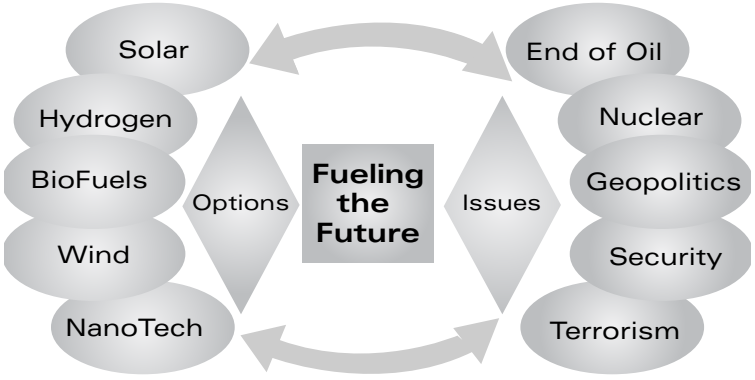
CHAPTER 2

Fueling the Future

A New Energy Age

Several years ago, a former Saudi oil minister issued what has since become an oft-quoted prophecy: "The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil." It was a lament, an acknowledgment that a day of reckoning was coming that would change the global balance of wealth and power. A fluke of geology had made the vast emptiness of the Saudi desert the number one source of the most important commodity on earth. But the good times would not, and could not, last forever, and he knew it.

If you go back far enough, you can trace the prosperity and security of nations, corporations, and even individuals to energy. And in our petroleum-dependent world, that, for the most



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THE TOP TEN EXTREME ENERGY TRENDS

1. We are running out of energy. New global demands from every nation will outpace supply within twenty-five years unless plentiful new sources are found. Less energy will be a drag on GDP.

2. Democracy is at risk. Energy terrorism will become a future weapon threatening democratic reforms, the rights of the individual, global peace, and security.

3. Energy, being linked to all vital services such as health, food, transportation, and commerce, will be a key driver of the future global economy.

4. The world's addiction to oil must end. Clean, renewable energy sources such as solar, hydrogen, nuclear fusion, and wind will be essential for future prosperity.

5. Foreign oil is politically risky, expensive, and unreliable as a long-term fuel for the future.

6. New energy innovations must attract billions in investment. Economic growth and productivity will decline if non-oil energy solutions are not invented fast.

7. Pollution from fossil fuels will be linked to a growing number of future public health risks like global warming.

8. Energy security will become an explosive battleground in the twenty-first century, ushering in a new era of either global cooperation or conflict.

9. Nations will rise and fall based on their access to future energy resources. New economies like China and India will compete with the U.S. and Europe in a new geopolitical power struggle.

10. New energy innovations will invigorate global commerce, spawn new industries, and provide new jobs.

part, means oil. Governments rise and fall on it, armies run on it, companies rely on it, and consumers depend on it from the time they wake to their clock radios to the moment they turn off the TV and fall asleep. For the past century, despite rising prices and occasional "crises"—more often than not manufactured events resulting from political or economic forces—there has always been enough oil available to keep the engines of global growth humming. But that is a luxury of the past; in the Extreme Future, a new and uncertain energy age is emerging.

In 2004, I was having lunch in Paris with a group of clients from around the globe who had gathered to share perspectives, ideas, and solutions on critical future issues. To my right was an executive at the World Health Organization. To my left was a leading Saudi official from Aramco, the government oil company and a member of OPEC, the eleven-member Middle Eastern oil cartel that collectively controls about two-thirds of the world's oil supply.

I had just given a keynote presentation on the future, and I was deep in conversation with my Saudi host, who was the resident forecaster at his company. He quizzed me about my outlook, and I questioned him about his take on future supplies of oil.

"So, how long before we run out of oil? How many years do we have in the ground?" I innocently asked. I expected the stock response that it was impossible to say with precision—a sheikh cannot measure an underground oil field for future production the way, say, a farmer can count hogs to predict his output of pork bellies. At the same time, I anticipated that he would offer reassurance that, although no natural resource would last forever, oil supplies would be plentiful for our lifetimes and beyond.

Instead, between bites of sorbet and melon, he casually answered, "Oh, we think about twenty-five to thirty years before we run out of oil."

I was shocked by his candor. "Really, that's it?"

"Yes," he answered, "about thirty years. Unless, of course, we find more reserves."

"What are the odds we'll find them?" I asked.

"There's always a chance."

Lunch went on. But I couldn't get over his matter-of-fact admission about the end of oil. Blasphemy indeed! My mind was racing, stung by my Saudi friend's perhaps too-honest answer to my question.

The memory of that conversation came rushing back to me in the

summer of 2005 when I noticed a daring new advertising campaign from Chevron, in which CEO David O'Reilly wrote an open letter to the world that began with an echo of a warning I've been telling clients for years: "Energy will be one of the defining issues of this century. One thing is for sure: The era of easy oil is over. What we do next will determine how well we meet the energy needs of the entire world in this century and beyond."

