


## Script Key:

- **NARRATION**
- *On Screen Visuals*
- Annotation

## TEASE

 In TV terminology, a “tease” uses footage from the upcoming program to showcase some of the locations and people who will be appearing. So explanatory notes and background on these first scenes are provided later in the script, when these people and places appear at full length.

### **ALL ACROSS THE PLANET, NATIONS AND CITIES ARE WORKING TO REDUCE THEIR DEPENDENCE ON FOSSIL FUELS, AND PROMOTE SUSTAINABLE ENERGY OPTIONS.**

*Mayor Annise Parker of Houston, Texas. She begins speaking over shots of a geothermal power plant in New Zealand and wind turbines in West Texas:*

*...(because) it's the smart thing, (because)*

*Mayor Parker on camera:*

*...it makes business sense, and it's the right thing.*

*Construction scene in China, the mirrors of a solar power generating station in Spain, and a sugar cane plantation in Brazil:*

### **IN CHINA... EUROPE... AND BRAZIL, ENERGY INNOVATIONS ARE CHANGING HOW WE LIVE...**

*Scenes from Army training at Fort Irwin, California:*

### **...AND IN THE U.S., EVERY BRANCH OF THE MILITARY IS MOBILIZING TO CUT ITS CARBON FOOTPRINT.**

*Animated images of the cover and inside pages of the Pentagon's Quadrennial Defense Review:*

*Rear Admiral David Titley, Oceanographer and Navigator of the US Navy:*

*...we really believe that the climate is changing.*

*Richard on board an inflatable Zodiac boat on the terminus lake of the Tasman Glacier, New Zealand:*


### **IN THIS PROGRAM, WE'LL SHARE HOW WE KNOW EARTH IS WARMING, AND WHY...**

*Waves rush towards shore on the rocky California coast, and images showing renewables at work in Texas, Brazil and Spain:*

**...AND DISCOVER WHAT EARTH SCIENCE TELLS US ABOUT CLEAN, GREEN ENERGY OPPORTUNITIES.**


*Scenes of program host, Richard Alley, in various locations: in a helicopter above the Franz Josef Glacier, New Zealand, in the Algodones Dunes near Yuma, Arizona, and paddling a pirogue (a traditional boat used on the bayous of Louisiana) in Barataria Preserve, near New Orleans.*

**I'M RICHARD ALLEY. I'M A GEOLOGIST AT PENN STATE UNIVERSITY, BUT MY RESEARCH HAS TAKEN ME 'ROUND THE PLANET, FROM GREENLAND ...TO ANTARCTICA.**

 See Richard's [biography](#) elsewhere on this site. Please note that although Richard works for Penn State, and has helped the IPCC and other bodies, he is not representing them or speaking for them here.

**I'M FASCINATED BY HOW OUR CLIMATE HAS CHANGED DRAMATICALLY, AND OFTEN...**

**FROM TIMES WITH ICE EVERYWHERE...TO NO ICE ANYWHERE ON THE PLANET.**


 Richard's previous book, *THE TWO MILE TIME MACHINE*, covers his early work in Greenland, where he was part of the team studying more than 100,000 years of climate history in an ice core. Also see the upcoming sequence taped in the National Ice Core Lab in Denver, Colorado, for more detail on what ice cores can tell us.

**RECORDS OF PAST CLIMATE HELP US LEARN HOW EARTH OPERATES.**

**WHAT HAS HAPPENED, CAN HAPPEN AGAIN.**

**AND I KNOW THAT SOMETIMES THINGS CHANGE *REALLY* FAST...**


*Whoops and hollers as Richard bungy jumps from A. J. Hackett's location at the Kawarau Gorge, near Queenstown, New Zealand.*

 See the web exclusive video accompanying [FAQ #8](#) for more on this, and why Earth's climate sometimes goes "...bungy-jumping off the climate roller coaster." Richard was also chair of a National Academy of Sciences panel studying Abrupt Climate Change: Inevitable Surprises ([PDF](#)).

 An intriguing video showing “[Richard Alley’s Orbital and Climate Dance](#)” appeared at *The New York Times* on February 6, 2009.

*Richard cycling to work at Penn State, as he does most days:*

**I’M A REGISTERED REPUBLICAN, PLAY SOCCER ON SATURDAYS, AND GO TO CHURCH ON SUNDAYS.**

 As a footnote to book chapter 24 reads, “For those who see politics in physics, I am happy to confirm the public record, that I vote consistently, register as a Republican, and I am a loyal member of St. Paul’s United Methodist Church in State College, Pennsylvania, affiliated with a mainline Christian denomination. Who I vote for in any given election, and what I say in my prayers, are between me and my God, and you can take the matter up with him if you’re interested.”

*Alley seen teaching an Intro. Geology course at Penn State:*

**I’M A PARENT AND A PROFESSOR.**

**I WORRY ABOUT JOBS FOR MY STUDENTS AND MY DAUGHTERS’ FUTURE.**

*Richard at a meeting of the UN panel on climate change, the IPCC in Paris in 2007.*


**I’VE BEEN A PROUD MEMBER OF THE U.N. PANEL ON CLIMATE CHANGE...**

*Timelapse scene of the retreat of the Columbia Glacier, Alaska.*

 Longer timelapse sequences of glaciers appear later in this program. These scenes are from the fascinating work of James Balog’s [Extreme Ice Survey](#), which has many animations viewable online.

**AND I KNOW THE RISKS.**

**AND I’VE WORKED FOR AN OIL COMPANY, AND KNOW HOW MUCH WE ALL NEED ENERGY...**

 As Richard writes in the ETOM book, “I’m educated as a geologist, with climate and ice and water and a bunch of engineering thrown in. I’ve been an academic most of my professional life, but I worked for an oil company for a bit, and enjoyed both the money and the smart people doing interesting things there. My experience was similar to that of many geologists, who for more than a century have been getting good jobs to help people find valuable things in the Earth (oil, coal, diamonds, gold...)”

*Computer graphics show a retreating glacier, night time traffic timelapses, and a wind turbine against the morning sky, Texas:*

**AND THE BEST SCIENCE SHOWS WE'LL BE BETTER OFF IF WE ADDRESS THE TWIN STORIES OF CLIMATE CHANGE AND ENERGY, AND THAT THE SOONER WE MOVE FORWARD THE BETTER.**

*Richard speaks to camera at Hilo, Hawaii, on a black lava rock beach:*


*Our use of fossil fuels for energy is pushing us towards a climate unlike any seen in the history of our species, but a growing population needs more and more clean energy. But I believe science offers us an Operators' Manual with answers to both of these huge challenges.*


**MAIN TITLES:**

## ***EARTH: THE OPERATORS' MANUAL***

*Underwriter announcement, voice and video:*

**"EARTH: THE OPERATORS' MANUAL" IS MADE POSSIBLE BY NSF, THE NATIONAL SCIENCE FOUNDATION, WHERE DISCOVERIES BEGIN.**


 NSF funds research as well as education and outreach, and has supported studies by Richard and others, including the deep ice core in Greenland mentioned above. The ETOM program and website is also based upon work supported by the National Science Foundation under Grant DRL-0917564. However, any opinions, findings and conclusions or recommendations expressed in this material are those of Richard Alley and Passport to Knowledge / Geoff Haines-Stiles Productions, Inc., and do not necessarily reflect those of the National Science Foundation.

 Like an actual Manual, this video has 3 chapters, each indicated by a text superimposition. Later chapters are: [Chapter 2: CO<sub>2</sub> and The Atmosphere](#), and [Chapter 3: Toward a Sustainable Future](#).

## Chapter 1

# Humans & Energy

*The Earth at night, seen from space.*

 These spectacular images were made by astronaut Don Pettit during his time on board the International Space Station. [More images of the lights of Earth](#), and a [look at how Pettit built a special camera](#) from parts left aboard ISS by previous occupants can be found online.


**HUMANS NEED ENERGY...**

**WE ALWAYS HAVE, AND ALWAYS WILL...**

**BUT HOW WE USE ENERGY IS NOW CRITICAL FOR OUR SURVIVAL.**

*Close-up of wood burning in a campfire:*

**IT ALL BEGAN WITH FIRE...**


 Richard Alley's book *EARTH: The Operators' Manual* summarizes the use of fire for cooking as follows: "Burn some trees, use the heat released to make the food more digestible, and we get lots of energy from the food with a small investment in supporting our guts. The extra energy powers our minds, and we're human." (Page 15)

**TODAY IT'S MOSTLY FOSSIL FUELS.**

*Refinery flare: New York City traffic time-lapse, including scenes from Xintiandi at night with busy crowds. Nanjing Road crowds, Shanghai, China:*

**NOW WE'RE CLOSING IN ON SEVEN BILLION OF US...**

**...AND EARTH'S POPULATION IS HEADED TOWARD 10 BILLION.**

 The Population Reference Bureau released data on worldwide population in July 2009 in its 2009 World Population Data Sheet, ([PDF](#)). According to those data, the world population now stands at 6.8 billion people. The summary provided by the [Population Reference Bureau](#), puts worldwide population on track to reach 7 billion people in 2011, just 12 years after attaining the 6 billion mark in 1999. The United Nations Study World Population to 2300 ([PDF](#)), predicts a world population of 8.9 billion in 2050, with a high estimate of 10.6 billion and a low estimate of 7.4 billion people. The [Population Counter](#) gives "today's" figures.



## OUR CITIES AND OUR CIVILIZATION DEPEND ON VAST AMOUNTS OF ENERGY.

*Smear out headlights and tail lights in night time-lapse:*


**FOSSIL FUELS—COAL, OIL AND NATURAL GAS—PROVIDE ALMOST 80% OF THE ENERGY USED WORLD-WIDE.**

**NUCLEAR IS A LITTLE LESS THAN 5%...**

**HYDRO-POWER A LITTLE UNDER 6...**

**AND THE OTHER RENEWABLES—SOLAR, WIND AND GEOTHERMAL—ABOUT 1% BUT GROWING FAST.**


**WOOD AND DUNG MAKE UP THE REST.**

 Two leading and highly credible sources for statistics on energy use are the BP Statistical Review of World Energy (June 2010) ([PDF](#)), and the *International Energy Agency's World Energy Outlook 2010*. The BP Statistical Review provides detailed and current information on primary energy use by country and by the type of energy for the most important energy sources: oil, natural gas, coal, nuclear energy, solar power. The most difficult portion of the worldwide energy assessment deals with the contribution from plants and what is sometimes called "traditional biomass." This includes wood and dung (the words which our animated chart uses as shorthand for "traditional biomass"), which are used primarily in the least developed countries; these estimates appear in Table 2.2 of World Energy Outlook 2010. The 2002 draft paper "Macro Patterns in the Use of Traditional Biomass Fuels" ([PDF](#)) by Nadejda M. Victor and David G. Victor shows in Figure 1 how the proportion of energy supply from traditional biomass has declined from 1800 to 2000. Our graphic rounds numbers up and down to the nearest whole number. Different sources give somewhat different numbers both because of uncertainties and because of different choices about how to report traditional biomass.


## USING ENERGY IS HELPING MANY OF US LIVE BETTER THAN EVER BEFORE...

*An Earth Zoom takes us to Erg Chebbi, Morocco, on the edge of the Sahara. Bedouin girls go to the well for water. At night, the family eats dinner in a crowded tent by the light of propane lanterns.*

**YET WELL OVER A BILLION AND A HALF ARE LAGGING BEHIND, WITHOUT ACCESS TO ELECTRICITY OR CLEAN FUELS.**

 Data for the number of people living without access to electricity appear in the International Energy Agency's publication World Energy Outlook's "Energy Poverty: How to make modern energy access universal?" ([PDF](#)) The estimated number of those lacking

access to the energy grid also appears in the World Bank Study "LIGHTING AFRICA YEAR 1: Progress and Plans / Annual Report September 1, 2007 – August 31, 2008" ([PDF](#)), and in the joint World Bank and International Finance Corporation study "Lighting Africa," ([PDF](#)) which estimates that 589 million of the 1.6 billion people worldwide who lack access to the power grid live in Africa.

 Brazil's success in bringing rural residents online is documented in its government's "Luz Para Todos" or, in English, "Light for All", ([PDF](#)).

*An Earth zoom to Northeast Brazil: we're high in the hills close to the town of Quixadá, in the state of Ceará:*

**IN RECENT YEARS, BRAZIL HAS BROUGHT ELECTRICITY TO TEN MILLION, BUT IN RURAL CEARA, SOME STILL LIVE "OFF THE GRID."**

*A villager draws water from the nearby well. In Lucia's backyard we see her daughter feeding chicks, and cutting firewood for cooking:*

**NO ELECTRICITY... NO RUNNING WATER, AND NO REFRIGERATORS TO KEEP FOOD SAFE.**

**LIFE'S ESSENTIALS COME FROM THEIR OWN HARD LABOR.**


*Two of Lucia's children ride home on their donkey, and the Sun sets.*

**EDUCATION IS COMPULSORY, BUT STUDYING'S A CHALLENGE WHEN EVENING ARRIVES.**

*Lucia in the kitchen lights kerosene lanterns and prepares dinner.*

**THE ONLY LIGHT IS FROM KEROSENE LAMPS.**

**THEY'RE SMOKY, DIM ...AND DANGEROUS.**

 Richard Alley's book *EARTH: The Operators' Manual* discusses the dangers of fire from burning lamps in New York City tenements during the 19th century on page 31, using stories (see footnote 16) from *The New York Times*. "Camphene lamps provided good light from a relatively inexpensive mixture of alcohol and turpentine, but they had a tendency to blow up, Alley notes." A more general discussion of the [dangers of tenement living in 19th-century America](#) appears on the History.com website. The United Nations World Health Organization reports that [indoor air pollution causes the death of 1.6 million persons per year](#). We may compare this number with the World Health Organization's estimate of the [number of deaths worldwide from malaria](#) as between 700,000 and 1 million.

## SOME DAY, THIS MOTHER PRAYS, THE ELECTRIC GRID WILL REACH HER HOME.


*Lucia Bento de Souza speaks to camera.*

*The first thing I'll do when the electricity arrives in my place will be to say a rosary and give praise to God.*

*Earth zoom: fly from Brazil to China.*

*An old man and woman work in densely vegetated village fields of Erhezhuang, Fangshan District, China.*

## MORE THAN HALF OF CHINA'S 1.3 BILLION CITIZENS LIVE IN THE COUNTRYSIDE.


 In 2007, the Chinese government reported that the [Chinese rural population](#) was 56 percent of the total. The CIA publication [The World Factbook](#) states that in 2008 this figure was 57 percent.

*An old man pumps bellows to cook dumplings in a country home, near Xi'an:*

## MANY RURAL RESIDENTS STILL USE WOOD OR COAL FOR COOKING-AND-HEATING, ALTHOUGH MOST OF CHINA IS ALREADY ON THE GRID.

*Wires snake into a house on the outskirts of Xi'an, connecting to a satellite dish.*


## CHINA HAS USED ENERGY TO FUEL THE DEVELOPMENT THAT HAS BROUGHT MORE THAN HALF A BILLION OUT OF POVERTY.

 The World Bank, in "[Poverty Around the World](#)" by Anup Shah reports that between 1991 and 2005, the poverty rate in China fell from 85% to 15.9%. This decrease by 69% included nearly 800 million people, and represented almost the entire worldwide decrease in poverty.

## IN VILLAGE HOMES THERE ARE FLAT SCREEN TVS AND AIR CONDITIONERS.

*Transition from the countryside to the busy streets of Shanghai:*


## BY 2030, IT'S PROJECTED THAT 350 MILLION CHINESE, MORE THAN THE POPULATION OF THE ENTIRE UNITED STATES, WILL MOVE FROM THE COUNTRYSIDE TO CITIES... A TREND THAT'S ECHOED WORLDWIDE.

 The McKinsey Global Institute study "[Preparing for China's Urban Billion](#)" ([PDF](#)) states that China will add 350 million people to its urban population by the year 2025.




*Scenes from aerials over Rio de Janeiro, Brazil, Jemaa El Fna ("Jaffna Square") in Marrakesh, Morocco:*

**DEVELOPMENT IN ASIA, AFRICA AND SOUTH AMERICA WILL MEAN 3 BILLION PEOPLE WILL START USING MORE AND MORE ENERGY AS THEY ESCAPE FROM POVERTY.**

 The [United States Census Bureau](#) estimates that the world population will increase by just over 1.5 billion people, to a total of 8.5 billion, by the year 2030. In addition to this population growth, increased demand for energy will rise as more of the population moves from rural to urban areas, with China alone accounting for 350 million, as noted in the McKinsey study cited above. The Population Reference Bureau's report [World Population Highlights 2007: Urbanization](#) states that between 2000 and 2030, the urban population of Africa will increase by 430 million and Asia's by 1.2 billion, with more modest increases in Latin America and the Caribbean area. A [report by YARA International](#) projects that the worldwide urban population is expected to increase from 3.3 billion in 2008 to about 6.4 billion by 2050. For people who are well-off, living in cities may save energy compared to spreading out into suburbia (reference: Norman, J., H.L. MacLean and C.A. Kennedy, 2006, Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions, *Journal of Urban Planning and Development*, v. 132, no. 1, p. 10-21). But, moving from a dung cooking fire in the countryside to a modern urban lifestyle increases energy use.

*A large light bulb appears over an Earth at night computer graphic:*

**SUPPOSE WE MAKE THE FAMILIAR IF OLD-FASHIONED HUNDRED WATT LIGHT BULB OUR UNIT FOR COMPARING ENERGY USE.**

 Alley's book explains the rationale for using a 100 watt light bulb ([see excerpt](#)).

