Introduction

Global warming and climate change are now high-priority issues for most political leaders, despite the lingering resistance from isolated but sometimes powerful interest groups. The international scientific community, in its recently released report (Intergovernmental Panel on Climate Change [IPCC], 2007a, b), warns of impending climate changes that are much more dramatic than those our world presently experiences. Hence, more and more, people are demanding that action be taken urgently to address climate change challenges and prevent further damage to Earth.

Concurrently, anxieties over global and national energy security are developing at a time of record oil and gas prices and a rapid increase in global demand, particularly from fast-growing economies. At the same time, concerns about worldwide water resources are mounting regarding the need to share and better manage water availability to support an immense global population while ensuring sustainable socioeconomic development and reducing the gap between poor and rich countries. All this is happening in the context of an urbanizing and aging global population, faced with increasing competition for natural resources.

Both population growth and rapid socioeconomic expansion impose huge costs in the form of environmental degradation of land and the quality of air and water supplies; in turn, these costs are exacerbated by climate change. Through their activities, humans alter natural regimes with which organism have evolved over time. These changes in human and natural systems are occurring faster now than at any time in recent history. As a consequence, concerns arise now about human actions pushing the resilience of all ecosystems, from which humans benefit, to a breaking point beyond which they will no longer be able to adapt to changes and continue to sustain us.

The present dilemma is to find a balance between feeding the world's population and preserving the resilience of the essential ecosystems on which all lives

depend. This quandary is particularly acute now if we want to avoid passing on to future generations the high environmental costs already incurred, and a planet largely depleted of its most valuable resources. Indeed, in the time span of a few generations, rapid economic development, excessive resource use, and disregard for the planet are quickly exhausting some of the Earth's one-time resource endowment such as oil.

With fast-developing communications and transportation systems, these incredibly complex, swift, and interlinked changes are witnessed in real time by billions of people who struggle to comprehend their broad consequences and to prepare to address them.

Continuing with business as usual, whether it is in resource exploitation and management or unconstrained population growth, is neither sustainable in the short term nor the long. Reforms in governance, policies, and usage that balance the social, economic, political, and environmental dimensions of the Earth's energy and water resources are needed very soon. When combined, the scale of the challenges and the limited time available to address these problems create a sense of great urgency.

This book, *Oil, Water, and Climate: An Introduction*, deals with these rapid world-altering changes that interact synergistically, amplifying one another, and exacerbate existing challenges. These changes have the potential to give rise to international and intranational conflicts over resources and their allocation that could pit various stakeholders against one another.

Originating in a course I have taught at the University of California, Santa Barbara (UCSB) for several years, this book is addressed to students entering our universities – freshmen students – who want to learn about the global environmental challenges and consequences they must soon face. The book contains background material necessary to understand, formulate, and analyze these challenges and start thinking about how to address them. By highlighting the interconnections among energy, water, climate, and population, this book demonstrates the need to consider their linkages and synergies when making policy decisions. The presentation of such complex and interactive topics provides the big picture and can only offer a flavor of the greatest challenges, with the hope of spurring student interest in further exploration and understanding of these complex and interrelated issues of oil, water, climate, and population.

To limit the book's length and focus it at a reasonable level for its audience, I have made choices regarding the topics addressed and the depth to which they could be treated. In many instances, I have resorted to using simplifying concepts and summaries of complex processes to avoid complicated descriptions and fine points that would muddle the big picture this book is attempting to convey. As a result, I have omitted some aspects of many, if not most, of the

issues tackled. But the overall value of such a book lies more in the doors it opens than in comprehensive coverage of every individual topic.

In most instances, I have attempted to present scientific facts and not my own opinions, but such an ambitious aspiration is unfeasible. If only through the choice of topics addressed and the ways of addressing them, personal convictions and priorities inevitably enter. Throughout this book, it will become clear to the reader that I offer an environment-concerned point of view. Various other opinions are presented or at least touched on, even if lightly. The main pedagogical goal of this book is to develop the critical thinking of students and help them become managers and leaders capable of handling complexity.

I hope that the new generation of leaders now being educated in our universities will not only read this book but will also develop sufficient excitement and motivation about the topics discussed to continue learning on their own. Most importantly, I hope that this book will inspire them to act wisely and thoughtfully when it is their turn to make decisions regarding our environment and its resources.

I am grateful to the many people who have assisted me in the preparation of this book and to my colleagues who have helped make it better through their comments on earlier drafts. I especially thank Marianne Maggini, who devoted much time to editing the manuscript, and Michel Grégoire, who generously prepared all the illustrations. I am also deeply indebted to Pierre Morel for his honest feedback on the first draft.