This was no longer a Saudi oil minister making a broad analogy about epochal change, or an Aramco forecaster whispering in my ear over lunch in Paris. Now a clear, public warning was being sounded by the head of a major oil company. The question for anyone who cared about the future was no longer whether dependence on cheap oil was coming to an end. Now the question was what to do in the years before the spigot began to run dry.

FIVE THINGS EVERYONE NEEDS TO KNOW ABOUT ENERGY

- The era of cheap oil is over.
- Alternative energy, though promising, is not ready to produce adequate supply.
- We need to invest fast in new energy sources.
- We need to learn to conserve energy.
- Energy is a national security issue.

The Myth of Abundance

Most people in the U.S. are oblivious to our extreme dependence on energy. We expect energy to be there always, everywhere, for every need we have now or in the future. We live an illusion of sorts, perpetuated by the abundance of the moment, far from the reality of the future I am here to predict. Storms of change are brewing, driven by an energy-competitive and energy-restrictive future. Our cheap oil habit

and energy abundance, which is so fundamentally linked to everyday existence, is about to end. Unless, that is, there are fundamental changes in energy supply. Even president George Bush admitted, "We are addicted to oil."

First, some perspective. The United States imports about twelve million barrels of oil a day, or about 60 percent of the oil it consumes. In 1970, dependence on imported oil was just 21.5 percent of U.S. consumption, according to the U.S. Department of Energy. The U.S. is the world's number one oil consumer, using more than 26 percent of the world's oil (Japan and China, the next two leading consumers, together account for 13 percent). Roughly 11 percent of global oil production is devoted purely to providing gasoline for cars and trucks on American soil. America spends more than $25 billion a year on Persian Gulf oil. At the same time, the United States possesses only about 3 percent of proven reserves (opening the Arctic National Wildlife Refuge to drilling would increase that by just a fraction of 1 percent). Already, you can see just how close the ties are between oil—especially foreign oil—and what we consider the American way of life.

Looking ahead, world oil consumption is likely to rise by 50 percent by 2020, and the United States is projected to play a leading role in that anticipated increase. If you consider the needs of fast-growing, oil-hungry countries like China and India, as well as the other emerging developing countries in Asia and Latin America, what you have is an unsustainable energy world. China alone is expected to quadruple its oil demands by 2020. Now try adding three billion more people to the planet in the next fifty years. Oh, and did I mention that new global oil discoveries peaked several decades ago?

This all adds up to a picture of tremendous future uncertainty.

As the demand increases for a shrinking resource, so will prices (at least, that is, while there is oil to be bought). The three-dollar-a-gallon prices at gas stations might soon seem like the good ol' days. And as prices increase, so will the paranoia and uncertainty of the marketplace, of consumers. Once demand outstrips supply, it would be easy to envision a scenario of financial panic and a global recession, accompanied by political, economic, and social upheaval.

But let's not go there quite yet. There is still time to alter this unwanted future, as long as leaders—political, corporate, community, and nongovernmental—commit themselves immediately to pursuing alternatives to oil. Even former oilman George W. Bush has tiptoed toward

WHY WE NEED TO CUT OUR OIL DEPENDENCE: THE TOP RISK FUTURES

National Security at Risk—Oil will become a geopolitical weapon used between the net oil-producing and net oil-consuming nations.

Global Warming Threat—Research indicates that the world is undergoing climate change, which will have an adverse impact on the quality of life, food production, economic growth, and financial assets.

Mideast Conflict Exploding—Dependence on oil requires Western nations to devote enormous resources in the Persian Gulf region to secure vital energy resources.

Public Health Risks Escalating—The linkage between increased public health risks due to global warming and pollution is well documented. Environmental illnesses such as cancer and threats to the food supply are on the rise.

Increased Costs Inevitable—Increases in energy demands by nations will drive up the prices of a dwindling oil supply. Other essential oil-dependent products like drugs will cost more as well.

Unreliable Access at Best—There is no guarantee that oil resources—at any price—will be able to meet future demands. Oil-producing nations may become radicalized and reserve their oil for preferred customers only.

acknowledging that reality: "We must use our technology to move away from oil if we are to prepare for the future." But is there enough time to change? This will be one of the central challenges in the Extreme Future.

Postindustrial Dilemma

If civilization's future hinged on one issue—other than a global pandemic or war—that issue would be energy. The lack of energy to fuel transportation, health care, business, communications, or manufacturing would have a devastating effect. The absence of an adequate, cost-

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effective, abundant supply of energy would doom a society in the developed world for certain. Social stability and growth is linked to a pipeline of abundant energy. It is in the interest of all nations—developed and developing alike—to pursue energy security. Energy for the developing world may be vital to future economic prosperity, poverty reduction, and perhaps, democracy. Energy enables the freedoms and individual self-reliance that is the foundation of a democratic society. Energy fuels democracy.