*A few bulbs are superimposed over a North African scene:*

**IF YOU'RE "OFF THE GRID", YOUR SHARE OF YOUR NATION'S ENERGY WILL BE JUST A FEW HUNDRED WATTS, A FEW LIGHT BULBS.**

*A donkey cart and cars move towards camera in a street scene from Quixadá, Brazil:*

**SOUTH AMERICANS AVERAGE ABOUT 13 BULBS.**

*A display of faces on an electronic mural at the Shanghai EXPO, China: visitors take flash photos:*


**FOR FAST DEVELOPING CHINA, IT'S MORE LIKE 22 BULBS.**

*Crowds in the Copenhagen train station:*

**EUROPE AND RUSSIA, 5,000 WATTS, 50 BULBS.**

*New York City street scene, with the Chrysler building skyscraper seen over the cars:*

**AND NORTH AMERICANS, OVER TEN THOUSAND WATTS, MORE THAN 100 BULBS.**

 The energy consumption figures come from the two sources cited earlier: the BP Statistical Review of World Energy (June 2010) ([PDF](#)), and the International Energy Agency's *World Energy Outlook 2010*. The population data come from the Population Reference Bureau's 2009 World Population Data Sheet, ([PDF](#).) While the use of biomass is not well documented and sources differ, we have chosen to allocate it between regions based on population.

*On an original graphic, we see Earth's total population represented by number and region on the horizontal axis, and energy use, organized again by region, on the vertical:*

**NOW LET'S REPLACE THOSE LIGHT BULBS WITH THE ACTUAL NUMBERS...**

**POPULATION, SHOWN ACROSS THE BOTTOM, AND ENERGY USE, DISPLAYED VERTICALLY...**


**"OFF THE GRID" TO THE LEFT, NORTH AMERICA TO THE RIGHT.**

**IF EVERYONE, EVERYWHERE, STARTED USING ENERGY AT THE RATE NORTH AMERICANS DO, THE WORLD'S ENERGY CONSUMPTION WOULD MORE THAN QUADRUPLE...**

**...AND—USING FOSSIL FUELS—THAT'S CLEARLY UNSUSTAINABLE.**


**NO DOUBT ABOUT IT, COAL, GAS AND OIL HAVE BROUGHT HUGE BENEFITS.**

**BUT WE'RE BURNING THROUGH 'EM APPROXIMATELY A MILLION TIMES FASTER THAN NATURE SAVED THEM FOR US, AND THEY *WILL* RUN OUT.**

 Chapter 4 of *EARTH: The Operators' Manual* discusses the formation of fossil fuels, with further references provided in footnote 16. A good introduction to the subject can be found on the [U.S. Department of Energy's](#) website. The factor of one million by which the rate of our use of fossil fuels surpasses the rate at which nature saved them for us arises from the fact that the fossil fuels are almost all from the last hundred million years, but our society has been consuming them over a few hundred years, starting with the [Industrial Revolution](#).

*Coal plant emissions, cars on roads in cities worldwide:*

**WHAT'S EVEN WORSE, THE CARBON DIOXIDE FROM OUR ENERGY SYSTEM THREATENS TO CHANGE THE PLANET IN WAYS THAT'LL MAKE OUR LIVES MUCH HARDER.**

 Pages 80-81 of *Earth: The Operators' Manual* describes the "greenhouse effect" that carbon dioxide in our atmosphere produces (see [excerpt](#)).

*Houston refinery, China chimneys, New York and China autos:*

**SO WHY ARE FOSSIL FUELS SUCH A POWERFUL, BUT ULTIMATELY PROBLEMATIC, SOURCE OF ENERGY?**

*The camera is now onboard an airboat traveling through a series of wide canals and narrow bayous in the National Park Service's Barataria Preserve, part of the Jean Lafitte National Historic Park and Preserve, near New Orleans.*

**CONDITIONS ON THE WATERWAYS OF TODAY'S LOUISIANA HELP US UNDERSTAND HOW FOSSIL FUELS ARE MADE...**

**...AND WHY THEY'RE ULTIMATELY UNSUSTAINABLE.**

**OIL, COAL AND NATURAL GAS ARE MADE FROM THINGS, MOSTLY PLANTS, THAT LIVED AND DIED LONG AGO**


*Richard's boots stomp through swampy water, and he speaks to camera:*

*It's taken hundreds of millions of years for Nature to create enough of the special conditions that save the carbon and energy in plants to form the fossil fuels that we use.*

*Computer graphics show the processes by which fossil fuels are formed, showing diatoms falling to the bottom of a sea or swamp:*

**HERE'S HOW IT WORKS...**

**PLANTS, LIKE THESE TINY DIATOMS ENCASED IN SILICA SHELLS, GROW IN THE UPPER LAYERS OF LAKES AND OCEANS, USING THE SUN'S ENERGY TO TURN CARBON DIOXIDE AND WATER INTO MORE PLANTS.**


 Diatoms, a type of algae, are single-celled organisms that draw energy from sunlight. They are distinguished by a cell wall composed of silica (a compound of silicon with oxygen, akin to the silicate minerals in most rocks), and often form colonies in the shape of ribbons or fans. Some of the steps leading to diatoms building their shells from silica are presented in footnote 14 on page 373 of *Earth: The Operators' Manual*. Lots of other types of algae contribute to oil, too... but the producers and animators thought diatoms would look especially good in the show.

**WHEN THEY DIE, IF THEY ARE BURIED WHERE THERE'S LITTLE OXYGEN TO BREAK THEM DOWN, THEIR CHEMICAL BONDS RETAIN THE ENERGY THAT BEGAN AS SUNLIGHT.**

**IF ENOUGH CARBON-RICH MATTER IS BURIED DEEPLY ENOUGH, FOR LONG ENOUGH, THE EARTH'S HEAT AND PRESSURE TURN IT INTO FOSSIL FUEL, CONCENTRATING THE ENERGY THAT ONCE FED THE GROWING PLANTS.**

*Zooming back through oil-rich geological layers:*

**VARY WHAT GOES INTO EARTH'S PRESSURE COOKER, AND THE TEMPERATURE, AND YOU END UP WITH THE DIFFERENT KINDS OF FOSSIL FUEL.**

 *EARTH: The Operators' Manual* discusses the formation of fossil fuels on pages 52-53, beginning with the observation that the "[f]ormation of fossil fuels depends on having the right combinations of rapid plant growth and fine-grained sediment accumulating beneath low-oxygen waters."

*Richard is paddling the pirogue (a Cajun canoe), and we see close-ups plants on the waters surface and beside the bayou.*


***Woody plants make coal. Slimy plants, algae, will give you oil, and both of 'em give rise to natural gas.***

*Richard's paddle slices through the dark waters, and he speaks to camera:*

***The fossil fuels formed over a few hundred million years, and we're burning them over a few hundred years. And if we keep doing that, sooner or later they must run out.***


***But there's a bigger problem with fossil fuels. As we've seen, they're made of carbon primarily, and when you burn them, (you) add oxygen and that makes CO<sub>2</sub> that goes in the air.***

*We're reversing the process by which they formed.*

 As noted above, time intervals of hundreds of millions of years produced the fossil fuels—oil, coal, and natural gas—that we burn today. Much of the coal formation occurred during the [Carboniferous Period of the Paleozoic Era](#), which lasted from about 359 to 299 million years ago, and is named for all the carbon that was deposited in the coal. In the U.S., the deposits of the Carboniferous are so well-developed, and known so well from coal mining, that the period is split into two, the older Mississippian Period and the younger Pennsylvanian Period. Fossil-fuel formation continued through the end of [the age of dinosaurs](#), 65 million years ago, and more recently. Ages are from the [International Commission on Stratigraphy](#).

*We begin to hear the roar of an approaching jet plane:*

*And if we keep doing this, it must change the composition of Earth's atmosphere.*

 Contemporary measurements of the amount of atmospheric carbon dioxide, called the “Keeling curve” after the scientist who pioneered them, are shown and explained on NASA Earth Observatory website. The graph shown at this location extends from around 1957, during the International Geophysical Year when Keeling’s measurements began, to the present.

*Sudden cut to an Air Force jet flying by fast overhead:*

**WHAT CO<sub>2</sub> DOES WAS CONFIRMED BY BASIC RESEARCH THAT HAD ABSOLUTELY NOTHING TO DO WITH CLIMATE CHANGE.**

*We hear the voice of a newsreel announcer as balloons carrying instrument packages are launched:*

**“A CONTINUANCE OF THE UPPER AIR PROGRAM WILL PROVIDE SCIENTIFIC DATA CONCERNING THE PHYSICS OF THE UPPER ATMOSPHERE...”**



## Chapter 2

# CO<sub>2</sub> & The Atmosphere

**WORLD WAR II WAS OVER, BUT THE COLD WAR HAD BEGUN.**

*Scenes of 1950s military aircraft in flight, and animation of the A5 HEAT SEEKER missile:*

**THE U.S. AIR FORCE NEEDED TO UNDERSTAND THE ATMOSPHERE FOR COMMUNICATIONS... AND TO DESIGN HEAT-SEEKING MISSILES.**


*Test of a missile nose cone in jet exhaust:*

**AT CERTAIN WAVELENGTHS CARBON DIOXIDE AND WATER VAPOR BLOCK RADIATION.**


*Missile strike:*

**SO THE NEW MISSILES COULDN'T "SEE" VERY FAR IF THEY USED A WAVELENGTH THAT CO<sub>2</sub> ABSORBS.**


*Scenes at Hanscom and other USAF labs, from Air Force films housed at the National Archives:*

 Pages 81-83 of *EARTH: The Operators' Manual* describe the effect of atmospheric carbon dioxide and water vapor on the Air Force's development of heat-seeking missiles; Richard Alley observes that "[d]esigning sensors to see the hot target through the 'swamp' of greenhouse gases in the air required an understanding of those gases."

**RESEARCH AT THE "AIR FORCE GEOPHYSICS LABORATORY" IN HANSCOM, MASSACHUSETTS, PRODUCED AN IMMENSE DATABASE WITH CAREFUL MEASUREMENTS OF ATMOSPHERIC GASES.**

 Here is a description of the successor to this early work, a data base, called HITRAN (High-resolutionTRANsmission molecular absorption database.)

**FURTHER RESEARCH BY OTHERS APPLIED AND EXTENDED THOSE DISCOVERIES, CLEARLY SHOWING THE HEAT-TRAPPING INFLUENCE OF CO<sub>2</sub>.**

 Modern data on atmospheric carbon dioxide obtained from satellites and clearly showing increasing blocking of heat radiation is discussed on page 74 and in Figure 6.1 on page 79 in *EARTH: The Operators' Manual*; scientific references appear in footnote 3 on page 350 and in footnote 20 on page 386.

As Richard writes, "Satellites looking down see that Earth's atmosphere is blocking energy in just those wavelengths that the laboratory measurements and the calculations show are blocked by CO<sub>2</sub> and other greenhouse gases, and the satellites have seen increasing blockage over time as the levels of greenhouse gases have risen, while this increasing blockage is beautifully explained by the physical understanding of the greenhouse gases." The related footnote references an article by Harries, J. E., H. E. Brindley, P. J. Sagoo and R. J. Bantges, 2001, "Increases in greenhouse forcing inferred from the outgoing longwave radiation spectra of the Earth in 1970 and 1997," *Nature* 410: 355–57. Also see Griggs, J. A. and J. E. Harries, 2007, "Comparison of spectrally resolved outgoing longwave radiation over the tropical Pacific between 1970 and 2003 using IRIS, IMG, and AIRS," *Journal of Climate* 20: 3982–4001.

*Air Force researchers work on various atmospheric experiments, including launching balloons and monitoring experimental equipment:*

### THE AIR FORCE HADN'T SET OUT TO STUDY "GLOBAL WARMING": THEY JUST WANTED THEIR MISSILES TO WORK.

*A target plane is hit, and another plane releases a missile:*

### BUT PHYSICS IS PHYSICS.

*Missile approaches target, and hits:*

### THE ATMOSPHERE DOESN'T CARE IF YOU'RE STUDYING IT FOR WARRING OR WARMING.

*USAF jet banks away from camera:*


### ADDING CO<sub>2</sub> TURNS UP THE PLANET'S THERMOSTAT.

*The archival Air Force jet flies away into clouds, and a contemporary helicopter emerges out of the clouds: now we're traveling with Richard over the Franz Josef Glacier in New Zealand.*


### IT WORKS THE OTHER WAY AS WELL.

### REMOVE CO<sub>2</sub>, AND THINGS COOL DOWN.

**THESE ARE THE SOUTHERN ALPS OF NEW ZEALAND, AND THEIR CLIMATE HISTORY SHOWS THAT THE PHYSICISTS *REALLY* GOT IT RIGHT...**

 The Southern Alps are a mountain chain that runs for about 300 miles along the western side of New Zealand's South Island. Seventeen of the mountain peaks are more than 3,000 meters (about 10,000 feet) high, with [Aoraki \(Mount Cook\)](#) the tallest at 3,754 meters. Numerous glaciers spread along the mountain slopes, the largest of which, the Tasman Glacier, extends down the east slope to Lake Pukaki. The Franz Josef Glacier featured here extends down the west slope. This spectacular landscape figured prominently in the three films of the "Lord of the Rings" trilogy.

**THESE DEEP THICK PILES OF FROZEN WATER ARE *GLACIERS*, SLOW MOVING RIVERS OF ICE, SITTING ON LAND.**

 For more on glaciers, including informative images of "before" and "after" retreating (or melting back) visit the [National Snow and Ice Data Center](#) and download their overlays for Google Earth.

**BUT ONCE, WHEN TEMPERATURES WERE WARMER, THEY WERE LIQUID WATER, STORED IN THE SEA.**

**WE'RE GOING TO FOLLOW THIS ONE, THE FRANZ JOSEF, FROM SUMMIT TO OCEAN TO SEE THE REAL-WORLD IMPACT OF CHANGING LEVELS OF CO<sub>2</sub>.**

*The helicopter lands, and Davie Robinson (one of the two mountain guides accompanying the crew to keep them safe) helps Richard (three field seasons in Antarctica, eight in Greenland, and three in Alaska) rope up:*

**IT'S BEAUTIFUL UP HERE ON THE HIGHEST SNOW FIELD, BUT DANGERS LURK BENEATH THE SURFACE.**

**I'VE SPENT A LOT OF TIME ON THE ICE.**

**IT'S STANDARD PRACTICE UP HERE TO TRAVEL IN PAIRS, ROPED UP FOR SAFETY.**

*Richard describes the location, walking towards camera across the "neve" or upper snowfield. You can hear the exertion and effects of altitude in his voice:*

*The glacier is fed by something like 6 meters of water a year... maybe 20 meters, 60 feet of snowfall... it's a really seriously high snowfall.*

*The snow and ice spread under their own weight and it's headed downhill at something like a kilometer a year.*

*Aerial shots of the massive crevasses on the upper snowfield of the Franz Josef:*

*When ice is speeding up a lot as it flows towards the coast it can crack and open great crevasses that give you a view into the guts of the glacier.*

*Richard on camera, looks down into the crevasse:*

*Man, this is a big one... 10... 20... 30 meters more... 100 feet or more heading down in here, and we can see a whole lot of the structure of the glacier right here.*

*Richard is lowered into the crevasse by the mountain guide:*

*Davie, speaking to Richard:*

*So, what we're going to do is just gonna sit on the edge and then walk backwards, and I'll lower you.*

*Richard:*

*Tell me when. OK, rolling around, and down we go.*

*Richard speaks to camera, from down in the crevasse:*

*Snowfall arrives in layers, each storm puttin' one down... Summer sun heats the snow, and makes it look a little bit different than the winter snow, and so you build up a history.*

*In these layers there's indications of climate, how much it snowed, what the temperature was.*

*And all of this is being buried by more snow.*

*"CSI-effect" zoom into bubble CUs, courtesy Joan Fitzpatrick, US Geological Survey.*


*And the weight of that snow squeezes what's beneath it, and turns it to ice. And in doing that it can trap bubbles.*

*And in those bubbles are samples of old air, a record of the composition of the Earth's atmosphere, including how much CO<sub>2</sub> was in it, a record of the temperature on the ice sheets, and how much it snowed.*

*Assisted by Davie, Richard climbs up and out:*

**AS WE'LL SEE, WE CAN OPEN THOSE ICY BOTTLES OF ANCIENT AIR, AND STUDY THE HISTORY OF EARTH'S ATMOSPHERE.**

**THIS LANDSCAPE ALSO TELLS THE STORY OF THE "ICE AGES" AND THE FORCES THAT HAVE SHAPED EARTH'S CLIMATE.**


 Chapter 11 in the book, "The Great Ice That Covers The Land" (starting on page 133), tells the story of the ice ages. As summarized earlier in the book, "...the ice ages were caused by sunshine moving around on Earth due to features of its orbit, (that) the changing ice sheets and temperatures triggered feedbacks that included changes in CO<sub>2</sub>, and (that) the CO<sub>2</sub> in turn amplified the temperature changes. Physical understanding shows that CO<sub>2</sub> changes must affect temperature. Efforts to predict the size and geographic pattern of the temperature changes while ignoring the effects of the CO<sub>2</sub> have failed, while including the effect of the CO<sub>2</sub> successfully predicts the temperature changes."