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Overview

The unsustainable use of oil and water by a rapidly growing world population is creating serious environmental security challenges and geopolitical problems never before faced by humankind. As demonstrated throughout this book, changes in climate that are already underway and that are predicted to significantly increase in the next decades will exacerbate these challenges, thus playing a pivotal role in the overall environmental security equation.

Oil, Water, Climate, and Population: An Interactive System of Immense Complexity

Oil, water, climate, and population are strongly linked and can be considered as factors of a system in which all components are interconnected and interact among one another in multiple ways.[1] Oil, water, and climate security problems cannot fully be understood in isolation, nor can they be considered independently from demographic perspectives. Their various interconnections and dependencies can be highlighted when discussing the evolution of energy, population, climate, and water. The increased use of fossil fuels, particularly oil, in the last half of the 20th century, has provided the energy required to develop highly efficient technologies, relieving humans from heavy physical tasks and vastly increasing agricultural production, thereby enabling explosive population growth. In turn, population growth over the past few decades, projected population growth until at least 2050, and the rapid increases in the demands for energy and water resources needed to pursue global economic development race are the root causes of the unsustainable use of oil and water.

[1] This is the definition of what is usually called a "complex system."

The extensive and expanding use of oil (and other hydrocarbons) has led to increased emissions of carbon dioxide and other greenhouse gases and warmer Earth surface temperatures, together with a wide range of more or less obvious modifications of the global environment. Climate change has the potential not only to affect future energy choices by encouraging the use of less carbon-intensive sources but also may magnify the global water availability challenge by changing precipitation patterns and, thus, exacerbating regional water deficits. Millions of irrigation wells have been dug to extract water from ancient deposits in many regions, pushing the rate of water withdrawal well beyond the recharge ability of existing aquifers. Water pollution from agriculture, industry, and domestic wastewater is making both surface and groundwater resources scarce and decreasingly poor in quality. Simply put, the population explosion coupled with more efficient technologies is creating an ever-increasing demand for oil and water. To meet this demand, people are driven to use unsustainable levels of oil and water, which leads to a growing global scarcity of these resources. Such scarcity, which may well be exacerbated by the changing climate, is creating major societal and geopolitical challenges that have the potential to generate serious conflicts.

Coupled Unsustainable Use of Energy and Water Resources

Oil, the primary catalyst for economic growth, is currently being pumped out of the ground at a rate of about 1,000 barrels a second (Tertzkian, 2006). This pumping rate is leading the world to a break point in terms of oil availability and will surely modify the way in which oil will be used in the future. Similarly, water, a primary life-giving resource and an essential element for life and economic growth, is being pumped out of the ground at a rate that depletes aquifers all over the world, leading to water shortages for billions of people. Actually, oil and water extraction are intertwined closely. Oil, or more appropriately energy, is needed to extract water from ever deeper aquifers, and vast amounts of water are used to push oil out from depleting fields[2] and, even more so, to extract it from the sands where it is embedded.[3] Therefore, the use of one resource is accelerating the extraction of the other.

Role of Population and Economic Development in Oil and Water Use

Population growth is a crucial factor in these environmental security concerns, especially when coupled with economic development. The world population has

[2] Usually nonpotable water.
[3] Mostly potable water in the oils sands of Alberta, Canada.

grown at the rate of about 85 million per year over the past few decades (United Nations Population Division [UNDP], 2003); it reached 6 billion around the end of the 20th century. With a growth of 70 million people per year, it is now projected to approach 9 billion by 2050 and to stabilize there,[4] with nearly all of the predicted growth expected to occur in developing countries. Many of these developing countries will go through a phase of accelerated economic growth that requires the consumption of large amounts of energy and water, thus exacerbating environmental and climate impacts. Already, the intensification of economic development in China, India, and elsewhere is accelerating resource usage. In particular, the automobile sector, which now accounts for about half of overall oil consumption, continues to expand in developed countries – particularly in North America – and is beginning to explode in some developing countries – notably China – as a growing middle class develops an appetite for the automobile. As development intensifies and new technologies emerge, water is being extracted at a faster pace and from deeper layers in Earth, rapidly drying out aquifers.

The rapidly increasing average resource consumption per person and the more efficient technologies used, when added to a growing population, will accelerate oil and water extraction and seriously affect the long-term sustainability of these resources.