Ironically, developing nations might at first survive without existing levels of energy resources. But eventually, unless less industrial societies were desirable, they would come to face future challenges along with the rest of the world, just later. The inevitable challenge would be the same—the world needs affordable, abundant, nonpolluting, renewable sources of energy to sustain life, support growth, and maintain or improve quality of life.

As a futurist looking at the total global energy picture, I recognize that there are actually many energy resources yet to be exploited. In the U.S., there are ample stores of natural gas and coal. In North America, there are vast quantities of shale and oil sands, a substance that, with the right extraction technology, may be converted into oil. The shale deposits, if the extraction process is developed fast enough, could produce enough energy to offset the diminishing oil reserves for decades. There is even an argument to return to nuclear power, as the Europeans have. Global gas reserves look promising. But, as we'll see in this chapter, there are even more hopeful technologies that, with enough support financially and politically, might truly be the petroleum substitutes the world will soon need.

There is a timing issue: having the right amount of energy, the supply available when we as a nation and a world need that energy to meet demand. This will be the challenge we will face in the mid-twenty-first century.

Future Survival

Given current forecasts of gross domestic product, the universal measure of the growth of nations and the global economy, we will be struggling within thirty years to support our energy demands. The U.S. economy's GDP growth is about 4 percent per year. The Eurozone is at 2.5 percent. China alone is growing at almost 10 percent a year. With

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projected GDP growth in China of as much as 11 percent by 2035, the pressure on the energy marketplace, dominated by petro-sources such as oil, gas, and coal, could accelerate a global competition for energy. That could create a dichotomy of haves and have nots—those who can afford $300 per barrel oil and those who cannot.

Dead Dinosaurs

None of this is especially important to you if you are living "off the grid," such as those who have not ridden in a car, or seen an escalator, or enjoyed running water, or flipped an electrical switch to turn on a light. But most of the world relies heavily on the benefits, safety, and convenience of having access to multiple energy resources. Much of what we want to accomplish in the future, as nations, corporations, or individuals, revolves around energy access. From growth to poverty reduction will depend on energy access.

Enhanced health care, transportation, communications, education, and commerce require access to affordable and abundant energy. If anything, energy needs will accelerate and increase as nations in the developing world become developed. Strategic actions must be taken now to head off a crisis that will affect every nation and every person on the planet in the twenty-first century if cheap energy is not found.

HEADLINES FROM THE FUTURE: 2015

Oil Hits $300 a Barrel; World Markets Shudder

The seeds of this energy-competitive Extreme Future have already been planted. Dead dinosaurs are at the heart of this bizarre global battle. The global competition for natural resources is just starting to heat up. Most governments, individuals, and businesses are beginning to become aware of the brewing twenty-first century battle over energy that is just taking shape today. Some countries and some corporations are ahead of the game. Certain Gulf states and multinational companies like GE and IBM are aware of this growing threat. They are future-ready, plotting for the time when energy independence and sustainability will pay off in growth, security, or quality of life.

Governments in China and elsewhere are today locking up future oil reserves in the ground. The Chinese have contracted with the

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South Americans and Africans for future oil supplies reaching deep into the twenty-first century. They are defending against Japanese rights to oil-potential deposits in the seas. They are scouring the planet from Australia to Ecuador for all commodities, especially energy-related ones. The energy wars are here, but not everyone has noticed.

The Chinese recognize that they cannot grow their nation's prosperity, the economic juggernaut that will transform their society from a preindustrial giant to a postindustrial global power, without energy. They rightfully are seeing into the Extreme Future. The Chinese see a global battle for energy resources to fuel their future. Nations that get access to this energy will be the winners. A new global order will emerge, perhaps based on energy. Nations will rise and fall. A massive global power shift is coming based on energy access.

There will be plenty of losers as well, perhaps including the United States, if we don't deal with the energy problem brewing in our midst. In a world of diminishing energy, especially nonrenewables such as oil, there will be a fierce competition among the developed countries of the world for who gets access and who does not. This is truly survival of the energy rich versus the energy poor.

Fueling a Prosperous World

As an advisor to corporate boards and government leaders for many years, I am used to wrestling with difficult challenges and finding solutions. Forecasting complex, large-systems change is my business. When it comes to energy, the test is daunting, to say the least. But there are solutions.

If we can't fix the coming energy shortage with existing technology and resources, then we need to identify new forms of energy, since no one would seriously suggest that we roll back the advances in society. In fact, quite the opposite.

Developing nations need reliable and cost-effective energy to defeat poverty, install democracy, develop the middle class, and grow commerce. Another forecast is that a battle looms between energy-independent economies and energy-deprived economies. Energy independence may take many forms that are not politically popular or even safe in the short run but essential in the long view. A new global source of tension between nations is being cast today, and energy is at the core of this issue.

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The Europeans and the Japanese have invested wisely for energy-independent futures based on nuclear technology and alternative energy like wind. Alternative energy in Germany alone accounts for more than 12 percent of overall energy. By 2020, this approach to diversifying their energy mix with nuclear energy will prove to be strategically smart.