**OVER THE LAST MILLIONS OF YEARS THE BRIGHTNESS OF THE SUN DOESN'T SEEM TO HAVE CHANGED MUCH, BUT THE EARTH'S ORBIT, AND THE TILT OF ITS AXIS, HAVE SHIFTED IN REGULAR PATTERNS OVER TENS AND HUNDREDS OF THOUSANDS OF YEARS.**

**THE ORBIT CHANGES SHAPE, VARYING HOW CLOSE AND FAR THE EARTH GETS AS IT ORBITS THE SUN EACH YEAR.**


**OVER 41,000 YEARS, THE TILT OF EARTH'S AXIS GETS LARGER AND SMALLER, SHIFTING SOME OF THE SUNSHINE FROM THE EQUATOR TO THE POLES AND BACK.**

**AND, OUR PLANET HAS A SLIGHT WOBBLE, LIKE A CHILD'S TOP, ALTERING WHICH HEMISPHERE IS MOST DIRECTLY POINTED TOWARD THE SUN WHEN EARTH IS CLOSEST TO IT.**

 *EARTH: The Operator's Manual* discusses these changes on pages 134-137 (see excerpt). See also two articles by Donald Goldsmith: "Turn, Turn, Turn," in *Natural History* for December 2006, about the precession of the Earth and "Ice Cycles" in *Natural History* for March 2007, about the Milankovitch cycle of ice ages.

**OVER TENS OF THOUSANDS OF YEARS, THESE NATURAL VARIATIONS SHIFT SUNLIGHT AROUND ON THE PLANET, AND THAT INFLUENCES CLIMATE.**

**MORE THAN 20,000 YEARS AGO, DECREASING AMOUNTS OF SUNSHINE IN THE ARCTIC ALLOWED GREAT ICE SHEETS TO GROW ACROSS NORTH AMERICA AND EURASIA, REACHING THE MODERN SITES OF NEW YORK AND CHICAGO.**

 The Geological Survey of Ireland shows the extent of ice sheets in Europe as well as North America 20,000 years ago. To look farther back in time, consult the images that are



part of the extensive depictions of Earth's distant past created by Ron Blakey, who consulted with ETOM on this program. Also see the resources of the National Climatic Data Center of NOAA.

### SEA LEVEL FELL AS WATER WAS LOCKED UP ON LAND.

### CHANGING CURRENTS LET THE OCEANS ABSORB CO<sub>2</sub> FROM THE AIR.

*Richard walking on the seracs, and swooping aeriels:*

**THAT COOLED THE SOUTHERN HEMISPHERE, AND UNLEASHED THE IMMENSE POWER OF GLACIERS SUCH AS THE FRANZ JOSEF, WHICH ADVANCED DOWN THIS WIDE VALLEY, FILLING IT WITH DEEP, THICK ICE.**

*Approaching the coast, and we see rocks in the ocean:*

**NOW WE'RE FLYING OVER TODAY'S COASTLINE, WHERE GIANT BOULDERS ARE LEFT OVERS FROM THAT LAST ICE AGE.**

*Richard emerges from the chopper, and walks to camera:*


**A glacier is a great earth-moving machine. It's a dump truck that carries rocks that fall on top of it. It's a bulldozer that pushes rocks in front of it. And it outlines itself with those rocks making a deposit that we call a "moraine", that tells us where the glacier has been.**

*Richard, to camera, with rock in hand by the giant boulder:*


**We're 20 kilometers, 12 miles, from the front of the Franz Josef Glacier today, but about 20,000 years ago the ice was depositing these rocks as it flowed past us and out to sea.**

*The helicopter-borne camera flies out to sea, passing over the rocks in the ocean:*

### THE ROCKS WE CAN STILL SEE TODAY CONFIRM WHERE THE GLACIER ONCE WAS.


 This site offers a well-illustrated description of the [recent history of the Franz Josef glacier](#). Be aware that this is a commercially-supported site, so it is trying to sell things, but it does have good pictures and information. Also note that a glacier such as the Franz Josef, with its immense snowfall, does a lot of "wiggling"; just as the warming from winter to summer involves a few cold snaps on the way, you need to watch for a while to separate the "climate" from the "weather" of the glacier. Overall, the Franz Josef has been retreating recently, and has retreated greatly from the last ice age, but with wiggles on the way.

**NOW, IN A COMPUTER-GENERATED TIMELAPSE CONDENSING THOUSANDS OF YEARS OF EARTH HISTORY... WE'RE SEEING WHAT HAPPENED.**

 The Advance of the Franz Josef Glacier: No one was there to see exactly what the glacier looked like as it advanced and retreated, but we know where it was at various times, and this animation is based on geological data and contemporary pictures of the glacier to look as realistic as possible. Animation by [422 South](#), geological consultant, Andrew Mackintosh.

**LOWER CO<sub>2</sub>, COLDER TEMPERATURES, MORE SNOW AND ICE, AND THE FRANZ JOSEF ADVANCED.**

**20,000 YEARS AGO, 30% OF TODAY'S LAND AREA WAS COVERED BY GREAT ICE SHEETS, WHICH LOCKED UP SO MUCH WATER THAT THE GLOBAL SEA LEVEL WAS ALMOST 400 FEET LOWER THAN TODAY.**

 NASA's Goddard Institute for Space Studies has a useful discussion of [sea level variations](#) during the past 20,000 years. A scholarly discussion appears in the book *Sea-Level Changes: The Last 20,000 Years* by Paolo Antonio Pirazzoli (Wiley, 1997). Also see information on [sea-level change](#) from the US EPA and chapters 4 and 6 of Working Group 1 of the Fourth Assessment Report of the [IPCC](#).


*In CGI (Computer-Generated Imagery), the ancient Franz Josef melts away, and we dissolve to our flyover of today's ocean:*

**THEN, AS EARTH'S ORBIT CHANGED, TEMPERATURES AND CO<sub>2</sub> ROSE, AND THE GLACIER MELTED BACK.**

**THE ORBITS SET THE STAGE, BUT BY THEMSELVES THEY WEREN'T ENOUGH.**

*Flying back along the coast:*

**WE NEED THE WARMING AND COOLING EFFECTS OF RISING AND FALLING CO<sub>2</sub> TO EXPLAIN THE CHANGES WE KNOW HAPPENED.**

 In the ETOM book, pages 137-138, Richard provides additional background. "Ice across northern lands reflected a lot of sunshine while grinding up rocks and causing other changes that generated extra sun-blocking dust. Grasslands or tundra replaced dark forests, reflecting more sun. But the extra reflectivity from the full-size ice-age ice sheets, the dust and vegetation then, as well as the water-vapor and other feedbacks, account for only about half of the cooling that occurred. Furthermore, in some sense we are cheating to get half of the cooling this way. Until something else caused the other half of the cooling, the ice and dust and vegetation wouldn't have changed as much as they did and

so wouldn't have caused as much cooling. To get out of this problem, we need some help from ice-core data. As described in chapter 8, the ice cores show clearly that the temperature changes of the ice-age cycle were accompanied by CO<sub>2</sub> changes, as well as by changes in the less important greenhouse gases methane and nitrous oxide. If doubling of CO<sub>2</sub> levels contributes about 5oF (3oC) of warming or a bit more, as expected based on our best science, then the changes in greenhouse gases can explain the remaining half of the temperature change. The CO<sub>2</sub> must be a feedback on other Earth-system processes—we know of no way in which changing orbits could directly alter the amount of CO<sub>2</sub> in the air. Instead, the orbits must have affected ice and other things that then affected CO<sub>2</sub>. But the records show that only a small amount of temperature change occurred before the CO<sub>2</sub> began changing, and then temperature and CO<sub>2</sub> changed together. The ice ages show that changes in sunshine in a region have a huge effect on climate, but that CO<sub>2</sub> does too ...proper accounting for the ice ages, including the effects of the CO<sub>2</sub> on the ice sheets, suggests that if our models are in error, they are underestimating the changes that we may cause by continued fossil-fuel burning."

*Dissolve to scenes traveling out on the terminus lake of the Tasman Glacier, aboard a bright yellow Zodiac. A vibrantly-blue recently overturned iceberg is our destination:*

**TODAY, ATMOSPHERIC CO<sub>2</sub> IS INCREASING STILL MORE, TEMPERATURES ARE RISING, AND GLACIERS AND ICE SHEETS ARE MELTING.**


**YOU CAN SEE THIS CLEARLY ON THE LAKE FORMED BY THE SHRINKING TASMAN GLACIER ...ACROSS THE RANGE FROM THE FRANZ JOSEF.**

*Richard to camera and VO:*

*This is what the end of an Ice Age looks like. Glaciers falling apart, new lakes, new land, icebergs coming off the front of the ice.*

*In the early 1980s we would have been inside New Zealand's Tasman Glacier right here. Now we're passing icebergs in a new lake from a glacier that has mostly fallen apart and ends over 6 kilometers, 4 miles, away.*

*One glacier doesn't tell us what the world is doing, but while the Tasman has been retreating, the great majority of glaciers on the planet have gotten smaller.*


 A gallery of photographs of Himalayan glaciers "then and now" can be found [here](#). Jim Balog's [Extreme Ice Survey](#) shows many more glaciers in Alaska, Greenland and Iceland, with videos featuring commentary by some of the researchers who have documented their behavior. The United States Geological Survey has a report on the [Columbia Glacier](#), and many photo pairs from the United States Geological Survey can be found [here](#), as well as this [site](#).

**THIS IS THE COLUMBIA GLACIER IN ALASKA. IT'S A TYPE OF GLACIER THAT MAKES THE EFFECTS OF WARMING EASY TO SEE.**

**IT'S BEEN RETREATING SO FAST THAT THE "EXTREME ICE SURVEY" HAD TO REPOSITION THEIR TIMELAPSE CAMERAS TO FOLLOW ITS MOTION.**

*Time-lapse melting of the Solheimajkoll Glacier, Iceland:*

**IN ICELAND, WARMING AIR TEMPERATURES HAVE MADE THIS GLACIER SIMPLY MELT AWAY, LEAVING STREAMS AND SMALL LAKES BEHIND.**


 Here is a website maintained by Ólafur Ingólfsson, a professor of geology at the University of Iceland, describing glaciers in Iceland.

*Richard VO and to camera:*

*Thermometers in the air show warming, thermometers in the air far from cities, show warming.*

*Put your thermometer in the ground, in the ocean, look down from satellites, they show warming.*

*The evidence is clear. The Earth's climate is warming.*

 Additional details on the details of Earth's warming trend may be found in the [FAQ](#) section of this site, but sometimes it's possible to focus on the "detailed details" and lose the big picture, seeing only the trees and losing the forest. That's the argument of ETOM Advisor and *New York Times/DotEarth* blogger, Andy Revkin. He says there can and certainly should be ongoing scientific debate about the details, but that the [overall direction of global change](#) is relatively certain. (See this site also.) He says it's like a school bus packed with kids, [rolling down a hill towards a cliff](#): Do you worry about the speed it's rolling at, or try to grab the steering wheel?


*The blue ice of the Tasman Glacier iceberg dissolves into shiny metallic tubes enclosing ice cores at NICL, the National Ice Core Lab in Denver, CO, operated by USGS with support from NSF:*

**THIS FROZEN LIBRARY, THE "NATIONAL ICE CORE LAB" IN DENVER, COLORADO, HAS ICE FROM ALL OVER... KEPT AT MINUS 35 DEGREES.**

*The camera pans along row upon row of shiny metal tubes. It's a colder (much, much colder) version of the warehouse at the end of "Raiders of the Lost Ark":*

**THE OLDEST CORE HERE GOES BACK SOME 400,000 YEARS.**



 The website of the [National Ice Core Laboratory](#) includes a discussion of the usefulness of ice cores and an inventory of the laboratory's holdings. [More information on ice cores](#), other paleoclimatic archives, and what they show, plus many of the important data sets, are available from the NOAA's National Climate Data Center.

### HERE REALLY ANCIENT ICE FROM GREENLAND IN THE NORTH, AND ANTARCTICA IN THE SOUTH, REVEALS EARTH'S CLIMATE HISTORY.


*Richard reaches into the racks and pulls out a core tube, which he puts on a trolley and pushes off:*

#### LET'S SEE WHAT CORES LIKE THIS CAN TELL US.

*In what looks something like a dark-room, over a backlit inspection table, Richard studies a core:*

*First are those layers I mentioned in the New Zealand snow. They've turned to ice, and we can count them, summer, winter, summer, winter. Like tree rings, we can date the core.*

#### OTHER CORES TELL OTHER STORIES...

 Richard Alley's contribution to the 2004 Roger Revelle Commemorative Lecture Series, [Abrupt Climate Changes: Oceans, Ice and Us](#), (appearing in *Oceanography*, 17(4), 194-206), offers more on ice cores and what they tell us, including abrupt climate changes. Scroll down to find the free PDF.

*Richard points to a dark band that looks rather different:*

*Look at this... it's the ash of an Icelandic volcano that blew up to Greenland 50,000 years ago.*

*Richard looks back at the light table and we see close up images of bubbles in the ancient ice:*

*Cores hold other and even more important secrets... Look at these bubbles. They formed as the snow turned to ice and trapped old air that's still in there.*

*Scenes of NICL technicians and graduate students, prepping core samples:*

**SCIENTISTS NOW ARE WORKING WITH CORES FROM ANTARCTICA THAT GO BACK EVEN FURTHER.**




**THEY TELL US, WITH A VERY HIGH DEGREE OF ACCURACY, HOW MUCH CARBON DIOXIDE WAS IN THE AIR THAT FAR BACK.**

*Scenes in Ed Brook's lab (at Oregon State University) showing how ice is put inside a vacuum chamber and the gases analyzed:*


**RESEARCHERS BREAK CHUNKS OF ICE IN VACUUM CHAMBERS AND CAREFULLY ANALYZE THE GASES THAT COME OFF.**

**THEY'RE ABLE TO MEASURE VERY PRECISELY LEVELS OF CARBON DIOXIDE IN THAT ANCIENT AIR.**


 Animation of the CO<sub>2</sub> line Caption: Rise and fall of atmospheric CO<sub>2</sub> derived from analysis of ice cores from Russia's Vostok Station, Antarctica. Animation by Crazybridge.

**LOOKING AT THE CORES WE SEE A PATTERN THAT REPEATS...**

**...280 PARTS PER MILLION OF CO<sub>2</sub>, THEN 180, 280, 180, 280.**

 The *EARTH: The Operators' Manual* book briefly describes the use of ice-core data to reconstruct the history of atmospheric carbon dioxide on pages 95-96. A full discussion appears in Richard Alley's book *The Two-Mile Time Machine* (Princeton University Press, 2002). Another good summary can be found in Chapter 22 of the book *Earth: Evolution of a Habitable World* by Jonathan Lunine and Cynthia Lunine (Cambridge University Press, 1999).

**BY ANALYZING THE CHEMISTRY OF THE OXYGEN ATOMS IN THE ICE YOU CAN ALSO SEE THE PATTERN OF RISING AND FALLING TEMPERATURE OVER TIME...**

 Oxygen atoms come mostly in two *isotopes*, oxygen 16 and oxygen 18, and scientists can measure their relative abundances with high precision. Water molecules (H<sub>2</sub>O) that contain oxygen 18 weigh about 11 percent more than those with oxygen 16. This difference in weight makes the lighter water molecules evaporate a bit more easily than the heavier water does, and once evaporation occurs, the heavier molecules with oxygen 18 condense more readily into rain or snow than the lighter molecules do.

The snow that falls in the center of the Antarctic or Greenland ice sheets started as water vapor evaporated from the ocean. The air containing that vapor cools as it moves toward the poles and up the edge of the ice sheet. This cooling reduces the ability of the air to hold water vapor, causing the vapor to condense and then fall as rain or snow. And because the water with oxygen 18 is concentrated in the rain and snow, the remaining vapor begins to run out of water with oxygen 18. Thus, the snow that falls from colder air is poorer in oxygen 18 and richer in oxygen 16. When the climate cools, this enrichment in oxygen 16 becomes even stronger. The water is still water—you wouldn't notice any

difference at all—but the difference is very easy to measure with great precision using modern instruments. (Some water molecules have oxygen 17, and some have the heavy form of hydrogen, called deuterium, but the same explanation works for all of these.) Cooling preferentially removes the heavy water from the air before it snows on the middle of an ice sheet, so a colder ice sheet receives snowfall with less of the heavy water. Various other ways exist to estimate past temperature on an ice sheet, and these agree well with the isotopes.


**...COLDER DURING THE ICE AGES, WARMER DURING THE INTERGLACIAL PERIODS.**

**NOW PUT THE TWO LINES TOGETHER... AND YOU CAN SEE HOW CLOSELY TEMPERATURE AND CARBON DIOXIDE TRACK EACH OTHER.**

*Close up of the chart around the time of the Last Glacial Maximum, about 20,000 years ago, showing a rise in the temperature preceding a rise of CO<sub>2</sub>:*

**THEY'RE NOT EXACTLY ALIKE.**

**AT TIMES THE ORBITS CAUSED A LITTLE TEMPERATURE CHANGE BEFORE THE FEEDBACK EFFECTS OF CO<sub>2</sub> JOINED IN.**

 The website of the Environmental Protection Agency summarizes the [histories of carbon dioxide and temperature changes](#), together with a useful graph comparing the two, based on reports from the U.S. National Academy of Sciences and the IPCC.

