm ideas simultaneously and anonymously, and comment on each other's ideas. The writers for each of the scenarios mined this computer-enhanced brainstorming session to add specificity and realism to the basic scenario plots. Each scenario was then written as a three- to four-page narrative. The boxes below capture the scenario highlights.

It is important to be clear that these scenarios are not predictions. They are simply alternative stories of how the future might unfold — stories that compile information about divergent trends and potential developments into internally consistent images of plausible alternative futures. The four scenarios are not equally likely, although Scenario Development Team members believed they are all within the realm of plausibility. They were designed to span the full range of potential future conditions. The actual future is not likely to match with any one of these four images, but it will probably fall somewhere within the "possibility space" that the scenarios explore.

The future is inherently uncertain. Scenarios force us to face that uncertainty, but they also make the uncertainty easier to think about by bounding it within a small number of explicit stories. This disciplined process makes possible a level of strategic thinking, strategic conversation, and strategic planning that is more sophisticated than activity based only on the momentum of business-as-usual or on implicit and unexamined assumptions about the future.

### Eco-Efficiency Revolution (High Economic Growth and High Social Cohesion)

- "Remediable crises" become turning points, changing the character but not the pace of growth.
- Energy price increases during the 2000s make energy a major issue.
- Fuel cells proliferate for power generation in the 2000s; fuel cell cars come on the market in the later 2000s. In the 2010s, ultra-light "hypercars" flourish, running directly on hydrogen. Use of energy from wind and photovoltaics grows rapidly.
- In the late 2000s, a water crisis threatens China's stability. The United Nations Asian Water Initiative recommends changes related to water efficiency, water resource development, deforestation, desertification, and climate change. China embarks on an all-out effort to implement these recommendations.
- The idea of "Eco-efficiency" is popularized globally by the rapid spread of more efficient, cleaner energy technologies and China's successful response to its water crisis.
- In the 2010s, an eco-efficiency design revolution affects energy production and use, the chemical industry, manufacturing, construction, and transportation.
- "Greening of the private sector" occurs as eco-efficiency proves highly profitable. High economic growth is focused on investment in a more environmentally advanced technical infrastructure.
- Environmental protection increasingly focuses on a larger strategy of sustainable development, including technology research and development, improved science, coordination across agencies and levels of government, partnerships with the private sector, open information access, and innovative approaches to public dialogue.
- The United States plays an international leadership role promoting a shift to eco-efficient technologies.
- WATER – Water-efficiency technologies are adopted extensively.
- CHEMICALS – Production increases rapidly but with a shift toward "green chemistry."
- SPRAWL – Hypercars encourage continuation of sprawl, fragmenting ecosystems.
- BIO/NANO TECH – "Biotechnology soft path" emerges, not a rejection of biotech.
- CLIMATE – Emissions are reduced by the shift toward higher energy efficiency, fuel cells, and renewable energy, with positive economic impacts.

### Full Speed Ahead (High Economic Growth and Low Social Cohesion)

- The global "Long Boom" is still going strong in 2020, with info-tech the critical catalyst.
- The information revolution becomes an across-the-board technology revolution as it transforms every other area of technology, from genomics to manufacturing.
- A breakthrough to molecular nanotechnology and nanomanufacturing occurs late in the 2010s.
- Market-oriented policies around the world accelerate economic globalization.
- Integrated transnational corporations emerge and merge on a global scale. By 2020, a handful of economic giants dominates the world's increasingly borderless economy.
- Large transnationals sometimes play countries off against one another with little regard for health and environmental impacts on people in weaker countries; but they also serve as efficient conduits for transferring technology, capital, and expertise.
- Not everyone benefits from growth. Rich-poor gaps widen sharply within and especially between nations. Economic disasters befall nations that resist globalization. Dysfunctional nations in Africa, the former Soviet Union, and Asia are left behind.
- Huge increases in the use of energy, materials, and water have significant environmental impacts but receive little attention given the focus on growth and the promise of nanotechnology.
- WATER – Decisionmakers take a supply-oriented approach with huge infrastructure costs and growing conflicts.
- CHEMICALS – Chemical production increases rapidly, with new chemicals introduced too fast for adequate testing. Production increasingly shifts to locations closer to major new overseas markets, where there are growing health and environmental impacts, and novel problems from chemical interactions.
- SPRAWL – Sprawl continues unabated with loss of wetlands, ecosystem fragmentation, other impacts.
- BIO/NANO TECH – Regulatory process fails to keep up with new biotech products; significant problems emerge such as gene transfer and phenotypic surprises, loss of biodiversity in food crops; nanotechnology offers high promise but poses novel risks of serious accidents and malicious misuse.
- CLIMATE – Rapid growth in energy/fossil fuel use leads to rapid rise in $CO_2$ concentrations; measurable impacts occur in areas such as loss of tundra, extreme weather events.