Effects of Energy Demand and Use on Global Warming

The use of these invaluable resources is occurring in the context of global warming and climate change, which creates an extremely complex environmental conundrum that has the potential to exacerbate resource scarcity. Indeed, the increase in greenhouse gas emissions from growing human activities, whether fossil fuel burning or land-use changes, has led to an increase in atmospheric carbon dioxide (CO_2). Although the land and oceans can take up and store some of the additional CO_2 through photosynthesis or dissolution at the ocean surface, this uptake offsets only about half of the anthropogenic emissions. The other half remains in the atmosphere and creates an augmentation (enhancement) of the natural greenhouse effect. By trapping in the atmosphere the radiation that is emitted by the Earth's surface and that normally escapes to space, the increased greenhouse gas concentration, in particular that of carbon dioxide, causes the Earth's surface to warm. The surface temperature has been increasing

[4] In reality 8.9 billion people according to the UN medium variant (United Nations Population Division, 2003).

rapidly over the last several decades. This increase is responsible for the melting of ice caps and glaciers, greater accumulation of heat in the ocean, and increased sea level.

Climate Change Can Exacerbate Water Scarcity

Global climate change will certainly affect fresh water resources, but predictions of its impact on the water cycle are still uncertain. More extreme hydrological regimes – in which droughts or floods are exacerbated – are quite probable in regions already vulnerable to water vagaries. Changes in rainfall and snowmelt patterns will undoubtedly threaten water systems all over the world. Changes in snowmelt amount and timing will have a strong impact in areas that rely on snowmelt for their water supplies like the western United States or the nations at the foot of the Himalayas. Long before rising sea levels threaten lives, Pacific Island nations and low-lying coastal areas may become uninhabitable as ocean water contaminates supplies of fresh water and consequently people's life. More intense and long-lasting hurricanes with extremely powerful winds, extensive storm surges, and heavy precipitation have the potential to bring havoc to local water supplies and people. Intensified and possibly more frequent El Niño events could change precipitation patterns for long periods of time, bringing extensive droughts to large areas of the western Pacific and limiting water availability for months.

Oil and Water Resource Issues Share Many Features

Exhaustion of Easily Accessible Resources

Oil and water issues and their implications share many common aspects. First, there is the near physical exhaustion of easily accessible oil and water deposits at a time when the global demand for both is accelerating. In the case of oil, a principal engine of industrial development, the reserves of easily accessible and therefore cheap oil are dwindling fast: the remaining amount of recoverable oil on Earth is nearing half the original endowment, and accordingly, extraction rates will reach a peak soon. In the case of water, a resource indispensable to life and also a key factor in socioeconomic development, the pressure of a rapidly growing population coupled with climate change strongly limits water availability and intensifies competition for existing resources, which are rapidly becoming depleted in many regions of the world. The poor management of existing water resources compounds the problem, plaguing rich and poor countries alike, even when the resources should be adequate to meet demand.

Realization of Finiteness of Resources and New Strategies

Because Earth's resources are finite, resource overuse cannot continue for much longer without dramatic consequences for human civilization. The decrease in the rate of extraction of easily accessible oil reserves, which is likely to occur in the next decade or two, will predictably entail a series of serious consequences. The history of oil supply crises suggests that the price of oil will likely increase dramatically, affecting the world economy, which is made up of inherently energy-intensive industries, with energy-inefficient activities being hit the hardest. High oil prices, in turn, will provide an incentive for undertaking new and expensive exploration, as well as belated efforts to develop energy substitutes. However, new oil is very difficult to find because most of the really big oil fields have already been identified, and even when new ones are found, it is more costly to produce from them because they are small. Two likely upshots will be the opening up of the bituminous sand oil fields of Canada and Venezuela to oil exploration (where oil will be difficult to refine and its extraction will be environmentally damaging) and the production of oil in locations where it can only be retrieved at very high financial and environmental costs (e.g., the Arctic and Antarctic). Both options are already being explored actively as seen by the opening of the Arctic National Wildlife Refuge (ANWR) in the United States and the large exploitation and refining investments being made in Alberta, Canada.

The realization of the finiteness of resources, however, does not automatically imply negative outcomes. For instance, the increase in costs associated with water scarcity will make it economically feasible to invest in water treatment systems. Also, technology will tend to be focused on products or systems that can produce increased use efficiency (e.g., inexpensive, efficient watering systems), and sometimes unexpected replacement products may be developed.

