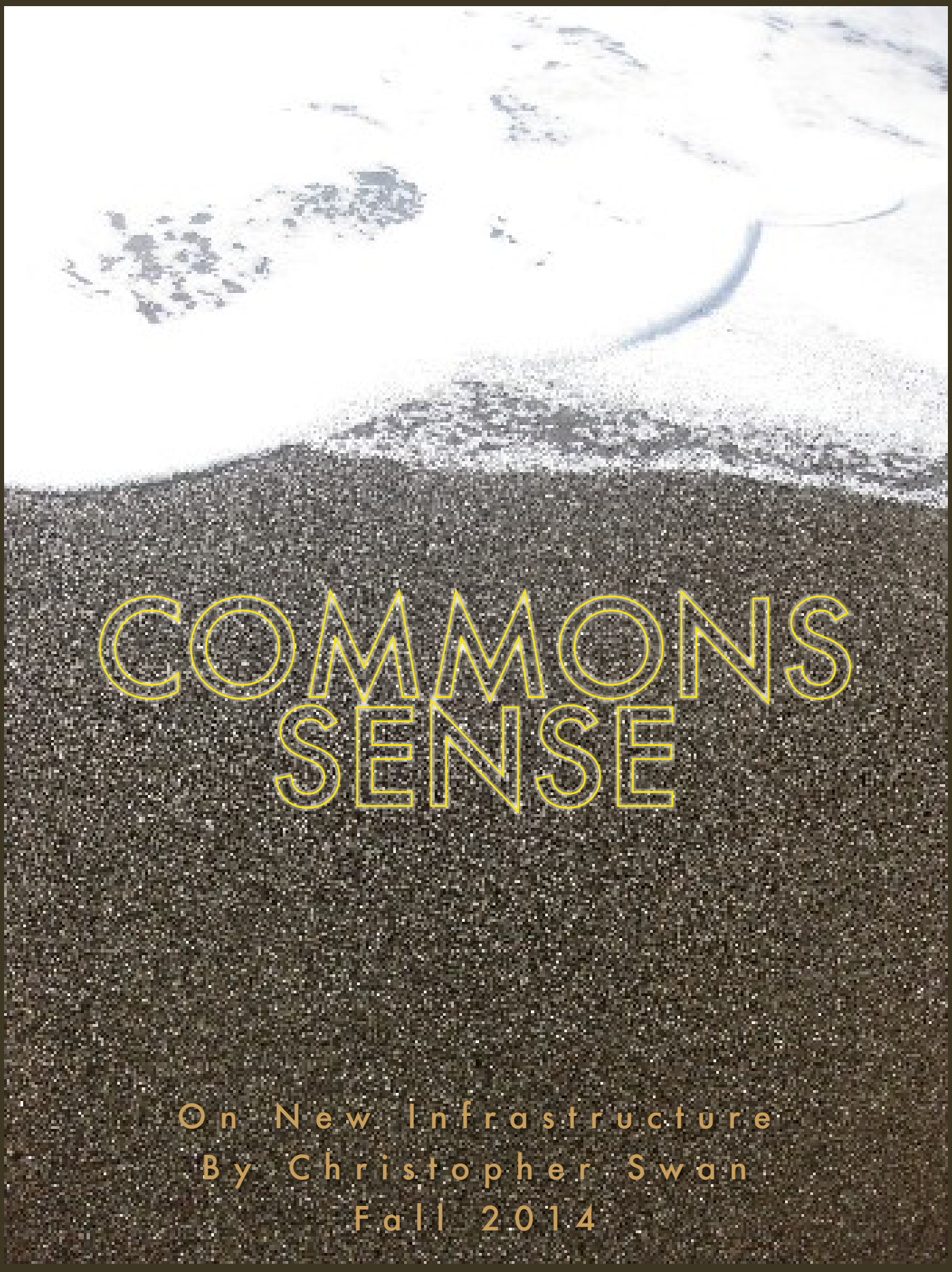


COMMONS SENSE

On New Infrastructure

By Christopher Swan

Fall 2014

Where are we going?

As a designer and writer Christopher Swan has written four books and dozens of articles on the infrastructure of transportation, energy, water and land use. His most recent book, *Electric Water* (New Society Publishers, 2007), outlined new trends and predicted an infrastructure revolution now taking place. In his earlier works, dating back to *YV88* (Sierra Club Books, 1977), a science fiction book, Mr. Swan accurately predicted the growth of renewable energy, specifically use of photovoltaic cells to power buildings independently; a new industry in ecological restoration; the return of railways; development of new modes of agriculture; and many other trends and technologies. As a generalist Mr. Swan can identify relationships others are too specialized to recognize, and develop wholly new business or cultural opportunities.