The U.S.—despite having invested heavily in nuclear energy—was never able to deal with negative public perception about it. Nuclear energy accounts for less than 8 percent of all U.S. energy consumption. The Eurozone enjoys more than twice this percentage of consumption from nuclear power. In all fairness, the Three Mile Island accident in 1979, the media, and the nuclear waste problem all contributed to a distorted perception about nuclear energy. There have been many developments in ensuring safety and performance that would make nuclear fast-breed reactors a productive solution for America's future. Also, a futuristic new approach called nuclear fusion, safer yet very costly, could satisfy America's needs.

HEADLINES FROM THE FUTURE: 2018

Energy Thieves Steal Billions Daily

End of the Game

The American public, unlike the Europeans, has been spoiled by cheap oil, which has created the illusion of plenty while the reality of diminished reserves has escaped public scrutiny. The Europeans accelerated this public awareness by taxing gas, making it routinely two to three times as expensive as gas in the U.S. More than 85 percent of new auto buyers in Europe are concerned about fuel efficiency. Fewer than 15 percent of Americans care about fuel efficiency, because in a world of cheap oil, they don't have to.

This era is over, and Americans are ill-prepared to meet the challenges of either an energy-restricted future, characterized by slow growth, or one in which expensive energy curbs business productivity and national GDP growth. Everyone will need to face the stark realities of an energy-constricted and costly future. The time to have acted was ten to twenty years ago. Now the world must play catch up, especially America.

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The Path to Self-Reliance

The future-ready strategy effectively used by the Europeans has been a smart way to create a public that is supportive and educated about the high cost of energy. No pain, no gain. This strategy has allowed the Europeans to direct public funds and support toward a lack of dependency on oil at the precise time that actual oil reserves are diminishing. The U.S. has not been as smart, and it will pay later with expensive energy—at least.

European investments in nuclear, which have been put in place over the past decades, will now handsomely pay off as oil prices continue to climb, global energy competition by nations increases, and the geopolitical realities of Middle East oil become fraught with risk. It is a nervous world uncertain about the future. Energy is a key element in this future anxiety, and with good reason. We need to explore new frontiers—and with great speed.

Future Energy Alternatives

We start this journey of discovery with the U.S. Department of Energy's NanoSummit, held in June 2004 in Washington, D.C. As an early advisor to the U.S. government's nanotechnology efforts, I was gratified to see that nanotech, a powerful new bucket of innovations, was being supported by the DOE. In addition, then-Secretary of Energy Spencer Abraham was giving one of the keynotes along with a colleague of mine, Dr. Richard Smalley, the Nobel Prize–winning chemist from Rice University and a pioneering leader in nanotechnology.

Nanotechnology is the manipulation of matter at the atomic scale to create useful tools and substances. For example, imagine a team of infinitesimally small robots injected into your bloodstream to scrub out the gunk from your clogged arteries. From an energy perspective, nanotechnology is seen as a potential source of devices that could, among other things, generate huge amounts of mechanical and thermal energy and then transfer it into electrical energy.

The Marriott hotel where we were meeting was filled with government lab presentations, each one more interesting than the last. It was an energy-innovation bazaar of sorts, each a unique research-and-development stab at redefining the world's energy future, from solar

and wind, to nanotech materials, to lightning and alternative fuels for transportation.

But the real action was taking place inside the closed-door sessions with a rare assembly of experts. I recognized that such a meeting—encapsulating the supply-and-demand dynamics that lie at the heart of the global energy future—was ultimately a window into the Extreme Future. Some 300 of the nation's leading experts—scientists and engineers from universities, industries, and government labs—had been assembled to convey one of the most powerful forecasts I have ever heard in one place at one time. Forecasts usually run the gamut of possibilities: the good, the bad, and the ugly. Then, based on varying data sets, scenarios, and discussions, possible future worldviews emerge. Not here.

Reality Check

Instead, a forecast emerged that will influence the future of every person on the planet. It can be boiled down to six powerful words: We are running out of energy. Based on current production and consumption technologies and trends, we as a civilization—not just as a nation—do not have the existing or projected energy resources and production means that we will need to sustain growth, security, quality of life, and productivity by 2040—and possibly sooner. This includes all current energy resources and production sources, from oil to solar to nuclear. If the future of democracy, both in the West and in the developing nations of the world, can be linked to energy access, we are in deep trouble.

Talk about a reality check. This was not a politically influenced forecast, but a serious-minded examination of supply and demand. Without discovering significant new sources of energy, we as a civilization may face stagnation. Democracy may be in peril. Capitalism, the engine of global economic growth from China to America, may be hurt. It was agreed that we owe the world our best efforts to solve this energy crisis before it derails progress, growth, and even democracy itself. We are faced with an enormous challenge: How do we not run out of energy? This is what sparks the human spirit.