*Zoom out from a close up of the chart to see the full 400,000 year linked patterns: first one and then the other line flashes:*

**BUT—JUST AS WE SAW IN NEW ZEALAND—WE CAN'T EXPLAIN THE LARGE SIZE OF THE CHANGES IN TEMPERATURE WITHOUT THE EFFECTS OF CO<sub>2</sub>. THIS IS THE SIGNATURE OF NATURAL VARIATION, THE CYCLE OF THE ICE AGES DRIVEN BY CHANGES IN EARTH'S ORBIT, WITH NO HUMAN INVOLVEMENT.**

*The CO<sub>2</sub> line animates upward past 380... with no clear indication of where it might be ending:*

**BUT HERE'S WHERE WE ARE TODAY.**


**IN JUST TWO HUNDRED AND FIFTY YEARS, SINCE THE INDUSTRIAL REVOLUTION, WE'VE BLOWN PAST 380 WITH NO SIGN OF SLOWING DOWN.**

*A close up of Richard, and then a full frame view of the CO<sub>2</sub> and temperature chart, with the top feathered out at about 400ppm (parts per million) which is where we'll be in about 5 years (from about 390ppm in 2010) assuming a continued rise of 2ppm per year:*

**IT'S A LEVEL NOT SEEN IN MORE THAN 400,000 YEARS, 40 TIMES LONGER THAN THE OLDEST HUMAN CIVILIZATION...**

*Richard inside the freezer, looking at the cores:*

**SO PHYSICS AND CHEMISTRY TELL US THAT ADDING CARBON DIOXIDE TO THE ATMOSPHERE WARMS THINGS UP...**

 This NASA website has an excellent graph of the [changes in atmospheric carbon dioxide](#) during the past 400,000 years. Although older ice is not stored at NICL, a similar pattern can be found in the [EPICA ice core](#), drilled by European researchers, which reaches back almost 800,000 years.

**AND EARTH'S CLIMATE HISTORY SHOWS US THERE WILL BE IMPACTS, FROM MELTING ICE SHEETS, TO RISING SEA LEVEL.**

**BUT HOW DO WE KNOW, WITH EQUAL CERTAINTY, THAT IT'S NOT JUST MORE NATURAL VARIATION, THAT HUMANS ARE THE SOURCE OF THE INCREASING CO<sub>2</sub>?**

*We see Richard walking on the barren landscape of Hell's Gate Thermal Reserve, near Rotorua, on the North Island of New Zealand. Close-ups of bubbling mud pots and steaming fumaroles:*

**WHEN WE LOOK AT A LANDSCAPE LIKE THIS ONE WE KNOW IMMEDIATELY THAT VOLCANOES PUT OUT ALL SORTS OF INTERESTING THINGS. AND THAT INCLUDES CO<sub>2</sub>.**

*Richard, to camera:*

*So how do we know that the rise of CO<sub>2</sub> in the atmosphere that we see, comes from our burning of fossil fuels, and not from something that the volcanoes have done?*


*Well, the first step in the problem is just book-keeping.*

*Computer animation of a volcano spewing stylized CO<sub>2</sub> molecules, auto tailpipes, y chimneys and humans casting long shadows, walking on a plaza:*

**WE MEASURE HOW MUCH CO<sub>2</sub> COMES OUT OF THE VOLCANOES.**

**WE MEASURE HOW MUCH CO<sub>2</sub> COMES OUT OF OUR SMOKESTACKS AND TAIL-PIPES. THE NATURAL SOURCE IS SMALL.**

**HUMANS ARE PUTTING OUT 50 TO A 100 TIMES MORE CO<sub>2</sub> THAN THE NATURAL VOLCANIC SOURCE.**

 *Earth: The Operators' Manual* provides this ratio and discusses carbon-dioxide emission from volcanoes on pages 124-125, with a footnote providing scientific references. The United States Geological Survey has a more detailed comparison of the [emission of carbon dioxide from human activities and volcanoes](#) and a description of [the composition of volcanic gases](#). This site confirms that humans now out-produce volcanoes by more than a hundred times. Kilauea in Hawaii continues to be one of Earth's most active volcanoes and this USGS site provides links to [updated videos of eruptions](#) and outgassing. A sort of "urban legend" has arisen that some volcanic outbursts, such as the Chaiten eruption in Chile in 2008, emit far more carbon dioxide in a year than humans do, but this is simply not so. It is important, however, to recognize the importance of the time period being considered: If volcanoes increased the amount of carbon dioxide they emit, and kept the new, higher level for a long time (tens or hundreds of thousands of years), they could noticeably affect the composition of the atmosphere. According to a recent report in *Science* magazine, such [enormous, continuing eruptions over hundreds of thousands of years](#) might have caused the mass extinction at the time of the Triassic-Jurassic transition, about 200 million years ago, which ranks among the greatest of all extinctions in the fossil record—a reminder of how large the impact of atmospheric carbon dioxide can be. Changes in volcanic supply of carbon dioxide to the air are implicated in other climate changes of the past, too (see note 36 in chapter 10 of *Earth: The Operators' Manual*).


*Richard to camera:*

*We can then ask the air whether our book-keeping is right, and the air says that it is.*

*CGI shot of red-hot lava emerging from a volcano, refinery smokestack, and a chart showing the linked behavior of rising CO<sub>2</sub> and falling oxygen:*

**VOLCANOES MAKE CO<sub>2</sub> BY MELTING ROCKS TO RELEASE THE CO<sub>2</sub>. THEY DON'T BURN AND THEY DON'T USE OXYGEN. BUT BURNING FOSSIL FUELS DOES USE OXYGEN WHEN IT MAKES CO<sub>2</sub>.**

**WE SEE THAT THE RISE IN CO<sub>2</sub> GOES WITH A FALL OF OXYGEN, WHICH SAYS THAT THE RISING CO<sub>2</sub> COMES FROM BURNING SOMETHING.**

 See the [FAQ](#) section of this website for additional data and further explanation of this.

*Richard to camera:*

*We can then ask the carbon in the rising CO<sub>2</sub> where it came from.*


*CGI animation shows the three varieties of carbon, differentiated by their atomic weights.*



**CARBON COMES IN 3 FLAVORS: THE LIGHTWEIGHT CARBON 12, WHICH IS ESPECIALLY COMMON IN PLANTS.**

**THE MEDIUM-WEIGHT CARBON 13, WHICH IS A LITTLE MORE COMMON IN THE GASES COMING OUT OF VOLCANOES.**

**AND THE HEAVYWEIGHT CARBON 14.**

 The element carbon appears in nature in three types, or **isotopes**: carbon 12, carbon 13, and carbon 14. These isotopes differ in the number of neutrons that each atomic nucleus contains (6 for carbon 12, 7 for carbon 13, and 8 for carbon 14), along with the 6 protons in the nucleus of every carbon atom. Carbon 12, the lightest and most abundant of these isotopes, forms 98.9% of all the carbon on Earth, while carbon 13 provides almost all of the remainder. Its additional neutron makes carbon 13 about 8 percent heavier than carbon 12, and carbon 14 atoms weigh almost 8 percent more than carbon 13.

Carbon 14 atoms, the heaviest of carbon's three isotopes, are far less abundant than either of the others. They decay radioactively, with a "half-life" of 5,730 years: After this amount of time, half of any group of carbon-14 atoms will have turned into nitrogen-14 atoms. Carbon 14 is made by cosmic rays striking nitrogen 14 in the air, and is quickly converted to carbon dioxide (this process makes TINY amounts of carbon dioxide compared to other sources!) that is taken into plants, and into animals when they eat the plants. Thus, the relative abundance of carbon 14 in living organisms closely matches that in the air that the plants "breathe". After organisms die, they do not take in more carbon 14, while the carbon 14 in them decays radioactively. After about 50,000 years, the carbon 14 in a dead organism is essentially gone. During the first 50,000 years after death, the carbon 14 remaining can be measured and used to **tell the date** when the organism died. But, fossil fuels are so old that they don't contain carbon 14.

Carbon 13 is more common in the air than in plants, which are especially enriched in carbon 12 because the lighter atoms participate more readily in the chemical reactions that allow plants to grow. And, carbon 13 is a little more common in the carbon dioxide coming from volcanoes than in the modern air, and a little more common in the carbon dioxide dissolved in the ocean than in the gases from volcanoes.

We see that the carbon dioxide rising in today's air is rich in carbon 12 and poor in carbon 13 and carbon 14. The scarcity of carbon 13 means that the carbon dioxide comes from plants, not from volcanoes or the carbon dioxide dissolved in the ocean. And, the lack of carbon 14 means that the plants have been dead for a long time—fossil fuels.

**IT'S RADIOACTIVE AND DECAYS ALMOST ENTIRELY AFTER ABOUT 50,000 YEARS... WHICH IS WHY YOU WON'T FIND IT IN VERY OLD THINGS, LIKE DINOSAUR BONES... OR FOSSIL FUELS.**

**WE SEE A RISE IN CARBON 12, WHICH COMES FROM PLANTS.**



WE DON'T SEE A RISE OF CARBON 13, SO THE CO<sub>2</sub> ISN'T COMING FROM THE VOLCANOES. AND WE *DON'T* SEE A RISE IN CARBON 14, SO THE CO<sub>2</sub> CAN'T BE COMING FROM *RECENTLY-LIVING* PLANTS.

*CGI shows CO<sub>2</sub> emerging from the crankcase of a car engine, and stylized lines of autos approach camera:*

AND SO THE ATMOSPHERE SAYS THAT THE RISING CO<sub>2</sub> COMES FROM BURNING, OF PLANTS THAT HAVE BEEN DEAD A LONG TIME...

*Richard to camera:*

*That is fossil fuels. The CO<sub>2</sub> is coming from our fossil fuels. It's us.*

SO... PHYSICS AND CHEMISTRY SHOW US CARBON DIOXIDE IS AT LEVELS NEVER SEEN IN HUMAN HISTORY. AND THE EVIDENCE SAYS IT'S ALL OF US BURNING FOSSIL FUELS THAT'S DRIVING THE INCREASE.


*Richard replaces one of the ice core tubes on the "library shelves" of NICL:*

BUT WHAT ABOUT CLIMATE CHANGE AND GLOBAL WARMING ...ARE THEY FOR REAL? HERE'S WHAT THOSE WHO HAVE LOOKED AT ALL THE DATA SAY ABOUT THE FUTURE.

*3rd party voice:*

"CLIMATE CHANGE, ENERGY SECURITY AND ECONOMIC STABILITY ARE INEXTRICABLY LINKED..."

CLIMATE CHANGE WILL CONTRIBUTE TO FOOD AND WATER SCARCITY, WILL INCREASE THE SPREAD OF DISEASE, AND MAY SPUR OR EXACERBATE MASS MIGRATION..."

 The two quotations above appear on pages 108 and 107, respectively, of the Quadrennial Defense Review (QDR). The Department of Defense issues the QDR at four-year intervals to set its priorities and objectives and to connect them to its budget. The Pew Charitable Trusts provide a useful [summary of the QDR](#).

*Richard to camera in the NICL freezer, ice forming on his beard:*

*Who do you suppose said that? Not a pundit, not a politician... the Pentagon.*

*Shock cut to simulated firefight at Fort Irwin, CA.*

THESE WAR GAMES AT FORT IRWIN, CALIFORNIA, PROVIDE REALISTIC TRAINING TO KEEP OUR SOLDIERS SAFE.

**THE PURPOSE OF THE PENTAGON'S "QUADRENNIAL DEFENSE REVIEW", THE "Q.D.R.", IS TO KEEP THE NATION SAFE. THE REVIEW COVERS MILITARY STRATEGIES FOR AN UNCERTAIN WORLD.**

*Soldiers and others "acting" as Iraqi military officers study a map:*

**THE PENTAGON HAS TO THINK LONG-TERM, AND BE READY FOR ALL CONTINGENCIES.**


**THE 2010 Q.D.R. WAS THE FIRST TIME THAT THOSE CONTINGENCIES INCLUDED CLIMATE CHANGE.**

**REAR ADMIRAL DAVID TITLEY IS OCEANOGRAPHER OF THE NAVY, AND CONTRIBUTED TO THE DEFENSE REVIEW.**

*Admiral Titley to camera and VO:*

*I think the QDR really talks about climate change in terms that really isn't for debate.*

*And you take a look at the global temperatures ...you take a look at sea level rise, you take a look at what the glaciers are doing, not just one or two glaciers but really glaciers worldwide, and you add all of those up together, and that's one of the reasons we really believe that the climate is changing. So the observations tell us that. Physics tells us this as well.*

 Warmer air flowing over the vast ocean picks up and carries along more water vapor. So, when the conditions are right for precipitation, more rain or snow can fall from the wetter air. But, as every home gardener knows, the ground can dry out faster in hot weather. Furthermore, we expect the patterns of wet and dry to shift in some regions, with expansion of the subtropical dry zones (see, for example, figure SPM7 in IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.). So, more droughts and more floods are expected in a warmer world.

An Op-Ed column entitled "[Global Weirding](#)," published in *The New York Times* on February 17, 2010, written by Thomas Friedman, states that "[o]f all the festivals of nonsense that periodically overtake American politics, surely the silliest is the argument that because Washington is having a particularly snowy winter it proves that climate change is a hoax and, therefore, we need not bother with all this girly-man stuff like renewable energy, solar panels and carbon taxes." Friedman notes that "[t]he fact that it has snowed like crazy in Washington—while it has rained at the Winter Olympics in Canada, while Australia is having a record 13-year drought—is right in line with what

every major study on climate change predicts: The weather will get weird; some areas will get more precipitation than ever; others will become drier than ever." Additional articles dealing with this topic include "[Another Blizzard: What Happened to Global Warming?](#)" by Brian Walsh, published in *Time* magazine on February 10, 2010 and, for a more recent winter, "[Snow is consistent with global warming, say scientists,](#)" published in the British newspaper *The Telegraph* on February 18, 2011.)

### WHAT CLIMATE CHANGE MEANS FOR KEY GLOBAL HOT-SPOTS IS LESS CLEAR.

*Admiral Tittley, both to camera and over scenes of intense rainfall:*


*We understand the Earth is getting warmer, we understand the oceans are getting warmer. What we do not understand is exactly how that will affect things like strong storms, rainfall rates, rainfall distribution.*

*So, yes, climate change is a certainty, but what is it going to be like in specific regions of the world and when?*


### ONE AREA OF PARTICULAR CONCERN TO THE NAVY IS SEA LEVEL RISE.

*Admiral Tittley:*


*Sea level rise is going to be a long term and very, very significant issue for the 21st. century...*

 Table 3.1 on page 23 of the Intergovernmental Panel on Climate Change's publication *Climate Change 2007: Synthesis Report*, ([PDFs](#)) presents the report's best estimates of worldwide temperature change and sea-level rise by the final decade of the 21st century. The most favorable scenario predicts a sea-level rise of 18 to 38 centimeters (7 to 15 inches), and the least favorable a rise of 26 to 59 centimeters (10 to 23 inches), "excluding future rapid dynamical changes in ice flow". However, as discussed in that report, the flow of ice sheets has been accelerating recently in response to warming. The science reviewed in that report had not accurately projected the changes, and so it was not possible "to provide a best estimate or an upper bound for sea level rise" (p. SPM14). Several studies have been conducted more recently, attempting to reduce this uncertainty. A review of many of these shows a wide range of estimates, but with a rise of 1 meter or even somewhat more by the end of this century consistent with most of the studies. (Phil. Trans. R. Soc. A 2011 369, 161-181 Robert J. Nicholls, Natasha Marinova, Jason A. Lowe, Sally Brown, Pier Vellinga, Diogo de Gusmão, Jochen Hinkel and Richard S. J. Tol [Sea-level rise and its possible impacts given a "beyond 4°C world" in the twenty-first century.](#)) A 2007 World Bank study concluded that "with a one meter sea-level rise, approximately 0.3 percent, or 194,000 square kilometers and 56 million people (1.28 percent of the population) in 84 developing countries would be impacted. An estimated 1.3 percent of GDP would be lost for those countries."

## THE QDR INCLUDED AN “INFRASTRUCTURE VULNERABILITY ASSESSMENT” THAT FOUND THAT 153 NAVAL INSTALLATIONS ARE AT SIGNIFICANT RISK FROM CLIMATIC STRESSES.

 The 2010 QDR states on page 85 that “In 2008, the National Intelligence Council judged that more than 30 U.S. military installations were already facing elevated levels of risk from rising sea levels.” The total number of military installations now at significant risk has not been formally released, but Admiral Titley wrote in his article “[Navigating Through a Changing Climate](#),” published in *Surface Warfare* magazine in 2010 that “The QDR also included an Infrastructure Vulnerability Assessment study that found that 153 naval installations are at significant risk from climatic stresses.”

## FROM PEARL HARBOR, HAWAII, TO NORFOLK, VIRGINIA, THE BASES AND THEIR NEARBY COMMUNITIES WILL HAVE TO ADAPT.

 An article published in *The New York Times* on November 25, 2010 describes the [effects of sea-level rise on the port city of Norfolk, Virginia](#). The article notes that “[l]ike many other cities, Norfolk was built on filled-in marsh. Now that fill is settling and compacting. In addition, the city is in an area where significant natural sinking of land is occurring. The result is that Norfolk has experienced the highest relative increase in sea level on the East Coast—14.5 inches since 1930, according to readings by the Sewells Point naval station here.”


*Admiral Titley:*

*...even with one to two meters of sea level rise, which is very, very substantial, we have time. This is not a crisis, but it is certainly going to be a strategic challenge.*

 See elsewhere on this website for a [transcript](#) of the full interview with Admiral Titley.