Commons Sense
By Christopher Swan

San Francisco, California
415.368.9981
swantrain@comcast.net

PIECES

1—Future Primitive:

A generation of innovators created a new vision of life that requires far less of all resources, offering a pathway to sustainable civilization, and a natural world restored.

2—They Left the Farm, Not the Land:

Beginning decades ago a small but growing portion of the population returned to the land, as people who increasingly recognized the wisdom in the wild, and in ecological restoration.

3—Seeking Water, Standing in the Rain:

Long ago people built elaborate water systems to bring pure water to cities. Now many cities can recycle water, and rely on rain they already receive. Rivers are being restored.

4—Standing in the Energy of Light:

Oil created a fossil fuel infrastructure. Renewable energy requires a fraction the resources and produces no pollution. Renewables will supplant all other energy sources in 15-20 years.

5—Riding by Light:

Batteries and hydrogen fuel cells are primary means of storing energy, allowing solar-electric vehicles. Electric cars, trucks, trains, ships and planes will end internal combustion engines.

6—Changing Climate in the Air:

Change in proportion of atmospheric gases threatens the viability of global civilization. Three changes, energy conservation, renewables and sequestration, all have been underway for decades.

7—Profit by All Measure:

Profit is popularly defined only in monetary terms. But all people seek profits that involve quality of life. New infrastructure represents economic, cultural and environmental profits.

CAFE SOCIETY

Cities changed while no one was looking. Over a few decades many cities in the world have gained cafes, plazas and parks as retailers and politicians discovered the value of social space. Cities once devoid of life at night are now alive with people. Museums, parks, sports and entertainment venues are increasingly centered in the city. Such vibrant urban areas encourage people who might otherwise never meet to get to know one another. Significantly cities consume less of all resources, and residents typically drive less than half that of their suburban counterparts.

1—Future Primitive

Everyone will say they have no idea what might happen in the future. Cynics will claim humanity has no future, citing a litany of horrific problems as if the sheer measure of pain was sufficient to dispel anyone's hope. Yet all investments are based on the hope that something bought or something made will be more valuable in the future.

Economists and presidents agonize over what's wrong with the economy. They talk of tweaking the knobs of the economy, as if it were just a machine requiring a tune-up. Meanwhile the people divide less money into smaller piles.

The economy is no machine. It's a living $80 trillion global event expressing the constant ebb and flow of values, aspirations and fears shared by the population of the planet. It's driven by faith; that by reasoned judgement or pure intuition things will be better in the future.

Assaulted by criminal activity at the highest levels, coupled with a long steady decline in incomes, an absence of jobs, and the threat of climate change, millions of people have lost faith in the institutions of society and the prospects for their future. Faith drawn down to hopelessness doesn't engender creativity, or new economic activity. On the contrary, faith diminished leaves the door open for rage and its neighbor depression. In depression people withdraw and economies contract. A societal "depression" is an emotional event not a mathematical reality.

Four decades ago a sizable portion of the baby boom generation, having come of age under the threat of nuclear Armageddon and confronted with environmental destruction, spontaneously recognized the culture they were born into was built by the exploitation of resources and people, and was unsustainable, possibly suicidal. They recognized population could not keep growing and taking more from Earth, and that doing so could only lead to rapid decline.

In response to this realization they invested their creative energies in a new future. Unlike many contemporaries they focused not on the politics of the day, but on the mundane institutions and technologies forming society's guts; the infrastructure of energy, water, communications, transportation and land use — the basics.

These innovators held to one task: inventing a new future. Their creative energies were focused on alternatives to existing tech. Unfortunately they found

themselves ignored in a society permeated with irony and obsessed with end times visions, from bare survival in a dystopian society to biblical Armageddon to sudden extinction by apocalypse du jour.

Nevertheless they persisted. Three central ideas emerged in this new vision: We are all connected, we function as one and Earth is our commons. Translated to action: think seven generations out and consider everything, not just what makes a profit if you ignore what's "thrown away."