Although I had been running scenarios for clients on a restricted energy future, and we had come to similar conclusions, this across-the-board consensus, this broad universal honesty, confirmed by the U.S. Secretary of Energy, was unanticipated. I know I was not alone in this conclusion. There was a palpable sense among the attendees that we

bore an awesome weight of responsibility to try to avoid a future global energy crisis. But can we? What is to be done now that we know the problem?

The rest of the forecasts, made with plenty of supporting data, led to the inescapable conclusion that even if we were to start feverishly building nuclear reactors, solar and wind farms, hydroelectric plants, and other renewable energy sources, we still would not be able to meet the rapidly expanding energy demands in thirty years. This second forecast, more astounding than the first, was hard to digest, even for those of us who conduct strategic "big picture" thinking.

As the conference continued, I began to focus on the logic pattern that was forming in my mind. Not only are we running out of energy to fuel the world in the future—with obvious critical implications for global security, national security, growth, and prosperity—but even if we start now, building every energy-producing facility from electric to nuclear to solar, we could not meet the growing demand! This was a considerable amount of information to grapple with. I wondered: Where do we go from here?

Nano-Energy

At this point in the meeting, Dr. Rick Smalley gave his presentation. His eloquence was not limited to the problem—our running out of energy. Nor did he waste time with the notion that we cannot do anything. Instead, Smalley talked about nanotechnology, describing a sweeping vision to transform the energy debate by pursuing an alternative path using nanotech. He proposed a distributed energy plan using leading innovations like nano to provide new alternative energy network. I recognized his larger point: the need for an innovation revolution in energy sources that we must build toward and invest in today for the sake of our children and the world.

Nanotechnology represents a radical solution, requiring the harnessing of the quantum, the manipulation of atoms. This is fantastic new science that is only hinted at as a remote possibility—it exists today in embryonic form, an innovative theory of the possible. But still, knowing this, our spirits lifted in the room, as though a thousand-pound weight had been removed from each of our chests at once.

It was as though we were all listening to President Kennedy speaking at Rice Stadium in September 1962, when he told the nation and

the world that we would send a man to the moon before the end of the decade. The NASA officials listening that day were as shocked as we were while listening to the experts at the beginning of the day proclaim that we were doomed by diminished oil reserves, only to be lifted up by the proclamation that we could meet this challenge.

As Americans, we have always pushed the envelope of the possible in forging new adventures. The quest for nano-energy fit the bill—the transformation of the impossible into the possible. Led by the wisdom of a Nobel Prize winner, it seemed like a good bet. More than that, we wanted—indeed, needed—to believe that nano would work. The prospect of running out of energy is too dire a scenario to consider.

Part of this bold forecast remains highly speculative. Nobody really knows if nanotech can do the job. Nanotech may help to unravel new energy solutions, but nano is only one of a number of solutions to our energy crisis. There is much to do, and we will review this landscape of future opportunities and innovations. Still, despite that disclaimer, I can forecast that nanotech will likely lead to amazing breakthroughs in energy development, storage, and supply—if we invest now.

ENVIRONMENTAL COSTS OF AMERICA'S OIL HABIT

- The U.S. is the world's largest producer of greenhouse gases from fossil fuel use.
- Americans produce, per person, the most CO_2 emissions of any citizens in the world—more than 6.8 tons of CO_2, per year, twice that of Europeans.
- China produces only 1.1 tons per person per year.
- India produces 0.5 tons per person per year.
- The U.S. is the only major industrial nation that has refused to ratify the Kyoto Accord, which seeks to reduce carbon emissions and limit greenhouse gases.

CIA, IEEE, 2005

The Future of Energy

A variety of energy sources are emerging now that will offer productive choices in the future. Some of these sources have the potential to be significant in becoming viable alternatives to petro-based energy. First, though, it is useful to forecast the preferred ingredients that would drive these trends. The following is a list of six requirements for future energy sources that would make a difference in weaning us off the oil habit and enabling a more sustainable global world. New energy sources must be

- Abundant
- Reliable
- Renewable
- Clean
- Affordable
- Secure

Depending on whom you speak with, there are any many potential sources that might satisfy all those requirements. I'll touch on several, but based on my forecasts, the two that offer the most promise, and therefore deserve the most immediate attention, are hydrogen and nanotech.

The Hydrogen Future

Are you ready for cars that go 10,000 miles before they need a refill and cost pennies on the dollar? Get ready for hydrogen. It will change everything. Maybe.

On a trip to the East Coast, I interviewed a highly placed executive at Toyota about the future of energy. I suspected that Toyota was ahead of the game in realizing that the end of oil is coming. I was curious about how he saw this emerging trend and how Toyota was positioning the company, or changing the company, to get ready for the future.