## GLOBALLY, CLIMATE CHANGE IS EXPECTED TO MEAN MORE FIRES, FLOODS AND FAMINE.

### NATIONS MAY BE DESTABILIZED.

 In a research interview for this documentary, retired USAF Major General Richard Engel, the director of the Climate Change and State Stability Program of the National Intelligence Council, commented that “[w]e focused on mid-range IPCC scenarios and targeted their effort on approximately 50 [countries] we judged had the potential to impact US security interests ...Overall we judge that global climate change will have wide-ranging implications for US national security interests over the next 20 years because it will aggravate existing problems—such as poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions—that threaten state stability...”




However, climate change alone is highly unlikely to trigger failure in any state out to 2030 but it will potentially contribute to intra- or, less likely, interstate conflict, possibly over access to scarce water resources ...Sub-Saharan Africa, because of its limited coping capacity is the most vulnerable region to the impact of climate change, with resulting challenges to its economic development and political stability. For Africa in general, higher rainfall anomalies and more intense and widespread droughts are projected. Climate change probably will cause agricultural losses of up to 50 percent for some rain-fed grain crops in some North African countries."

### **FOR THE PENTAGON, CLIMATE CHANGE IS A "THREAT MULTIPLIER."**

### **BUT WITH SOUND CLIMATE SCIENCE, TITLEY BELIEVES, FOREWARNED IS FOREARMED.**

*Admiral Titley:*

*...the good thing is, is the science has advanced enough in oceanography, glaciology, meteorology, that we have some skill, at some time frames, of predicting this. And if we choose to use those projections, we can in fact, by our behavior, alter the future in our favor.*

 On pages 168-169 of *Earth: The Operators' Manual*, Richard Alley describes the progress of science in these terms: "When a pioneer lays down a new thread of knowledge toward the future, science does not rely on it until it has been tested and retested, by different groups using different techniques and different data in different ways. When there is such a weave of supporting results that the original could be cut out and thrown away without notably weakening the whole, the result is passed to the broader community through the assessment process, and the pioneer is put in line for invitations to give review talks and receive awards. Today, you cannot make evolution disappear by denying Darwin, nor relativity by erasing Einstein. Likewise, climate does not hang by the thread of the CRU [the Climate Research Unit of the University of East Anglia in Great Britain] or a hockey stick [a well-known graph reconstructing worldwide temperatures over the last millennium which has been criticized by climate contrarians]." On page 173, Alley adds: "Because we don't know which scenario will actually end up being closest to correct, climate scientists cannot predict the future; instead, science must project what will happen if humans follow a particular path, and try to provide projections for enough different paths to allow wise choices."

### **TITLEY AND THE PENTAGON THINK THE FACTS ARE IN.**

*Admiral Titley:*


*...climate change is happening, and there is very, very strong evidence that a large part of this is, in fact, man-made.*



## Chapter 3

# Toward a Sustainable Future

*Soldiers at Fort Irwin consult a map and discuss tactics: armored vehicles patrol "Iraqi" streets during the war games:*

 In the first part of this section you'll see how the Army and Marines are working hard to cut back on fossil fuels. This is a Pentagon-wide initiative, but in some ways the Marines are out ahead. (Semper Fi) [Here's](#) the background to the USMC specifics coming up in the next few pages.

"Marines are modern-day Spartans—our ethos demands that we change the way we think about energy as we train, equip, and lead our expeditionary force.

Marines in Afghanistan use about 200,000 gallons of fuel a day to power our warfighting capabilities and sustain our forces. While we have proven lethal fighting in rugged environments for nearly a decade now, we've dramatically increased our energy consumption. Because of our thirst for liquid fuel, we're not as light and agile as we once were, putting both our Marines and our expeditionary capabilities at risk. The Marine Corps Expeditionary Energy Strategy, spanning Bases to Battlefield, centers on changing the way we think about energy—that our warrior ethos equates the efficient use of energy and water resources with increased combat effectiveness.

Our priority is to save lives by reducing the number of Marines at risk on the road hauling fuel and water. Our objective is to allow Marines to travel lighter, with less, and move faster by reducing the size and amount of equipment and dependence of bulk supplies. The key elements for success are to aggressively pursue innovative solutions to reduce energy demand in our platforms and systems, to increase our self-sufficiency in our sustainment, and to reduce our expeditionary footprint on the battlefield.

...To this end, by 2025 we will reduce by 50 percent our battlefield requirement for energy. By 2020 fifty percent of our bases and stations will be net-zero energy consumers."


### **THE MILITARY IS AMERICA'S SINGLE LARGEST USER OF ENERGY ...AND IT RECOGNIZES THAT ITS USE OF FOSSIL FUELS HAS TO CHANGE.**

 A Reuters article on attempts by the military to reduce its energy use can be found [here](#).

On page 20, the 2010 QDR states that "[c]limate change and energy will play significant roles in the future security environment. The Department is developing policies and plans

to manage the effects of climate change on its operating environment, missions, and facilities. The Department already performs environmental stewardship at hundreds of DoD installations throughout the United States, working to meet resource efficiency and sustainability goals. We must continue incorporating geostrategic and operational energy considerations into force planning, requirements development, and acquisition processes.”

### **THE PENTAGON USES 300,000 BARRELS OF OIL EACH DAY. THAT'S MORE THAN 12 MILLION GALLONS.**


 An article “Greenery on the March,” published in *The Economist* magazine on December 10, 2009, considered the situation of the United States military and asked, “What has changed? During the invasion of Iraq in 2003, America’s marines often found themselves outrunning their fuel supplies. ‘Unleash us from the tether of fuel,’ their then commander in Iraq, General James Mattis, later pleaded. (See this website’s [web exclusive video](#) by that name on our homepage (video #5 in the player). And in 2008 the spike in oil prices played havoc with military budgets: the Pentagon’s fuel bill rose from \$13 billion in 2007 to about \$20 billion. ‘So it is not a question of preventing climate change, reducing dependence on imported oil, or even complying with President Barack Obama’s green agenda. The need for alternative sources of energy is a military necessity.’”

*Scenes of American military vehicles on dusty roads:*

**AN ARMORED HUMVEE GETS 4 MILES TO THE GALLON.**

**AT FULL SPEED, AN ABRAMS BATTLE TANK USES FOUR GALLONS TO THE MILE.**

**AND IT CAN COST AS MUCH AS 400 DOLLARS A GALLON TO GET GAS TO SOME REMOTE BASES IN AFGHANISTAN.**

 In an interview with National Public Radio in 2010, retired U.S. Army Brigadier General [Steve Anderson](#) stated that “a gallon of gas might costs \$2.75 here in the United States, and that—and it’s purchased as such by the Defense’s energy supply center out of Fort Belvoir. But by the time you deliver it over those mountainous goat trails in Afghanistan, it can be as high as \$200, \$300, even \$400 a gallon. And when you understand those kinds of costs, then you realize, well, doggone it, we’ve got to do something about that. We’ve got to, you know, reduce our energy requirements.” An interview with General Anderson will be available in the interview section of this website after April 22.

*Soldiers at Fort Irwin unfold flexible solar panels:*

**FORT IRWIN IS A TEST BED TO SEE IF THE ARMY CAN OPERATE JUST AS EFFECTIVELY WHILE USING LESS FOSSIL FUEL, AND MORE RENEWABLES.**

*Wind and solar installations beside one of Fort Irwin's "foam domes":*

### AND IT'S NOT JUST FORT IRWIN AND THE ARMY.

*Shock cut to a squad of marines jogging down the road, chanting "Mama, Mama, can't you see/What the Corps has done to me..."*

### AT CAMP PENDLETON, MARINES WERE TRAINED ON AN ENERGY-SAVING "EXPERIMENTAL FORWARD OPERATING BASE" THAT DEPLOYED WITH THEM TO AFGHANISTAN.

*Other marines move forward to begin training on solar panels. Brigadier General Robert Hedelund, Commander, Marine Corps Warfighting Lab:*

*Before any equipment goes into theater, we want marines to get trained on it. So what are some of the things that we could take hold of right away and make sure that we can make a difference for the war-fighter down range?*

*Marines work with the solar panels:*

### THEY TEST OUT DIFFERENT KINDS OF PORTABLE SOLAR POWER UNITS.

*Pan over water, covered in green slime, and a marine throws in the plastic float of the water purification gear:*


### THEY ALSO PRACTICE HOW TO PURIFY STAGNANT WATER AND MAKE IT DRINKABLE.

*Off screen marine:*

*"It's good..."*


*Looking out the windshield of a jeep at Fort Irwin:*

### THE ARMY AND MARINES BOTH WANT TO MINIMIZE THE NUMBER OF CONVOYS TRUCKING IN FUEL AND WATER.

 A 2010 Marine Corps [report](#) from the corps' base at Quantico, Virginia describes the importance of the new Experimental Forward Operating Base (ExFOB) as follows: "With the ExFOB, we are working to reduce the logistic needs of the warfighter," said Brig. Gen. Robert Hedelund, the Marine Corp Warfighting Lab commander who is heading the experiment. "Aside from the ecological and cost benefits, we want units to be more efficient through reduced consumption," he said... "The commandant (former Marine Corps Commandant James T. Conway) feels strongly about this," said Hedelund. "If we could lighten the load of these Marines and decrease the power and water needs of their forward operating bases, we'd cut down on the requirement for resupply. Fewer resupply convoys means we get Marines off the road, keeping them safer," he explained.

*An explosion in Iraq sends a column of brown smoke high up into the sky:*

**A REPORT FOR THE ARMY FOUND THAT IN 5 YEARS MORE THAN 3,000 SERVICE-MEMBERS HAD BEEN KILLED OR WOUNDED IN SUPPLY CONVOYS.**

 On page 196 of *EARTH: The Operators' Manual*, Richard Alley notes that “[d]ata from a report prepared for the U.S. Army from the years 2003 to 2007 show the high human cost, with 188 resupply convoy casualties (killed or wounded) in Afghanistan and 2858 in Iraq. Because about half the load of those convoys was fuel, gains in energy efficiency or alternate-energy generation in the field would translate directly into lives saved.”

*B/G Hedelund:*

*And if you've got marines guarding that convoy, and, God forbid it get hit by an IED, then what are the wounded, what are the deaths involved in that, and really, are we really utilizing those Marines and that capability the way we should.*

*Soldiers type on laptops inside an air-conditioned tent, full of radios and communications equipment:*

**GENERATORS USED TO KEEP ACCOMMODATIONS LIVABLE AND COMPUTERS RUNNING ARE ALSO MAJOR GAS-GUZZLERS.**


*Marines carry over and begin to erect the Power Shade energy efficient tent. Captain Adorjan Ferenczy, Engineer Officer, Marine Corps Warfighting Lab:*

*Right now what we are doing is putting up a Power Shade. It has flexible solar panels on the top, and gives us enough power to run small electronics such as lighting systems and laptop computers. It also provides shade over the tent structure.*

*Experimenting with this equipment in Africa proved that it could reduce the internal temperature of the tent 7-10 degrees...*

*A Marine peers into the dark interior, and we see white and blue LED lights:*

**ALL THE L.E.D. LIGHTS IN THE ENTIRE TENT USE JUST 91 WATTS, LESS THAN ONE SINGLE, OLD-FASHIONED INCANDESCENT BULB.**

 Pages 295-297 of *EARTH: The Operators' Manual* give a complete description of the processes that allow LED bulbs to produce light. The main advantage of LEDs over traditional incandescent bulbs lies in the fact that incandescent lights must heat their filaments to high temperatures, producing more heat than light, whereas LEDs work at room temperatures.



*Capt Ferenczy:*

*It's a no-brainer when it comes to efficiency.*

*A marine holds an LED light-set and lets it drop to the floor:*

**LIGHT EMITTING DIODES DON'T WEIGH MUCH, BUT THEY'RE STILL RUGGED ENOUGH TO SURVIVE A TYPICAL MARINE'S GENTLE TOUCH!**

*Zach Lyman, Civilian contractor, ZeroBase Energy:*

*When we put something into a military application and they beat it up, it's ruggedized. It's ready for the worst that the world can take.*

*And so, uh, one thing that people say is if, you know, if the military has used this thing and they trust it, then maybe it's OK for my backyard.*

*U.S. Navy ships at sea:*

**RENEWABLE ENERGY WILL ALSO PLAY AN IMPORTANT ROLE AT SEA, AND IN THE AIR.**


*Helicopters land on the deck of the USS Makin Island:*

**THE NAVY'S "MAKIN ISLAND" IS AN AMPHIBIOUS ASSAULT SHIP WITH JUMP JETS, HELICOPTERS AND LANDING CRAFT.**

**IT'S THE FIRST VESSEL TO HAVE BOTH GAS TURBINES AND A HYBRID ELECTRIC DRIVE, WHICH IT CAN USE FOR SEVENTY FIVE PER CENT OF ITS TIME AT SEA.**

*Close-ups of the control screens of the Makin Island, high-tech and looking complex, and sailors on the bridge:*

**THIS "PRIUS OF THE OCEAN" CUT FUEL COSTS BY 2 MILLION DOLLARS ON ITS MAIDEN VOYAGE.**


 A National Public Radio [interview](#) with retired U.S. Army Brigadier General Steve Anderson and Secretary of the Navy Roy Mabus quoted Secretary of the Navy Roy Mabus as stating that "on its maiden voyage from Pascagoula, Mississippi, around to its home port in San Diego, around South America, [the Makin Island] saved almost \$2 million in fuel cost with that hybrid drive." The home page for the USS Makin Island can be found [here](#).



**BY 2016 THE NAVY PLANS TO HAVE WHAT IT CALLS A “GREAT GREEN FLEET”, A COMPLETE CARRIER GROUP RUNNING ON RENEWABLE FUELS, WITH NUCLEAR SHIPS... HYBRID-ELECTRIC SURFACE VESSELS...**

*Marine Corps Green Hornet jet in flight:*


**...AND AIRCRAFT FLYING ONLY BIOFUELS.**


 In an [interview](#) for this documentary, Admiral Titley said that “the byproduct of a Navy that is looking for increased tactical flexibility and [improving] energy efficiency, is by reducing our carbon footprint, we frankly provide leadership to the country... We’re not going to go live in caves ...The United States Navy will do our mission. But if we can do our mission at a significantly reduced carbon footprint, I believe that we can help show the way for the country on how to have our quality of life that we have all grown up for, and frankly expect and demand, but by doing that with a lower carbon footprint.”

**BY 2020, THE GOAL IS TO CUT USAGE OF FOSSIL FUELS BY 50%.**

*Stills of the Ex-FOB seen at Camp Pendleton, is actual use in Helmand Province, Afghanistan:*

**ONCE DEPLOYED IN AFGHANISTAN, THE EX-FOB CUT DOWN ON GAS USED IN GENERATORS BY OVER 80%.**


 Another Marine Corps news [article](#) about the deployment of the ExFOB in Afghanistan states that “[t]he Marines and sailors of Dark Horse 3/5 have been using an array of solar equipment since their pre-deployment workup, (code named) Enhanced Mohave Viper, at Marine Corps Air Ground Combat Center, in Twenty Nine Palms, Calif., in July. The Marines were able to save up to eight gallons of fuel, per generator, a day... ‘Our generators typically use more than 20 gallons of fuel a day. We are down to 2.5 gallons a day,’ said Doty, 3rd Squad Leader, with 1st Platoon, ‘I’ Company, and Fulton, Mo., native. ‘The system works amazing. By saving fuel for generators, it has cut back on the number of convoys, meaning less opportunity for one of our vehicles to hit an IED.’”

 In his Op-Ed article “[The U.S.S. Prius](#),” published in The New York Times on December 18, 2010, Thomas Friedman wrote that “the thing I love most about America is that there’s always somebody here who doesn’t get the word—and they go out and do the right thing or invent the new thing, no matter what’s going on politically or economically... Spearheaded by Ray Mabus, President Obama’s secretary of the Navy and the former U.S. ambassador to Saudi Arabia, the Navy and Marines are building a strategy for ‘out-greening’ Al Qaeda, ‘out-greening’ the Taliban and ‘out-greening’ the world’s petro-dictators. ...Mabus’s argument is that if the U.S. Navy and Marines could replace those generators with renewable power and more energy efficient buildings, and run its ships on nuclear energy, biofuels and hybrid engines, and fly its jets with bio-fuels, then it

could out-green the Taliban—the best way to avoid a roadside bomb is to not have vehicles on the roads—and out-green all the petro-dictators now telling the world what to do.... I don't know what the final outcome in Iraq or Afghanistan will be, but if we come out of these two wars with a Pentagon-led green revolution, I know they won't be a total loss. Wars that were driven partly by our oil addiction end up forcing us to break our oil addiction? Wouldn't that be interesting? ...That could save lives, money and the planet, and might even help us win—or avoid—the next war. Go Navy!"

*Training scenes, with both soldiers and marines using renewables:*


### **IN THE PAST, THE PENTAGON'S INNOVATIONS IN COMPUTERS, GPS AND RADAR HAVE SPUN-OFF INTO CIVILIAN LIFE.**

 The Federal Reserve Bank of Dallas has a list of important spin-offs from military innovations [here](#).

### **IN THE FUTURE, THE MILITARY'S USE OF RENEWABLE ENERGY CAN REDUCE DEPENDENCE ON FOREIGN OIL, INCREASE OPERATIONAL SECURITY, AND SAVE LIVES AND MONEY.**

*Colonel Jim Chevallier, Commander U.S. Army Garrison and National Training Center, Fort Irwin, CA:*

*A lot of the times it is a culture change more than anything else. And the Department of Defense over the years has proved, time and time again, that it can lead the way in that culture change.*

 While the Army and Marines focus on the dangers of convoys of fuel trucks supporting remote operating bases, some see the lines of oil tankers snaking across the globe bringing oil to the United States as similarly dangerous to the homeland. Presidents from Nixon in the 1970s to Obama in March 2011 have urged policies to reduce this dependence on foreign oil. Blogger [Andy Revkin](#) of *The New York Times* has heard the talk before, and is anxious to see actions not words.