Value of Efficiency Improvement

Improvements in efficiency in the use of both oil (and energy, more generally) and water promise a significant decline in usage and thus should figure prominently in any portfolio of strategies to ensure their security. For energy, improvements might come from efficiencies in buildings' energy systems and passenger vehicles, whereas for water they might come from more efficient agriculture irrigation, rainwater harvesting, and household usage. The present efficiency improvement rate could be significantly increased, particularly in the United States, but also in other countries in which energy and water usage is intensive. With simple behavioral changes, improvements at the individual household and the collective levels could have a notable effect on decreasing

energy and water demand, without necessarily translating into hardships. Market forces alone will not be sufficient to deliver the full potential of energy and water savings and efficiency improvements, however. Incentives will need to be implemented to promote those improvements.

Oil and Water Security Concerns

The scarcity of both oil and water raises serious security concerns. Most of the new oil reserves are located in geographically and politically problematic regions. Some of the large oil-producing countries use their resources to promote political objectives that sometimes go counter to sound economic rationale. Both internal and external conflicts to secure or acquire these assets may result. Over the past 30 years, the negotiation of oil resource sharing between nationalized and private oil companies (e.g., the formation of Aramco in Saudi Arabia) has been contentious. In the future, the nationalized companies with their enormous oil reserves and consequent financial capacity might be in a position to impose their rules and even take over major Western private companies whose reserves are dwindling without much hope for replenishment.

Similarly, the most serious cases of water scarcity are in regions with a political infrastructure that is inadequate to address, in a coherent and insightful manner, the developing water crisis. Even in industrialized countries with a stable political infrastructure, conflicts arise because of the increasing demand for available water resources by urban users, industries, and farmers, who battle for usage rights of this dwindling resource. However, the picture is more nuanced because, in many cases, the need to share water has created cooperation among unexpected partners (e.g., between India and Pakistan).

Poor Management of Oil and Water Resources

In some areas, oil and water are easily accessible resources but they are poorly managed. Immense quantities of oil are lost through leakages in oil pipelines and, more generally, through inefficiencies or unnecessary losses during energy production.

As for water, all aspects of the water infrastructure could be improved, reducing greatly the amount of water lost. Most of the existing infrastructure has leaks, and much water is wasted through irrigation of fields: at most, 30% of water extracted from the ground reaches the intended crops. Water is lost primarily through evaporation in canals or inefficient watering systems. Whereas most water in rivers in developed countries has been reused many times before reaching the ocean, in developing countries, where water scarcity is often the rule, wastewater is rarely treated and reused because of the inability to finance treatment plants.

Aging Infrastructure and Magnitude of the Needed Investments

Another common problem plaguing oil and water supply systems is the aging of the existing infrastructure and the consequent need for huge financial investments to maintain and update it. Power plants and refineries in all producing and refining countries need to be upgraded to face increasing demand. This upgrade will be extremely costly, but it cannot be postponed for very long, lest critical shortages develop in the oil supply needed for economic growth in developing countries. The same can be said of the world water infrastructure. Many of the running water pipes and sewer networks in older industrialized countries were installed in the 19th or early 20th centuries and are now showing their age. Replacing this aging infrastructure that covers millions of miles all over the developed world is indispensable from both operational and public health standpoints, but is also extremely expensive.

Urgency and Window of Opportunity

There is clearly both an element of urgency in oil, water, and climate security matters and a window of opportunity to act in a deliberate manner. All the indicators – from worldwide oil consumption, water resource usage, and population growth, to projected global warming and the potential development of renewable energies – suggest that a business-as-usual policy cannot be sustained. The growing oil demand, coupled with a decline in global reserves, strongly indicates that oil will soon have to be replaced by another type of fuel. Coal and natural gas are the most serious contenders for replacing oil on the scale needed as their exploitable reserves are quite large, and it is no secret that the world will burn more coal to produce energy (Goodell, 2006). However, both coal and natural gas have drawbacks, including a significant impact on climate. Costly and time-demanding changes in the way they are burnt to produce energy will have to be implemented for these hydrocarbons to be used, and particularly for coal to be burned cleanly. There is also the possibility that there will be large-scale development of non-carbon-based forms of energy (e.g., nuclear, solar, wind, or biomass). But as Chapter 8 shows, these forms of energy provide only a small share of the overall energy portfolio, and much investment will have to be made to boost their share of the global energy market. Although wind-driven energy production has been gaining market share relatively rapidly, solar and biomass plant energy will also need to grow rapidly to be ready when hydrocarbons cannot be used any longer because either they are depleted or their impact on climate is too large. Otherwise, these potential energy sources will, at best, be considered as minor components of an overall energy security plan.