He made it very clear that although current hybrids are interesting, they are an interim solution to the auto industry's ability to meet the

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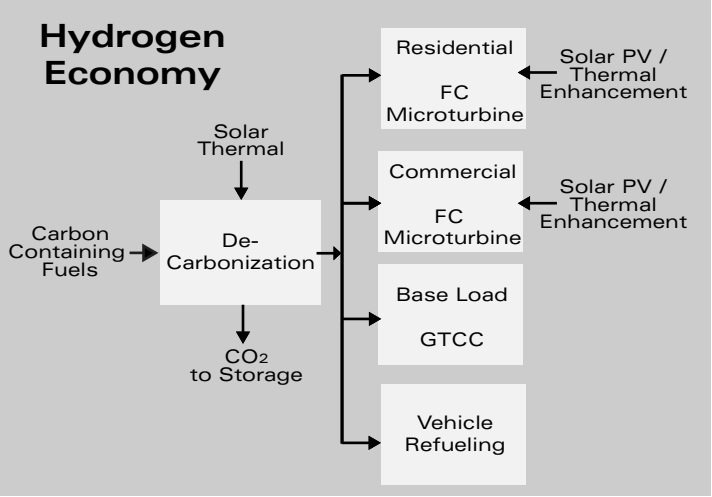
2030 ENERGY FORECAST

- The global demand for energy will increase by 70 percent.
- There will be a 50 percent increase in energy demand from developing nations, especially China and India.
- Energy access is an essential enabler of higher standards of living in the developing world.
- Increased energy access in the developed world will be necessary to sustain productivity and growth.
- Energy has become the leading global and national security issue.
- China's energy needs will be double those of the U.S. and the EU.
- Renewable energy will account for more than 35 percent of total global energy needs to offset reduced oil reserves.
- Innovations like fusion, nanotechnology, and solar will replace oil.
- Distributed small scale, person-to-person electricity generation will be sustainable.
- Breakthroughs in hydrogen and renewable energy will provide new energy supplies.

DOE, CIA, 2005

real challenge: making hydrogen work. Hydrogen is the future fuel that will define the twenty-first century. Hydrogen represents the most significant challenge that the auto industry has faced since its inception. The death of the combustion engine is upon us, and the death knell will be dealt by the auto industry itself. Key industry leaders understand that they need to make a swift transition from present technology that runs on gas to technology that runs on hydrogen.



Splitting Molecules

Hydrogen is the most plentiful gas in the universe. It's also a powerhouse—it has the highest energy content per unit of weight of any known fuel. It's abundant, reliable, renewable, clean (a hydrogen-powered car produces water as its exhaust), and secure (because hydrogen is everywhere, America wouldn't have to rely on foreign suppliers). That leaves just one requirement: affordability. The trick with hydrogen is that it never occurs by itself in nature; it always combines with other elements, such as oxygen or carbon. At the moment, it's quite costly to separate it from those other elements and transfer it into fuel cells, which are the standard storage technology for this form of energy. In fact, the cost of doing so is greater than the current value of the energy created. That's why you don't yet drive a hydrogen-powered car. But that will change.

HEADLINES FROM THE FUTURE: 2042

Hydrogen Energy Trading Exchange Opens for Business

Hydrogen-powered vehicles are coming in the future. Hydrogen-generating power plants are farther down the road, but they are coming, too. There is one in Iceland, the first of its kind to fuel a city. In fact, the hydrogen economy, a holistic transportation infrastructure, will arrive within thirty-five years.

When you consider how the auto industry started and how the mass market for automobiles evolved, it is not hard to envision the beginning

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of the hydrogen industry. At the turn of the last century, the idea of personal transportation that people could use to pick a destination and choose whenever they wanted to leave was a revolutionary concept. But it was the relatively inexpensive production of cars that made Henry Ford's breakthrough brilliant. His vision of factory automation enabled the Model T to become a mass-market success.

Hydro Futures

When hydrogen becomes inexpensive in the coming years, it will follow a similar path into the future. Just as thousands of affordable Model T's came off the assembly line into the marketplace, transforming mobility in America and the world, hydrogen, with a hungry mass market waiting, will find similar success.

To be sure, hydrogen has problems other than high cost. It is unstable and needs to be controlled. The manufacture of hydrogen requires other energy usage, such as nuclear or oil. The technology needed to store and pump hydrogen into vehicles is still primitive and not yet adopted for wide usage. But none of these obstacles is impossible to overcome. Hydrogen will transform the future of energy and ensure a more secure and reliable source of fuel for consumers, business, mass transportation, and even for space travel. Hydrogen is coming fast.

More than $5 billion is being spent around the globe by government and industry for research and development on hydrogen—the United States has already launched a $1.2 billion hydrogen initiative, and auto, utility, oil, and gas companies are falling over each other to rush innovative breakthroughs to market. The largest investments are being made today at General Motors, Shell, Exxon, BP, Toyota, Ford, BMW, and Honda. More than twenty governments are directing their energy investments to hydrogen, sensing that this is the next big thing. Though significant work needs to be done, hydrogen holds the potential for fueling the future, more so than anything else.