President Obama: "We've known about the dangers of our oil dependence for decades. Presidents and politicians of every stripe have promised energy independence, but that promise has so far gone unmet. I've pledged to reduce America's dependence on oil too, and I'm proud of the historic progress we've made over the last two years towards that goal. But we've also run into the same political gridlock and inertia that's held us back for decades. That has to change. We cannot keep going from shock to trance on the issue of energy security, rushing to propose action when gas prices rise, then hitting the snooze button when they fall again. The United States of America cannot afford to bet our long-term prosperity and security on a resource that will eventually run out. Not anymore. Not when the cost to our economy, our country, and our planet is so high. Not when your generation needs us to get this right."


And in the ETOM book, on p. 196, Richard Alley writes “These national-security issues arose for the United States during the Korean War as well. President Harry S. Truman’s Materials Policy Commission examined shortages of strategic materials caused by the war, and recommended avoiding dependence on imported oil, especially from the volatile Middle East, through development of alternatives—solar energy, and also synthetic fuels.

Note 22 for this chapter shows that this was a 1952 report—almost 50 years now to get essentially the same message. (The material on p. 196 goes on to quote a scholarly paper that credits an oil-industry-related group for convincing Eisenhower not to listen to act on the recommendations of the 1952 report.)

### IF THE U.S. MILITARY IS THE LARGEST USER OF ENERGY IN AMERICA...

*Earth zoom to China, and cut to busy traffic on a street in Xi’an:*

### CHINA IS NOW THE LARGEST CONSUMER ON THE PLANET.

 According to the *BP Statistical Review of World Energy* (June 2010), [PDF](#), China (including Hong Kong) edged ahead of the United States in energy use in 2009.

### AT 1.3 BILLION, CHINA HAS A POPULATION ABOUT 4 TIMES LARGER THAN THE U.S., SO AVERAGE PER PERSON USE AND CO<sub>2</sub> EMISSIONS REMAIN ABOUT ONE QUARTER THOSE OF AMERICANS.

*Scenes showing, and on board, the Shanghai MagLev train speeding from the airport towards downtown:*

### BUT LIKE THE U.S. MILITARY, CHINA IS MOVING AHEAD, FULL SPEED, ON MULTIPLE, DIFFERENT SUSTAINABLE ENERGY OPTIONS.

### AND IT PRETTY MUCH HAS TO: CITIES ARE CONGESTED. THE AIR IS POLLUTED.

### CONTINUED RAPID GROWTH USING OLD TECHNOLOGIES SEEMS UNSUSTAINABLE.

*Scenes of participants being lined up for a group photograph at JUCCE’s training workshop for Mayors in the ballroom of a luxury hotel in Beijing:*

### THIS MEETING IN BEIJING BROUGHT TOGETHER MAYORS FROM ALL OVER CHINA, EXECUTIVES FROM STATE-OWNED ENTERPRISES, AND INTERNATIONAL REPRESENTATIVES.

*Peggy Liu, Chairperson, JUCCE, Joint US-China Collaboration on Clean Energy at the podium:*

### THE ORGANIZER WAS A U.S.-CHINESE N.G.O., HEADED BY PEGGY LIU.

*Peggy VO city scenes, and also see her [interview](#) elsewhere on this site:*


*...over 20 years, we're going to have 350 million people moving into cities in China, and we're going to be building 50,000 new skyscrapers, the equivalent of ten Manhattans, 170 new mass transit systems, I mean it's just an incredible, incredible scale.*

*Crowds stroll along the Bund, in downtown Shanghai:*

**THIS MASSIVE, RAPID GROWTH COMES WITH A HIGH ENVIRONMENTAL COST.**


*Martin Schoenbauer, Executive Director, U.S. Department of Energy, Beijing office, and also see his [interview](#) elsewhere on this site:*

*They're recognizing that they're spending as much as six percent of their gross domestic product on environmental issues...*

 In an [interview](#) for this documentary, Marty Schoenbauer noted that “[i]n the U.S. when we identify new technology, we’ll typically prove that in a laboratory in a small scale, and then we’ll engineer and raise it up to a larger full-scale deployment. In China a lot of times what they’ll do is, they’re willing to take the risk to build full-scale plant as a first step, and so it’s much more risky but the payoffs are much greater. And so it’s kind of like a baseball player swinging for a home run instead of a single. When they hit that home run, the payoff is much greater, but they lose some in the way. Most other countries aren’t willing to invest that amount of money to go large-scale first, where they are here. So that’s an advantage. And so all countries actually can learn from China in that they quickly scale up. And so collaboration with China in that regard benefits the world, because it more quickly gets to large-scale deployment and you better understand the nuances associated with large scale versus laboratory scale.”

*An old man on tricycle cart rides in front of a large billboard for “...Ecological, Low-carbon living...” and scenes inside the research labs of Xi’an’s Thermal Power Research Institute:*

**IN 2009 CHINA COMMITTED 35 BILLION DOLLARS, ALMOST TWICE AS MUCH AS THE U.S., TO ENERGY RESEARCH AND INCENTIVES FOR WIND, SOLAR, AND OTHER CLEAN ENERGY TECHNOLOGIES.**

 In a website [news release](#) on March 24, 2010, the Pew Charitable Trusts noted that “For the first time, China led the United States and other G-20 members in 2009 clean energy investments and finance ...Last year, China invested \$34.6 billion in the clean energy economy—nearly double the United States’ total of \$18.6 billion. Over the last five




years, the United States also trailed five G-20 members (Turkey, Brazil, China, the United Kingdom, and Italy) in the rate of clean energy investment growth." And, in an [update](#) in March, 2011, the US had dropped to third, behind China (\$54.4 billion) and Germany (\$41.2 billion) (versus \$34 billion in the U.S.).

*Entrance to the Applied Materials research facility, in Xi'an:*

### **IT'S ATTRACTED AN AMERICAN COMPANY TO SET UP THE WORLD'S MOST ADVANCED SOLAR POWER RESEARCH PLANT.**

### **CHINA NOW MAKES MORE SOLAR PANELS THAN ANY OTHER NATION.**

 An article published in *The New York Times* on January 14, 2011, "[Solar Panel Maker Moves Work to China](#)", notes that "Chinese solar panel manufacturers accounted for slightly over half the world's production last year. Their share of the American market has grown nearly six-fold in the last two years, to 23 percent in 2010 and is still rising fast, according to GTM Research, a renewable energy market analysis firm in Cambridge, Mass." Uncertainties about the manufacturing costs of producing solar panels hinges on the issue of governmental subsidies, which are often not fully reported. The article states that "[t]he Obama administration has been investigating whether China has violated the free trade rules of the [World Trade Organization](#) with its extensive subsidies to the manufacturers of solar panels and other clean energy products," and describes the fact that Evergreen Solar, the third-largest maker of solar panels in the United States, is closing its factory in Devens, MA and moving to China, where the company "with help from its partners—the Wuhan municipal government and the Hubei provincial government—borrowed two-thirds of the cost of its Wuhan factory from two Chinese banks, at an interest rate that under certain conditions could go as low as 4.8 percent ... Best of all, no principal payments or interest payments will be due until the end of the loan in 2015. By contrast, a \$21 million grant from Massachusetts covered 5 percent of the cost of the Devens factory, and the company had to borrow the rest from banks ... Banks in the United States were reluctant to provide the rest of the money even at double-digit interest rates, partly because of the financial crisis. 'Therein lies the hidden advantage of being in China,' Mr. El-Hillow [the chief executive of Evergreen] said."

### **BUT IT'S ALSO PROMOTING LOW-TECH, LOW-COST SOLUTIONS. SOLAR WATER HEATERS ARE SEEN ON MODEST VILLAGE HOMES. SOME CITIES HAVE THEM ON ALMOST EVERY ROOF.**


*Peggy Liu:*


*China is throwing spaghetti on the wall right now, in terms of over 27 different cities doing LED street lighting, or over 20, 30 different cities doing electrical vehicles...*



*Smoke and steam pour out of giant chimneys at coal-powered generating stations: sunrise over a polluted city rooftop with characteristic Chinese ridge tiles.*

**BUT VISIT ANY CITY AND YOU CAN SEE THAT THE COAL USED TO GENERATE MORE THAN 70% OF CHINA'S ELECTRICITY HAS SERIOUS CONSEQUENCES WITH VISIBLE POLLUTION, AND ADVERSE HEALTH EFFECTS.**

 The graph at [this](#) website shows that in 2009 China used coal to generate approximately 2750 TWh out of a total of 3500 TWh, or 78.6%, of its electricity output. A Reuters news agency [story](#) on August 29, 2010 states that “[a] report released by Greenpeace and the China Disease Control Center said huge rates of coal consumption were a factor behind an increase in cancer and birth defects as well as non-specific and chronic nervous, immune and respiratory illnesses.”

 Evan Osnos's article in *The New Yorker*, “[Green Giant: Beijing's Crash Program for Clean Energy](#),” published on December 21, 2009, reports that:

“A China born again green can be hard to imagine, especially for people who live here. After four years in Beijing, I've learned how to gauge the pollution before I open the curtains; by dawn on the smoggiest days, the lungs ache. The city government does not dwell on the details; its daily air-quality measurement does not even tally the tiniest particles of pollution, which are the most damaging to the respiratory system.”

**CHINA USES MORE COAL THAN ANY OTHER NATION ON EARTH.**

 The [website](#) of the Pew Center on Global Climate Change states that “China's coal output increased from 1.3 billion tons in 2000 to 2.23 billion tons in 2005, making China by far the world's largest coal producer (next largest is the U.S. with 1.13 billion tons produced in 2005). About half of China's coal use is for electricity; and 80% of electricity generation is fueled by coal.” In 2009, according to the *BP Statistical Review of World Energy (June 2010)*, [PDF](#), China used three times more coal than the United States.


**BUT IT'S ALSO TRYING TO FIND WAYS TO BURN COAL MORE CLEANLY.**


*Scenes in the high-tech laboratories of the Thermal Power Research Institute, in Xi'an:*

*Peggy Liu:*


*In three years, 2006 to 2009, while China was building one new coal-fired power plant, a week, it also shut down inefficient coal plants. So, you know, it's out with the old, and in with the new. And they're really trying hard to invent new models.*

***Scenes of the pilot Carbon Capture and Sequestration Plant at the China Huaneng Group's Shidongkou #2 power station, outside Shanghai:***


 In his article “*Dirty Coal, Clean Future*,” published in *The Atlantic* in December 2010, James Fallows wrote that “[i]n the search for ‘progress on coal,’ like other forms of energy research and development, China is now the Google, the Intel, the General Motors and Ford of their heyday—the place where the doing occurs, and thus the learning by doing as well.... ‘You can think of China as a huge laboratory for deploying technology,’ the (U.S. government) official added. ‘The energy demand is going like this’—his hand mimicked an airplane taking off—‘and they need to build new capacity all the time. They can go from concept to deployment in half the time we can, sometimes a third. We have some advanced ideas. They have the capability to deploy it very quickly. That is where the partnership works.’”

 Evan Osnos’s article cited above, states that “[i]n 2006, Chinese leaders redoubled their commitment to new energy technology; they boosted funding for research and set targets for installing wind turbines, solar panels, hydroelectric dams, and other renewable sources of energy that were higher than goals in the United States. China doubled its wind-power capacity that year, then doubled it again the next year, and the year after. The country had virtually no solar industry in 2003; five years later, it was manufacturing more solar cells than any other country, winning customers from foreign companies that had invented the technology in the first place. As President Hu Jintao, a political heir of Deng Xiaoping, put it in October of this year, China must “seize pre-emptive opportunities in the new round of the global energy revolution.”

**THIS PILOT PLANT, DESIGNED FOR “CARBON CAPTURE AND SEQUESTRATION,” WAS RUSHED TO COMPLETION IN TIME FOR SHANGHAI’S 2010 WORLD EXPO.**

 The 2010 Shanghai exposition used the slogan “Better City, Better Life” to emphasize its focus on renewable energy technology. A report on the exposition in *The New York Times* can be read [here](#).


**IT ABSORBS AND SELLS CARBON DIOXIDE, AND WILL SOON SCALE UP TO CAPTURE THREE MILLION TONS A YEAR, THAT COULD BE PUMPED BACK INTO THE GROUND, KEEPING IT OUT OF THE AIR.**

 On pages 285-290 of *EARTH: The Operators’ Manual*, Richard Alley discusses the challenges of carbon capture and “sequestration”—securing the carbon, or carbon dioxide, in a safe place. He summarizes the difficulty of this task by noting that “[u]nfortunately, while a little CO<sub>2</sub> is easy to put down, sequestering a lot may prove harder. The expected CO<sub>2</sub> production from the United States over the next fifty years would cover the entire country in a liquid- CO<sub>2</sub> layer 2 inches (5 cm) thick. Doing the

equivalent of raising the country 2 inches, sticking CO<sub>2</sub> underneath, and not having leaks, is a very challenging problem. Very much leakage would defeat the effort. And leakage can be dangerous. Although CO<sub>2</sub> is normally mixed rapidly through the atmosphere and doesn't build up much near the main sources, a really big CO<sub>2</sub> leak or very unfavorable still-air conditions can produce dangerous concentrations. In 1986, a catastrophic natural release of volcanic CO<sub>2</sub> and perhaps other gases stored in the deep waters of Lake Nyos, Cameroon, killed over 1700 people."

**Marty Schoenbauer:**

***Here in China they are bringing many plants on the line in a much shorter time span that it takes us in the US.***

 In an [interview](#) for this documentary, Marty Schoenbauer stated that "both of our countries have set high goals to use renewable energies, to offset the need to produce new coal plants. I've only been in China a little over a year: when I first arrived, China's producing a new coal plant ...every week. Today they're bringing a new coal plant online about every week and a half. So it's a substantial change if you think about it, but it's still a lot of coal plants. Because they have a wide resource of coal, and coal is essentially cheap to use. But there are effects that come from using coal. It affects the environment. There are other costs. There's the CO<sub>2</sub> emissions and other emissions that result, uh, have a harmful effect. And so China recognizes that."


**Peggy Liu:**

***China is right now the factory of the world. What we'd like to do is turn it into the clean tech laboratory of the world.***


***Flags outside Shidongkou #2: the Chinese and the Huaneng Electric Group's banners:***

 In an [interview](#) for this documentary, Peggy Liu reached back to one of China's great gift to the world—noodles—for an analogy: "China is throwing spaghetti on the wall right now... once they get that model they are going to replicate it... You're going to see experiments and pilots succeed faster in China, out with the old and in with the new... they are really trying hard to invent new models."

**IF NATIONS CHOOSE TO PAY THE PRICE, BURNING COAL WITH CARBON CAPTURE CAN OFFER THE WORLD A TEMPORARY BRIDGE UNTIL RENEWABLES COME TO SCALE.**

 The United States Department of Energy's report [Clean Coal Technology & The Clean Coal Power Initiative](#), describes the initiative's progress in "providing government

co-financing for new coal technologies that can help utilities cut sulfur, nitrogen and mercury pollutants from power plants. Also, some of the early projects are showing ways to reduce greenhouse emissions by boosting the efficiency by which coal plants convert coal to electricity or other energy forms."

 The International Energy Agency's IEA Clean Coal Centre, which describes itself as the "world's foremost provider of information on the clean and efficient use of coal worldwide, particularly clean coal technologies, in a balanced and objective way, without political or commercial bias," has a useful data base entitled "Coal Online."


*Visitors to the renewable energy section of China Pavilion at the Shanghai EXPO walk through displays of wind turbines and solar power: battery-powered buses are recharged by robots.*

*Peggy Liu:*

*China is going to come up with clean energy solutions that are cost effective and can be deployed at large scale. In other words, solutions that everybody around the world wants.*

*The camera flies west across the United States as night falls, and lights turn on (computer graphics based on NASA data):*

### **CAN LOW-CARBON SOLUTIONS REALLY GIVE US ENOUGH ENERGY TO POWER THE PLANET AND A GROWING POPULATION?**

 Section 3 of the ETOM book has chapters on all of the major renewable energy options, and is the source of the relative contributions of each to today's total energy use: see the table summarizing potential on page 225.

*Street scenes in New York City and São Paulo, Brazil:*

**LET'S PUT SOME NUMBERS ON HOW MUCH ENERGY WE CAN GET FROM NON-FOSSIL FUEL RENEWABLES...**

**TODAY, ALL HUMANS, EVERYWHERE ON EARTH, USE ABOUT 15.7 TERA-WATTS OF ENERGY... THAT'S A BIG NUMBER...**

*Computer graphics showing 15,700,000,000,000 appear on screen:*

**IN WATTS, THAT'S 157 FOLLOWED BY 11 ZEROS...**

**...OR 157 BILLION OF THOSE 100 WATT LIGHT BULBS WE USED AS A REFERENCE.**




*Bright Sun over a vast expanse of dunes:*

**TO SHOW WHAT'S POSSIBLE LET'S SEE IF WE CAN GET TO 15.7 TERAWATTS, USING ONLY RENEWABLE ENERGY.**

*Richard appears on the crest of a dune:*

**I'M HERE IN THE ALGODONES DUNES NEAR YUMA, ARIZONA. THE *GUINNESS BOOK OF RECORDS* SAYS IT'S THE SUNNIEST PLACE IN THE WORLD. THERE'S BARELY A CLOUD IN THE DAYTIME SKY FOR ROUGHLY 90% OF THE YEAR.**

 Although the Atacama Desert in northern Chile ranks as the driest place on Earth, with essentially no rainfall for years on end, it experiences a fair amount of fog from the nearby Pacific Ocean. Yuma apparently wins the "sunniest" title because of its cloudless skies on most days around the year, even though it does have an annual rainfall of about 3 inches.