**Soft Landing (Low Economic Growth and High Social Cohesion)**

- Growth is rapid through most of the 2000s with global information infrastructure coming into place.
- An economic slowdown occurs at the end of the 2000s, with further slowing in the next decade.
- Initially, there is high frustration at our inability to halt or reverse the slowdown.
- Over time, an understanding grows that the slowdown is caused by unchangeable realities.
- Aging populations in industrial nations reduce investment as elders spend down savings, as younger workers are heavily taxed to support retired elders, and as working-age populations shrink.
- Many developing nations struggle to keep up with rapid population growth and the massive challenges they face of housing construction, infrastructure development, public health, and education.
- Global oil production peaks in the 2010s and begins to decline; there seems no escape from higher prices.
- During the 2020s, a realization spreads that this gradual slowdown has a positive side. Environmental impacts drop with slowing energy consumption and resource use. The slowing pace reduces stress, and family and community strengthen.
- Global growth "rebalances" as many developing nations with lower wages attract investment.
- Rising energy prices make it practical and necessary to improve energy efficiency; less money is available, but economic pressures to invest in efficiency are unrelenting.
- Global "cyberactivism" emerges as a major force in the evolution of global governance. Computer language translation dramatically enhances transnational citizen activism. Key goals of activists include helping nations most in need, protection of the global environment, democratization of emergent global institutions, and monitoring and regulation of transnational corporations.
- WATER – Water is used with greater efficiency; access to freshwater is recognized as a human right; and more careful communal decisions are made regarding development of water resources.
- CHEMICALS – U.S. chemical production declines; the greening of domestic manufacturers serves as a model for the developing world, but decreasing resources are available for research and development, cleanup, and scientific research on impacts.
- SPRAWL – Sprawl abates; smart growth emerges as the new ideal with more clustering of growth and transit-oriented development.
- BIO/NANO TECH – The promise of genetically engineered crops remains unfulfilled; agriculture takes more organic and ecological approaches.
- CLIMATE – Rise in greenhouse gases slows with lower growth.

### A Darker Age (Low Economic Growth and Low Social Cohesion)

- Warning signals emerge in the 2000s: lingering recession, incidents of international terrorism, instability in the Middle East, soaring oil prices, tightening global grain prices as China imports more, evidence that the 1990s Asian financial crisis was never really resolved, turmoil in Russia and China, and more.
- Nervousness about all these factors leads some investors to pull out of the market; big institutional investors follow suit, and in 2005 global stock markets crash.
- Crashing stocks set off a chain reaction of protectionist actions and negative economic and social events, which act to prevent an economic recovery.
- In the United States and other industrial nations, economic strains worsen sharply as Baby Boomers retire.
- In developing nations, large numbers of people are thrown back into grinding poverty.
- Rage grows against the world's rich, catalyzing a large increase in terrorism, including bioterrorism.
- Large numbers of newly desperate people and environmental refugees try to enter the United States.
- Many social problems worsen, including a politics of blame, growing intolerance, a narrowing sense of community, and an accelerating spread of AIDS and other new plagues.
- Some environmental impacts ease with slowing growth, but others worsen; some hard-won improvements in such basic environmental areas as air and water are lost.
- WATER – Water quality worsens, aquifers become contaminated, waterborne diseases are even more prevalent, and conflicts over access escalate.
- CHEMICALS – Production of chemicals slows down, but regulation declines.
- SPRAWL – Sprawl slows with the economy, but inner cities suffer from significant deterioration.
- BIO/NANOTECH – Progress is derailed by recession, and adverse effects receive little attention.
- CLIMATE – Greenhouse gas emissions continue to rise but slow with lower growth; no transition to superior technologies is fostered; tropical disease vectors advance in latitude.

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*Continued*

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Bengston, David N., comp. 2012. **Environmental futures research: experiences, approaches, and opportunities.** Gen. Tech. Rep. NRS-P-107. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 79 p.

These papers, presented in a special session at the International Symposium on Society and Resource Management in June 2011, explore the transdisciplinary field of futures research and its application to long-range environmental analysis, planning, and policy. Futures research began in the post-World War II era and has emerged as a mature research field. Although the future of complex social-ecological systems cannot be predicted, these papers show how futures research can offer perspectives and methods that help researchers, decisionmakers, and other stakeholders explore alternative futures and gain environmental foresight—insight that can inform decisionmaking on environmental challenges. One author points out that the study of the future can be thought of as the study of change. He discusses three types of futures: the expected future, a range of plausible alternatives, and the preferred future, which decisionmakers can shape depending on their choice of action. An example of the methodology of futures research is provided in another chapter, which illustrates the use of scenario development. Another chapter identifies global trends that could dramatically change social-ecological systems.

The second half of the collection applies the methods and approaches of futures research to natural resource management. A global and a regional scenario illustrate scenario planning, a methodology that produces sets of plausible futures that could develop from current conditions depending on alternative human choices and drivers of change. Another example demonstrates how analysts can incorporate global scenarios and modeling, and scoping of trends and issues, into forest inventory data to gain insight into the regional forests of tomorrow. A chapter on linking global scenarios with assessments of U.S. natural resources as required under the Resources Planning Act considers both opportunities and challenges. Lessons learned from an analysis of futures research conducted since the 1970s at the U.S. Environmental Protection Agency are also offered. These papers suggest that the perspectives and methods of futures research hold great potential for developing the foresight needed to meet environmental challenges of the 21st century.

KEY WORDS: strategic foresight, scenarios, trends, forecasting, change, environmental scanning

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