The likelihood is that significant innovations in this energy source are coming soon. I forecast that more than $10 billion will be needed and spent on hydrogen research over the next ten to fifteen years worldwide. This will lead to a mass-market set of innovations, similar to the innovations that first launched the modern auto, train, and shipping industries. By 2035, or even sooner, hydrogen will be a viable alternative to oil and gas, meeting as much as 35 percent of our energy needs.

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We are at the beginning of the hydrogen economy now. Get ready. It will change everything at a rapid pace never seen before in human history.

TOP FUTURE BENEFITS OF HYDROGEN

- **Reliable Source.** Increased access to a reliable source of energy makes hydrogen worth working toward.
- **Flexible.** Hydrogen can fuel personal and public transportation, and numerous energy-dependent devices, engines, and needs.
- **Self-Reliance.** Not having to count on foreign monopolies and the geopolitics of oil is worth the investment.
- **Environmentally Friendly.** Hydrogen produces water as exhaust, though oil is still necessary to produce hydrogen fuel.
- **Hydrogen Works Today.** We know hydrogen can provide power today—it is just too costly and is not yet ready for mass transportation use.
- **Unlimited Access.** Hydrogen could be an unlimited power source.
- **Ultimately Inexpensive and Cost-Effective.** If the Iraq war costs the U.S. between $500 billion and $1 trillion, and we were to invest half of that in hydrogen, we would see dramatic breakthroughs in energy—fast.

Nano-Forecast

In 2005, my think tank, the Institute for Global Futures, conducted the first forecast and analysis of the exciting new convergence of nanotech and energy. Before describing the results, it is worth taking a moment to explore what, exactly, I mean by "nano-energy."

Nanotechnology is a design science. It is the emerging science of manipulating molecules at the atomic scale. Move a few atoms around and you have wood. Move around a few more, and you have energy like hydrogen or solar. Nanotech, or "nano" for short, may be used to

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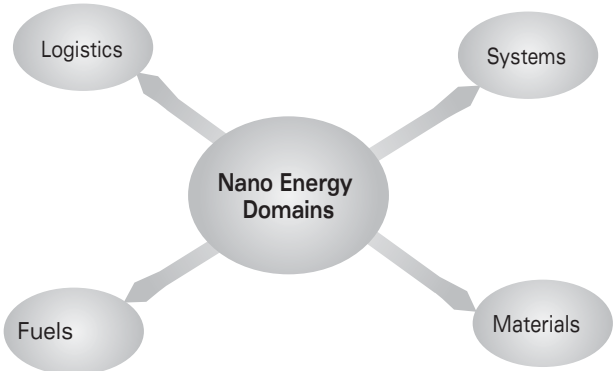
actually design new forms of energy or solve problems that will make other forms of energy productive, available, or useful. Carbon nanotubes have unique properties, such as being a hundred times stronger than steel, yet very thin and light. Nanotubes are also very small, a billionth of a meter. They also have a unique, high conductivity rate for carrying electricity. Today, nano is being investigated with an investment of more than $3 billion by the U.S. government. More than $20 billion will be invested in nano over the next ten years.

Nanotechnology plays a significant role in the coming energy crisis because it represents an emerging strategic platform for fabrication processes not previously available via other means. No one knows for certain if this direction will pay off. It is a gamble. Ultimately, though, nanotechnology may lead to new energy sources not contemplated before. Nanotechnology may express an entirely new paradigm of sustainable energy. This is the goal.

Nano-energy may accelerate the efficiencies of solar, biofuel, geothermal, or hydrogen sources, speeding up access to these renewables. Nano-energy may actually enable the production of more cost-effective sources of energy, possibly including new hybrid energy sources. Also, nano-energy may accelerate the transition toward a clean, sustainable, and renewable energy resource that promotes self-reliance from our current petro-energy dependence.

There are risks associated with the pursuit of nano-energy. We don't know how costly, safe, or difficult this will be, or how long it will take. We are entering new scientific domains. The imagination, innovation, and investment in shaping a new future, however, with the hope of inventing new sources of sustainable energy, looms large. This is one of the great challenges facing humanity today.



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Nano-energy can be divided into four specific domains: logistics, systems, fuels, and materials. This is the current map of nano-energy domains that points to the research-and-development efforts in this new technology. Specifically, however, nanotechnology will have its greatest impact in the areas of fuels and materials. Nanotech might, through the self-assembly of matter, actually *create* a new clean and abundant energy source. Such an energy source would transform the world overnight.

Numerous oil companies, auto companies, and other large corporations are investing billions in research and development on alternative energy, renewable fuels, and vehicles. Nano-energy breakthroughs down the road may be accelerators of hybrid vehicles, fuel cells, and transportation- and energy-system solutions. The U.S. Department of Energy has also taken bold leadership steps to invest in nano-energy, which will help to support private-sector investments. The collaboration of public- and private-sector efforts will be needed on global and national scales to create the breakthroughs needed to transform the energy equation. If nano-energy is to offer new alternative sources of sustainable energy in the future, it will come from collaborations such as these.