*Richard kneels and draws "0.01%" in the sand:*

**0.01%... 1/100th of 1%. If we could collect that much of the Sun's energy reaching the Earth, it would be more than all human use today.**

*Camera tilts up to the Sun, and dissolves to the Sun's intensely bright reflection on a tower at Abengoa Solar's plant, called *Plataforma Solucar*, near Seville, Spain:*

**TODAY'S TECHNOLOGIES HAVE MADE A START...**


**THIS WAS THE WORLD'S FIRST COMMERCIAL POWER STATION TO USE A TOWER TO HARVEST CONCENTRATED SOLAR ENERGY.**

*Camera pans right over the sea of mirrors, reflected sunlight streaming upwards:*

**NEAR SEVILLE, SPAIN, 624 MIRRORS STRETCH OVER AN AREA OF MORE THAN 135 ACRES, BEAMING BACK SUNLIGHT TO A TOWER NEARLY 400 FEET HIGH.**

*Sunlight flares through steam:*

**INTENSE HEAT PRODUCES STEAM THAT DRIVES A TURBINE, WHICH GENERATES ELECTRICITY.**

 Although not using a tower, in 1911 inventor Frank Shuman was using solar thermal energy to power a steam engine in Philadelphia, and then developed a concentrated solar plant in Egypt, not too different from modern ones, that successfully pumped Nile water to irrigate crops, as described on p. 240 in the book.

**WHEN COMPLETED THIS ONE FACILITY WILL BE ABLE TO POWER TWO HUNDRED THOUSAND HOMES, ENOUGH TO SUPPLY THE ENTIRE NEARBY CITY OF SEVILLE.**

**REMEMBER OUR TARGET OF 15.7 TERA-WATTS?**

*Animated summary of the Sun's contribution in terawatts, and the percentage of today's human use appears as computer graphics:*

**WELL, THE SUN DELIVERS 173,000 TERA-WATTS TO THE TOP OF EARTH'S ATMOSPHERE... 11,000 TIMES CURRENT HUMAN USE.**


*Computer graphics zoom out from an overhead view of Richard in the US Southwest to orbit, and to see the Sun setting in the West:*

**NO WAY WE CAN CAPTURE ALL THAT POTENTIAL ENERGY AT EARTH'S SURFACE, BUT THE DESERTS OF AMERICA'S SOUTHWEST, WITH TODAY'S TECHNOLOGY, HAVE ENOUGH SUITABLE LAND TO SUPPLY 80% OF THE ENTIRE PLANET'S CURRENT USE.**

*Sunset over the dunes, and then sunrise over the rim of the planet:*

**OF COURSE, THERE'S ONE BIG PROBLEM WITH SOLAR POWER... NIGHT.**

**BUT WITH MORE EFFICIENT TRANSMISSION LINES, AND AS PART OF A BALANCED RENEWABLE ENERGY PORTFOLIO THAT INCLUDES STORAGE, THE SUN'S POTENTIAL IS VAST.**


 See p. 241 in the ETOM book, where Richard writes "...some of the heat can be stored in giant vats of molten salt or in other ways, and then extracted at night." And see a recent proposal to power all of Australia through only wind and solar, using similar storage techniques. (PDF).

*Shock cut to aerial view of Iguazu Falls, on the border of Argentina and Brazil:*

**IN TROPICAL NATIONS LIKE BRAZIL THE SUN HEATS WATER, MAKES CLOUDS AND UNLEASHES RAINFALL THAT FEEDS SOME OF THE PLANET'S LARGEST RIVERS.**

**IGUAÇU FALLS IS A TOURIST ATTRACTION, ONE OF THE MOST SPECTACULAR WATERFALLS ON EARTH, WHERE YOU CAN FEEL THE IMMENSE POWER OF FALLING WATER.**

**THE NEARBY ITAIPÚ DAM, ON THE BORDER OF BRAZIL AND PARAGUAY, PRODUCES THE MOST HYDROELECTRIC POWER OF ANY GENERATING STATION IN THE WORLD.**

 Additional video of the Itaipú dam (in Portuguese) including some pretty amazing construction shots, can be found [here](#). The United States Geological Survey describes this dam, noting that this [world's largest hydroelectric generating facility](#) produces 14 gigawatts of power. The [Three Gorges Dam](#) in China has a peak output greater than this, but the fluctuating seasonal flow of water on the Yangtze River leaves the Itaipú dam still the champion on an annual basis.

*Giant pylons and transmission lines lead away from the dam:*


**THIS ONE DAM SUPPLIES MOST OF THE ELECTRICITY USED IN SÃO PAULO, A CITY OF MORE THAN 11 MILLION.**

**SÃO PAULO IS 600 MILES AWAY, BUT BRAZIL MADE THE DECISION TO BUILD INNOVATIVE “HIGH VOLTAGE DIRECT CURRENT” TRANSMISSION LINES TO MINIMIZE ENERGY LOSS.**

 A description and discussion of high-voltage direct-current transmission lines can be found [here](#).


**THE ITAIPU TO SÃO PAULO ELECTRICAL GRID HAS BEEN IN OPERATION SINCE 1984, AND SHOWS THAT RENEWABLE ENERGY CAN GO THE DISTANCE.**

**DAMS CAN'T BE THE ANSWER FOR EVERY NATION. THEY FLOOD LANDSCAPES, DISRUPT ECOSYSTEMS, AND DISPLACE PEOPLE.**

 As discussed in chapter 18 of the ETOM book, use of dams in irrigation projects may grow in coming years to feed the growing population. Hydroelectric power can be generated from these dams, but the timing of when and how may increasingly be controlled by the irrigation requirements. “Dams, in short, are intrusive, bringing major benefits but major costs, and getting a lot of people excited. We do know how to live with them, and have done so for a long time. Despite the world having almost one million dams more than 50 feet (15 m) high, and capable of holding back about 15 percent of global annual river runoff, many more dams could be built, and some of them are being built. A lot of hydropower is available—not enough to solve all of human energy needs, but enough to smooth the swings of other renewable energy sources. However, as the world population grows, the time may come when we will be looking for other ways to smooth those swings, because food has first call on the water.” (p. 251)

**BUT HYDROPOWER GIVES BRAZIL—A NATION LARGER THAN THE CONTINENTAL UNITED STATES—80% OF ITS ELECTRICITY.**

*Animated summary of hydropower's potential contribution in terawatts, and the percentage of today's human use that would be, appears as computer graphics:*

 The U.S. Energy Information Administration's [report](#) on electricity in Brazil has a graph showing the changes in the mix of energy sources for Brazil's electricity since 1998.

**AND WORLD-WIDE, HYDRO-POWER COULD CONTRIBUTE 12% OF HUMAN ENERGY USE... READY AT A MOMENT'S NOTICE IN CASE THE SUN GOES BEHIND A CLOUD.**

*Lens flare as the camera zooms towards the Sun behind sugar cane leaves:*


**BRAZIL IS ALSO USING ITS UNIQUE NATURAL ENVIRONMENT IN ANOTHER WAY.**

**ITS TROPICAL CLIMATE PROVIDES IDEAL CONDITIONS FOR SUGAR CANE, ONE OF THE EARTH'S MOST EFFICIENT PLANTS IN ITS ABILITY TO COLLECT THE ENERGY OF SUNLIGHT.**


*Scenes at the Fazenda São João, São Paulo state, showing the growing, harvesting and refining of sugar cane:*

**PLANTATIONS LIKE THIS ONE, HARVEST THE CANE FOR THE PRODUCTION OF SUGAR AND THE BIOFUEL CALLED "ETHANOL."**

**THE U.S. IS ACTUALLY THE NUMBER ONE PRODUCER OF ETHANOL IN THE WORLD, MOSTLY USING CORN INSTEAD OF CANE.**

 A news release from the [Global Renewable Fuels Alliance](#) contains the forecast that worldwide ethanol production in 2010 would amount to 86 billion liters, of which the United States would produce 45 billion. Brazil produced 27.5 billion liters of ethanol during the [2008-2009 growing season](#). Between them, the United States and Brazil produce more than 80 percent of the world's ethanol.

**BUT ETHANOL MADE FROM SUGAR CANE IS SEVERAL TIMES MORE EFFICIENT AT REPLACING FOSSIL FUEL THAN CORN-BASED ETHANOL.**

 An April 2007 Special Report of the Brazil Institute entitled "The Global Dynamics of Biofuels" ([PDF](#)) states that "[f]uel from sugarcane produces 8.2 joules of energy per unit of fossil fuel input compared to less than 1 joule for diesel and gasoline. Fuel from corn produces approximately 1.5 joules of energy, making it far less efficient than sugarcane-based ethanol." According to these numbers, sugarcane ethanol outperforms corn ethanol by a factor of 5.5.



**MODERN FACILITIES LIKE THIS ONE PIPE BACK WET WASTE TO FERTILIZE THE FIELDS, AND BURN THE DRY WASTE, CALLED "BAGASSE", TO GENERATE ELECTRICITY TO RUN THE FACTORY.**

**FOR BRAZIL, AT LEAST, ETHANOL WORKS.**

*Cut to traffic on the streets of São Paulo, and scenes in a GM factory building Flex cars:*

**TODAY ALMOST ALL CARS SOLD IN BRAZIL CAN USE "FLEX FUELS."**

*Customers filling up at a Petrobras gas station, showing both ethanol and blended gasoline pumps:*

**DRIVERS CHOOSE GASOLINE BLENDED WITH 25% ETHANOL, OR PURE ETHANOL, DEPENDING ON PRICE AND HOW FAR THEY PLAN TO DRIVE.**


*Early morning traffic backs up on streets near downtown São Paulo:*

**LOCAL RESEARCHERS SAY THAT IF ALL THE GASOLINE IN THE WORLD SUDDENLY DISAPPEARED, BRAZIL IS THE ONLY NATION THAT COULD GO IT ALONE AND KEEP ITS CARS RUNNING.**

*Cane stalks are washed before processing, and close-ups of a technician checking the purity of a sample of ethanol:*

**USING FOOD FOR FUEL RAISES BIG QUESTIONS IN A HUNGRY WORLD.**

**AS OF NOW, SUGAR-CANE ETHANOL HASN'T AFFECTED FOOD PRICES MUCH, BUT THERE ARE CONCERNS WITH CORN.**

 (Donald Mitchell for the World Bank, July 2008, "A note on Rising Food Crisis" ([PDF](#)). Also, see [Organisation \(sic\) for Economic Co-operation and Development \(OECD\)](#), 2008, Biofuel Support Policies: An Economic Assessment: "the high level of policy support contributes little to reduced greenhouse-gas emissions and other policy objectives, while it adds to a range of factors that raise international prices for food commodities."


*Richard and NREL's Jim McMillan walk through an experimental biofuels facility at NREL, near Denver, Colorado:*

**SO HERE IN THE US, GOVERNMENT LABS, LIKE NREL, THE NATIONAL RENEWABLE ENERGY LAB, HAVE LAUNCHED PROGRAMS TO SEE IF BIOFUELS CAN BE MADE FROM AGRICULTURAL WASTE.**

## IT DOES WORK, AND RESEARCHERS ARE TRYING TO BRING THE COST DOWN.

*Animated summary of the potential contribution of biomass in terawatts, and the percentage of today's human use that would be, appears as computer graphics:*

## SO WITH PLANTS CAPTURING ROUGHLY 11 TIMES HUMAN ENERGY USE, THEY'RE A GROWING OPPORTUNITY.

 The Food and Agriculture Organization of the United Nations maintains a website that estimates that of the approximately  $6 \times 10^{24}$  joules of solar energy that reach the Earth's surface each year, plants and other photosynthetic organisms use about  $3 \times 10^{21}$  joules, or about one part in two thousand, of this energy, and that humans consume about  $3 \times 10^{20}$  joules per year, or approximately one-tenth of the amount that plants utilize to perform the photosynthesis that turns carbon dioxide and sunlight energy into sugars and other compounds.

*Computer graphics Earth zoom from orbit to approach the North Island of New Zealand:*


## NEW ZEALAND TAKES ADVANTAGE OF ANOTHER KIND OF ENERGY.

**THESE ARE THE GEYSERS AND HOT SPRINGS AT ROTORUA ON THE NORTH ISLAND. ONCE THEY WERE USED BY THE NATIVE MAORI PEOPLE FOR COOKING AND BATHING.**

*Mighty River Power's Kawerau Geothermal Power Station, New Zealand:*

## NOW GEOTHERMAL POWER PLANTS HARVEST HEAT AND TURN IT INTO AS MUCH AS 10% OF ALL NEW ZEALAND'S ELECTRICITY.

 The use of geothermal power in New Zealand is discussed [here](#). For a recent discussion on NIMBY ("not in my backyard") and BANANA ("build absolutely nothing anywhere near anybody") see the blog of the [Arizona state geologist](#).

 Page 271 of the ETOM book explains how you can "mine" geothermal energy instead of "harvesting" it: "Yellowstone has about half of the world's active geysers. New Zealand used to have more than are currently active, but development of geothermal plants to supply electricity has drained the pressurized hot water from some of them. Once this problem became evident, the country acted to preserve the remaining geysers for future generations of tourists while maintaining power generation. This problem of draining hot water from geysers is not unique to New Zealand, and geothermal development elsewhere, including in Nevada (near the former Beowawe geyser field), has been linked to geyser loss. One estimate has more than 250 geysers lost in the United States, Iceland, and New Zealand, primarily from use of geothermal power. But the technology to provide geothermal power while minimizing impacts on geysers also opens a much greater potential resource, as we will see soon."

**MANY POWER PROJECTS ARE PARTNERSHIPS WITH THE MAORI, BENEFITTING LOCAL PEOPLE AND AVOIDING THE “NOT IN MY BACKYARD” PROBLEMS THAT OFTEN COMPLICATE ENERGY DEVELOPMENTS.**

*Animated summary of geothermal’s potential contribution in terawatts, and the percentage of today’s human use that would amount to, appears as computer graphics:*


**GLOBALLY, GEOTHERMAL ENERGY OFFERS 3 TIMES OUR TOTAL CURRENT USE.**

**BUT, WE CAN MINE GEOTHERMAL UNSUSTAINABLY, EXTRACTING THE ENERGY FASTER THAN NATURE SUPPLIES IT, COOLING THE ROCKS DEEP BENEATH US TO MAKE POWER FOR PEOPLE.**

**THIS ENERGY EXISTS EVEN WHERE YOU DON’T SEE GEYSERS AND MUD POTS, SO IT CAN BE EXTRACTED WITHOUT HARMING THESE NATURAL WONDERS.**

*Computer graphic flyover the USA, from South to North:*

**A STUDY BY M.I.T. SHOWED THAT THE ACCESSIBLE HOT ROCKS BENEATH THE UNITED STATES CONTAIN ENOUGH ENERGY TO RUN THE COUNTRY FOR 130,000 YEARS.**

 The 2006 study by MIT scientists and engineers “The Future of Geothermal Energy” (PDF), presents data showing that “[b]y almost any criteria, the accessible U.S. EGS [enhanced geothermal systems] resource base is enormous—greater than 13 million quads or 130,000 times the current annual consumption of primary energy in the United States. Of course, the economically recoverable reserve for EGS will be much lower, subject to many technical and economic constraints that are evaluated throughout this report. However, the report also notes that ‘based on our technical and economic analysis, a reasonable investment in R&D and a proactive level of deployment in the next 10 years could make EGS a major player in supplying 10% of U.S. base-load electricity by 2050. Further, the analysis shows that the development of new EGS resources will not be limited by the size and location of the resource in the United States, and it will occur at a critical time when grid stabilization with both replacement and new base-load power will be needed. Adding the EGS option to the U.S. portfolio will reduce growth in natural gas consumption and slow the need for adding expensive natural gas facilities to handle imported liquefied natural gas.’”

**AND LIKE HYDROELECTRIC, GEOTHERMAL CAN PROVIDE “PEAKING POWER”, READY TO GO AT A MOMENT’S NOTICE IF THE SUN DOESN’T SHINE AND THE WIND DOESN’T BLOW.**


*Clouds of steam at Rotorua dissolve into timelapse clouds:*

**MINING ENERGY FROM DEEP, HOT ROCKS IS A RELATIVELY NEW TECHNOLOGY, BUT PEOPLE HAVE BEEN USING WINDMILLS FOR CENTURIES. AND THE WIND BLOWS EVERYWHERE.**

*NASA computer graphics showing wind patterns over the USA, and original animation based on NREL data indicating where the strongest winds can be found:*

**HERE'S WHERE THE UNITED STATES IS VERY LUCKY.**

**LET'S TAKE A TRIP UP THE NATION'S WIND CORRIDOR, FROM TEXAS IN THE SOUTH, TO THE CANADIAN BORDER.**


 For national and regional wind maps, check out the many resources of the [National Renewable Energy Laboratory's pages](#). For a businessman's assessment of wind energy and other resources, check out [T. Boone Pickens' Plan](#). Clearly you don't have to be a TreeHugger to think that renewable energy makes economic sense.