There are numerous examples of nano-energy-related research projects that hold potential. Many of these programs are being funded by industry, government and academic institutions. The majority of these projects, however, are still very much in the early stage of development from a commercial perspective. There are still numerous proofs-of-concept yet to be revealed. Companies like DayStar, which is using nano to enable solar, or Nanomix, which has developed a nano-hydrogen storage product, point to a promising future for energy solutions. It is a risk we have to take to prepare for tomorrow.

Other Alternatives

Although I forecast that hydrogen and nano-energy are the two most promising solutions to the coming energy crisis, they are hardly alone. For instance, there is wind energy, which for the moment is the world's fastest-growing energy technology. One thing that surprises some people is that wind is actually a kind of solar energy—winds are created by the uneven heating of the atmosphere by the sun, as well as by the rotation of the earth and the uneven surface of the planet.

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For thousands of years, humans have recognized the power of the wind and have harnessed it to propel ships and provide mechanical power to grind grain, pump water, and perform other tasks. The future of wind energy, though, is in the large-scale production of electricity through wind turbines. Wind turns a turbine's blades, which are connected to a spinning shaft, which in turn is connected to a generator that transforms the mechanical power into electricity. A group of wind turbines could send electricity into a power grid—just like electricity produced by petroleum sources—to serve homes and businesses.

As with any energy source, there are pros and cons. Although wind is clean, renewable, and plentiful, it's also—as anyone who has ever flown a kite knows—intermittent. And for the most part, it cannot be

WIND ENERGY FUTURES

- Renewable energy's return on investment is increasing. Renewables can play a larger role in offsetting oil dependence in the future.
- The U.S. is losing the competition in renewable energy to Europe, which has moved ahead with wind power. Next to invest in wind is China.
- The U.S. produces less than 1 percent of its energy from wind and solar.
- Denmark produces more than 20 percent of its energy from wind sources today.
- By 2025, Denmark expects to produce more than 50 percent of its energy from wind.
- The U.K. produces more than 3 percent of its energy from wind.
- The U.K. will produce 10 percent of all energy from renewable sources by 2010, and 15 percent by 2015—wind is the primary source.
- The future of wind energy lies in offshore wind farms.
- The U.S. needs to wake up to wind power.

easily stored for times when electricity demand is greatest. An irony of wind power is that the best wind is often found in remote places, far from the cities that need the electricity most. The result is increased transmission costs and a greater initial investment than other energy technologies, though that may change.

Another exciting new energy technology is being developed that may point the way out of our energy-hungry trap. Cadarache, in southern France, will be the location of ITER, a multinational, $12 billion collaboration to build a nuclear fusion plant. Fusion seeks to harness the physics of the sun. It is safer, cleaner, and yet more powerful than the nuclear-fission technology common today. Nuclear fusion is the exact opposite of fission— it doesn't produce large quantities of radioactive waste and cannot explode, threatening life and the environment. Korea, Russia, the EU, and Japan are partners in this venture.

The fusion reactor would start generating power by 2015 and operate until 2035, producing 10,000 jobs and 500 megawatts of energy. A next-generation fusion reactor called Demo, which is scheduled to go online by 2035, would prove up fusion reactors for full deployment by 2050.

Toward a Future of Energy Independence

Energy will shape every aspect of the Extreme Future, from security to transportation to health care and growth. We must prepare now by investing in alternative energy sources, some through innovation like nano, and others through hydrogen. We must walk toward a future of energy independence. The future of nations will rise and fall, prosper or decline, based on their access to energy resources. From the vantage point of today, I would forecast that energy expenses for business and consumers will increase significantly—by more than 1,000 percent by 2035—unless innovative and sustainable energy sources are rapidly put in place. Access to energy will define competitive advantage in business.

There is a great danger that our energy needs in the near future—twenty-five years forward—will not be met adequately by current resources. Put another way, energy issues will become central issues to consumers, business, and governments as we begin to deplete existing energy sources and place increased demand on energy infrastructures. Energy issues will shape politics, transportation, health care, and security as the cost and availability of energy increases. The threat to

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national security in a world dominated by foreign oil is a growing risk to the stability of the U.S., the growth of the nation, and the prosperity of the world. We must change this dynamic now.

The good news is that we are on the verge of many exciting new innovations that have the possibility to make much of the world energy independent. This is a promise. New innovations will fuel the future, offering a security and self-reliance about energy we have not had in the past. This new energy access will be an enabler of future prosperity. I would forecast that the future of democracy may also be dependent on the future of energy. Creating this next generation of energy self-reliance will take what Americans are good at—invention, innovation, and marketing. But they are not alone. Many innovators are hard at work around the world in this historic race. An energy-hungry world awaits the new wave of innovations coming in the Extreme Future. Bold new leadership—in industry and government—will be required if we are to fix the energy crisis that is emerging.