**BRIGHT PURPLE INDICATES THE STRONGEST WINDS.**

**ALL ALONG THIS NEARLY TWO THOUSAND MILES, THERE'S THE POTENTIAL TO TURN A FREE, NON-CO<sub>2</sub> EMITTING RESOURCE INTO ELECTRICITY.**

*Computer graphics show the location and number of turbines (each turbine shown stands for 10 turbines) in Nolan County, West Texas:*

**BUT THAT TAKES CHOICES AND ACTIONS BY INDIVIDUALS AND GOVERNMENTS.**

 Here's where to find information from [Texas](#) and [national wind energy advocacy groups and trade associations](#).

**HERE'S WHAT'S BEEN HAPPENING IN WEST TEXAS.**

**IT'S A LAND OF RANCHES AND FARMS AND, OF COURSE, OIL RIGS AND PUMPJACKS BUT IN THE EARLY 90'S THIS WAS ONE OF THE MOST FINANCIALLY DEPRESSED AREAS IN THE STATE.**

*Derelict gas station and abandoned school playground:*

**COMMUNITIES LIKE NOLAN DIVIDE FELL ON HARD TIMES. SCHOOLS CLOSED. PEOPLE MOVED AWAY.**




**BUT SINCE 1999, THE NEW STRUCTURES TOWERING ABOVE THE FLAT FIELDS AREN'T OIL DERRICKS, BUT WIND TURBINES.**

*Computer graphics show a correctly-scaled representation of where wind turbines can be found:*

**THE LARGEST NUMBER—MORE THAN 1,600—IS IN NOLAN COUNTY.**

**GREG WORTHAM IS MAYOR OF SWEETWATER, THE COUNTY SEAT.**

 A *New York Times* story, "[Move Over, Oil, There's Money in Texas Wind](#)", published on February 23, 2008, describes wind-power development in and around Sweetwater.

Plus, click [here](#) for Greg's full ETOM interview, with some blunt comments about non-Texans who want to appear green without embracing what it takes to develop sustainable energy at large scale.

*Driving interview with Mayor Wortham:*

*...it wasn't a philosophical or political decision. It was ranchers and farmers and truck drivers and welders, and railroads, you know, and wind workers.*

*Steers in front of wind turbines, and a turbine beside the entry to Steve Oatman's ranch (click [here](#) for Steve's full interview):*

**STEVE OATMAN'S FAMILY HAS BEEN RANCHING THE "DOUBLE HEART" FOR THREE GENERATIONS.**

**STEVE MAY HAVE DOUBTS ABOUT THE CAUSES OF CLIMATE CHANGE, BUT NOT ABOUT WIND ENERGY.**

*Steve Oatman*

*...but it's been a blessing. It helps pay taxes, it helps pay the feed bill.*

*Steve signs a check to pay for a delivery of liquid food, the brown stuff we see slurping into a container later in this scene:*

*Steve:*

*"Roscoe, 30 mix..."*

*Greg Wortham:*

*...we talk about this being "green energy" because it pays money. The ranchers and the farmers call it "mailbox money." They have to get up, sweat and work hard all day long...*

*Greg continues speaking over shots of Steve and others at work:*

*Things are pretty stressful. And if you can just walk to the mailbox and pick up some money because you've got turbines above the ground...*

*Greg, driving:*

*...you know, that makes life a lot easier.*

**EACH WINDMILL CAN GENERATE BETWEEN 5 AND 15 THOUSAND DOLLARS PER YEAR, SO A RANCH WITH AN AVERAGE OF 10 TO 20 TURBINES CAN PROVIDE FINANCIAL STABILITY FOR PEOPLE WHO HAVE ALWAYS LIVED WITH UNCERTAINTY.**

 A description of windmills in this part of Texas appears on the NPR website.

*Steve Oatman:*

*You know, I don't just believe in it because I make a living from it. It's something that's gonna have to happen for the country.*


*Sounds of a girls' volleyball team, and a township sign. Cut inside to a school gymnasium, game in progress:*

**SO NOW LOCAL SCHOOLS HAVE GROWING ENROLLMENTS, AND FUNDS TO PAY FOR PROGRAMS.**


*Greg Wortham:*

*We had about 500 million dollars in tax base in the whole county in 2000, and by the late part of that decade, in less than ten years, it went up to 2.5 billion dollars in tax value.*


**BY THE END OF 2009, THE CAPACITY OF WIND TURBINES IN WEST TEXAS TOTALED CLOSE TO 10,000 MEGAWATTS.**

 In an update, the [Texas Wind Energy Clearinghouse](#) reported that as of March 2010, the installed capacity of wind turbines in the state surpassed 10 gigawatts (10,000 megawatts).

**IF TEXAS WERE A COUNTRY, IT WOULD RANK SIXTH IN THE WORLD IN WIND POWER.**


 A story in *The Wall Street Journal* on April 13, 2009, “[Wind Power: Everything’s Bigger in Texas](#)”, stated (somewhat snarkily) that “[l]eading the charge is Texas, which widened its lead over states by installing almost 2,700 megawatts of wind power last year. Only two countries in the world installed that much wind in 2008. In fact, if Texas were a country—an idea never entirely out of fashion in the Lone Star state—it would rank 6th in the world in wind power capacity.”

**THE US DEPARTMENT OF ENERGY ESTIMATES THAT WIND COULD SUPPLY 20% OF AMERICA’S ELECTRICITY BY 2030.****NEW OFFSHORE WIND FARMS WOULD GENERATE MORE THAN 43,000 NEW JOBS.****THAT TRANSLATES INTO A 200 BILLION DOLLAR BOOST TO THE US ECONOMY.**

 The Department of Energy’s study “20% Wind Energy by 2030” can be found [here](#). In addition to the creation of jobs and the boost to the economy, the study notes that this level of wind power usage would reduce cumulative water use in the electric sector by 8% (4 trillion gallons). A news story in *USA Today* cites President Obama as estimating that 250,000 new jobs would be created.


*Animated summary of wind’s potential contribution in terawatts, and the percentage of today’s human use that would be, appears as computer graphics:*

**WORLDWIDE, WIND COULD PROVIDE ALMOST 80 TIMES CURRENT HUMAN USAGE!**

 A news report on the study on the energy potentially available from wind power that was made by researchers at Harvard University and the VTT Technical Research Centre of Finland, and was published in 2009 in the Proceedings of the National Academy of Sciences, can be found [here](#). The abstract of the study is available [here](#).

For an enthusiastic and prescient view of the potential of wind power, see the quotation from President Abraham Lincoln, found in the ETOM book on page 229-230


**ABRAHAM LINCOLN, AMERICA’S ONLY PRESIDENT TO HOLD A SCIENTIFIC PATENT WAS DEFINITELY AHEAD OF HIS TIME IN SEEING THE POTENTIAL OF WIND ENERGY. HERE’S HONEST ABE’S PREDICTION FOR ONE WAY TO EMANCIPATE OURSELVES FROM DEPENDENCE ON FOSSIL FUELS:**

 "Of all the forces of nature, I should think the wind contains the largest amount of motive power—that is, power to move things. Take any given space of the earth's surface—for instance, Illinois; and all the power exerted by all the men, and beasts, and running-water, and steam, over and upon it, shall not equal the one hundredth part of what is exerted by the blowing of the wind over and upon the same space. And yet it has not, so far in the world's history, become proportionably valuable as a motive power. It is applied extensively, and advantageously, to sail-vessels in navigation. Add to this a few windmills, and pumps, and you have about all. That, as yet, no very successful mode of controlling, and directing the wind, has been discovered; and that, naturally, it moves by fits and starts—now so gently as to scarcely stir a leaf, and now so roughly as to level a forest—doubtless have been the insurmountable difficulties. As yet, the wind is an untamed, and unharnessed force; and quite possibly one of the greatest discoveries hereafter to be made, will be the taming, and harnessing of it. That the difficulties of controlling this power are very great is quite evident by the fact that they have already been perceived, and struggled with more than three thousand years; for that power was applied to sail-vessels, at least as early as the time of the prophet Isaiah." From "Discoveries and Inventions: A Lecture by Abraham Lincoln Delivered in 1860", John Howell, 1915, San Francisco.

**NO FORM OF ENERGY IS TOTALLY FREE OF ENVIRONMENTAL CONCERNS, OR HEFTY START-UP COSTS.**

**SOME EARLY WIND FARMS GAVE LITTLE CONSIDERATION TO BIRDS AND OTHER FLYING CRITTERS, LIKE MIGRATING BATS.**

**BUT RECENT REPORTS BY GREENPEACE AND THE AUDUBON SOCIETY HAVE FOUND THAT PROPERLY-SITED AND OPERATED TURBINES CAN MINIMIZE PROBLEMS.**

 From page 236 in the ETOM book: "Bird and bat deaths do occur—at speeds that may exceed 200 miles per hour, the turbine-blade tips rival a stooping falcon and outrace almost any other flying creature. But bat deaths can be reduced by perhaps three-fourths if turbines are turned off on the few nights when most migrants are streaming through, with very minor effects on power production. One recent review article even suggested that building wind farms to replace fossil fuels may reduce bird deaths by avoiding the loss of habitat caused by strip-mining and other issues caused by strip-mining"

The reports above are cited in the Department of Energy Assessment of Offshore Wind Energy Resources for the United States ([PDF](#)). See also the online website for [Audubon Magazine](#) which discusses the dangers that windmills pose to wildlife. The [Greenpeace website](#) states that wind turbines cause fewer than one in every 10,000 bird deaths (and that cats are responsible for 10 percent of the total).



**MAYOR WORTHAM, FOR ONE, WELCOMES WIND TURBINES INTO *HIS* "BACKYARD."**

*Greg Wortham:*

*We like them. Some people don't. But we're more than happy to export our energy to those states who want to buy green but don't want to see green.*

*Steve Oatman:*

*In the long run? I hope we have wind turbines everywhere they can produce energy. We need them. That's what America gonna have to do. That's the next stepping-stone to save ourselves.*

*Wind turbines over trees and an electric sub-station: cut to busy loading and unloading scenes in the *Port of Houston*:*

**THE STATE OF TEXAS HAS INVESTED FIVE BILLION DOLLARS TO CONNECT WEST TEXAS WIND TO BIG CITIES LIKE DALLAS AND FORT WORTH.**

**FARTHER SOUTH IS HOUSTON, ONE OF THE MOST ENERGY-HUNGRY CITIES IN THE COUNTRY.**

**ITS PORT IS AMERICA'S LARGEST BY FOREIGN TONNAGE.**


 Data for United States ports can be found [here](#).

**AND ITS REFINERIES AND CHEMICAL PLANTS SUPPLY A GOOD PORTION OF THE NATION.**

**BUT ALREADY—PERHAPS SURPRISINGLY—HOUSTON IS THE LARGEST MUNICIPAL PURCHASER OF RENEWABLE ENERGY IN THE NATION.**

*Solar panels on the roof of City Hall Annex:*

**30% OF THE POWER CITY GOVERNMENT USES COMES FROM WIND, WITH A TARGET OF 50%.**

 The United States Environmental Protection Agency ranks Houston at the top of the list of United States cities in using "green power," with 34 percent of that city's power obtained from wind turbines, as of January 11, 2011.

**AND ITS MAYOR WANTS TO CUT ENERGY COSTS AND INCREASE ENERGY EFFICIENCY.**

*Mayor Annise Parker:*

*I want to go from the oil and gas capital of the world to the green and renewable energy capital of the world.*

*A skilled technician, working for CenterPoint Energy, goes from house to house, installing smart meters:*

**SUPPORTED BY FEDERAL STIMULUS DOLLARS, THE LOCAL UTILITY IS AHEAD OF SCHEDULE TO INSTALL "SMART METERS." THESE WILL HELP CONSUMERS ECONOMIZE ON ENERGY USE.**


*Montage of traffic lights in downtown Houston:*

**THE CITY HAS ALREADY INSTALLED 2,500 L.E.D. TRAFFIC LIGHTS, USING 85% LESS ENERGY THAN TRADITIONAL INCANDESCENT BULBS.**

**THAT TRANSLATES INTO SAVINGS OF \$3.6 MILLION DOLLARS PER YEAR.**

*From a clogged freeway cut to to one of the City of Houston's fleet of plug-in Priuses, driven by Sustainability Director, Laura Spanjian (see [Case Studies](#)).*

**CITY HALL THINKS IT CAN ALSO IMPROVE AIR QUALITY BY CHANGING THE KINDS OF CARS HOUSTONIANS DRIVE.**


 **LED** (Light Emitting Diodes) produce light when an electrical current causes electrons in a semiconductor to make sudden jumps. Unlike incandescent lamps, which emit light when an electrical current heats a tungsten filament to high temperatures, LEDs operate at low temperatures, which allows them to produce light more efficiently. In addition, the light from LEDs can be more easily beamed in a particular direction than the light produced by incandescents. The National Association of Home Builders has a web page describing LED lamps [here](#).

*Mayor Parker:*

*...if we're gonna be a car city, that's great, but those vehicles are going to be non-polluting electric vehicles.*

**THE CITY ALREADY OPERATES A FLEET OF PLUG-IN HYBRIDS.**

**NOW IT'S ENCOURAGING THE DEVELOPMENT OF AN INFRASTRUCTURE TO MAKE DRIVING ELECTRIC-VEHICLES EASY, AND PRACTICAL.**


 Click [here](#) for more on the City's plans, and its collaboration with NRG Energy to support e-vehicles: the goal is to have no place in Houston more than 5 miles from a charging station.

**AND IN HOUSTON'S HOT AND HUMID ENVIRONMENT, IT HELPS TO HAVE AN INCREASING NUMBER OF ENERGY EFFICIENT, "LEED"-CERTIFIED BUILDINGS.**

*Mayor Parker:*

*We're going to do it because it's the smart thing, because it makes business sense, and it's the right thing.*

**SOME ESTIMATES ARE THAT THE U.S. COULD SAVE AS MUCH AS 23% OF PROJECTED DEMAND FROM A MORE EFFICIENT USE OF ENERGY.**


 Conservation and efficiency savings for the U.S. (Unlocking energy efficiency in the U.S. economy, McKinsey and Company, July 2009) and [worldwide](#) (Pathways to a low-carbon economy, January 2009) are from studies by McKinsey and Company.

*Mayor Parker:*

*Well if you are gonna tackle energy efficiency, you might as well do it in a place that is a profligate user of energy. And when you make a difference there, you can make a difference that's significant.*

*Animated summary of the potential contribution of conservation and efficiency in terawatts, and the percentage of today's human use that would be, appears as computer graphics:*

**GLOBALLY, EFFICIENCY COULD CUT THE DEMAND FOR ENERGY BY ONE THIRD BY 2030.**

 Additionally, pages 8-10 of the Worldwatch Institute's report "Renewable Revolution: Low-Carbon Energy by 2030" ([PDF](#)), contain a discussion of the amount by which improvements in efficiency could reduce the demand for energy.


**BOTTOM LINE... THERE ARE MANY WAYS FORWARD, AND WE CAN HIT THAT RENEWABLE ENERGY TARGET.**

**AND IF NEXT GENERATION NUCLEAR IS ALSO INCLUDED, ONE PLAN HAS THE POSSIBLE 2030 ENERGY MIX TRANSFORMED, FROM ONE RELYING ON FOSSIL FUELS, TO ONE THAT LOOKS LIKE THIS...**


**...WITH ALL RENEWABLES... SUN... WIND... GEOTHERMAL... BIOMASS AND HYDROPOWER... TOTALING 61%**

**...FOSSIL FUELS DOWN TO 13%**


**...AND EXISTING AND NEW NUCLEAR MAKING UP THE BALANCE.**

 These numbers closely follow those projected by renewable energy entrepreneur (and MacArthur “genius”) Saul Griffith, as published in his [THE GAME PLAN](#). (See [Resources](#).) However, there is no doubt that major reconsideration of the role of nuclear energy is likely after the tragic earthquake, tsunami and associated disasters at the Fukushima reactors in Japan. See [here](#), for the latest press releases from the [National Nuclear Security Administration](#) of the U.S. Department of Energy.

*A strong wind blows dry grasses, clear water pours down a mountain stream, and Sun over desert sands:*

 The Wind-Water-Solar plan, by Mark Jacobson and Mark Delucchi is presented in a very neat [interactive presentation](#) from Scientific American and FlypMedia.com.

**ANOTHER PLAN MEETS WORLD ENERGY NEEDS WITH ONLY WIND... WATER... AND SOLAR.**

 Richard Alley also discusses the “wedges” approach to addressing the need for clean, feasible and sustainable energy on pages 220 and following in the ETOM book.

**AND, IN FACT, THERE ARE MANY FEASIBLE PATHS TO A SUSTAINABLE ENERGY FUTURE.**

*Pan over trees in a sustainable eucalyptus plantation in Brazil, solar power mirrors in Spain, the Applied Materials solar R&D plant in China, and an orbital view of Earth leads us to high on Mauna Kea, Hawaii:*



**TODAY'S TECHNOLOGIES CAN GET US STARTED... AND A COMMITMENT TO RESEARCH AND INNOVATION WILL BRING EVEN MORE POSSIBILITIES.**

*Richard to camera on top of Mauna Kea:*

*We've traveled the world to see some of the sources the planet offers to meet our growing need for clean energy. There's too many good options to cover all of them here, and besides each nation, each state, each person must make their own choices as to what works best for them.*

*But the central idea is clear. If we approach Earth as if we have an Operators' Manual that tells us how to keep the planet humming along at peak performance, we can do this.*

*We can avoid climate catastrophes, improve energy security, and make millions of good jobs.*

*For EARTH: The Operators' Manual, I'm Richard Alley.*

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