These ideas now form the intellectual core of a movement involving tens of millions of people worldwide. The movement has been variously referred to as the "counterculture," "new age" or "alternative," but such terms now confine what has grown to include every imaginable expression of personhood, transcending gender and profession, and including all political views.

Rooted in primitive innocence yet aware of their power over nature these pioneers sought a future where humanity is in balance with the Earth. They bet on a new economy based on sustainable technologies, on light, wind, and the abiding realities of soil and water. They started an infrastructure revolution, and it's now happening at an exponential rate, with each innovation built upon the last and compounding like interest.

Innovators rediscovered the promise of industrialization as the means of sustaining a higher quality of life. They also recognized that personal security, liberty and peace are not sustained by weaponry, but by diligently developing and maintaining the commons all people share so all have a stake in the culture, economy and future of society. Open and accessible infrastructure is a precondition for an equitable and free society. It is the skeleton, bloodstream and nervous system of the social body.

Technologically the innovations that emerged decades ago have evolved into systems that are orders of magnitude more efficient, more accessible to all people and more profitable. Measured by projects built, inventions patented and countless billions of dollars invested in new businesses and new technologies, it's now obvious this quiet movement so often characterized as a quixotic fantasy about windmills on the mind has invented a future. It has really big windmills.

CITY CROPS

A city garden only two blocks from City Hall in San Francisco. While such gardens will not make a major dent in the city's demand for food they can provide fresh herbs and greens for many restaurants. As electric cars become common the pollution that might now damage such crops will vanish. Small gardens can also provide a means for children to experience the reality of vegetables, and for elderly people to retain a link to soil and plants.

2—They Left the Farm, Not the Land

In the 1970s thousands of people moved back to the land out of fear the economy might collapse. Some became organic farmers, learning to feel soil as a living matrix of loose grit bound by moisture and decaying matter alive with microorganisms. They saw how human health is linked to soil, and how modern food was poisoned by chemicals and drained of nutrients, while soil was treated as if it were a just a conveyor belt in a food machine.

Organic farmers came of age with science of ecology. They recognized technology could not replicate the biological legacy represented by forest or soil. One tree or blade of grass is a discrete thing, but it's also a member of a community of plants and animals living on fungus highways transporting nutrients and information over square miles. Plants and microorganisms communicate, even seeming to make choices. Wild life is far more sophisticated than machines. People make machines, but wild life made us.

In the sixties ecologists began to comprehend what science missed by focusing on single species. The "wild" may have seemed chaotic, but was in fact highly ordered. A forest is a civilization not just a random collection of biology. Shamans holding ancient knowledge of animals and plants represent a consciousness embracing water, land and air, and all species of plant and animal as one living thing, and so it is.

Over the last few decades countless studies of ecosystems revealed how the wild could be far more productive and efficient compared to domestic agriculture. Grasslands like the US Great Plains once supported hundreds of species in one square foot. The tall grass prairie included grasses taller than a man, and a root matrix that went down as far as the grass went up. This forest of grass drew in billions of tons of carbon dioxide and methane, leaving carbon to enrich deep black soil.

The belief domesticated plants and animals are a more efficient means of growing food led to monoculture fields, fish farming and feed lots. But countless studies of ecosystems suggest a wild grassland or river, or a farm based on ecological principles, can be more productive using less of all resources, including human care. Indian tribes and ranchers who recognized these efficiencies now manage commercial bison herds on the Great Plains. Ted Turner, founder of CNN, owns 18 ranches supporting some

50,000 bison, often accompanied by antelope or elk.

The new agriculture embraces ecological principles to achieve greater productivity using less land, water and energy, while relying on little or no external chemicals or soil nutrients. In the new science of "agroecology" growers create a small ecosystem with crops grouped for mutual benefit. Similarly the idea of "permaculture," as defined in 1978 by two Aussies, Bill Mollison and David Holmgren, involves farms with ever-changing garden beds, interspersed with fruit trees and native edible plants, all to create a farm-scale ecosystem, even a "food forest" a self-sustaining feast of greens and fruits, where low hanging fruit is breakfast.

Grassland and savannah regions are a priority in relation to climate change because grasses grow fast. Planes can drop "seed bombs," clusters of native plant seeds in a water soluble gelatin wrap full of nutrients. Such strategies make it possible to restore vast areas.

The Kansas Land Institute has pioneered research into perennial grain hybrids, so a prairie might include wild grains in the mix as a continually evolving plant community dominated by permanent and deeply-rooted perennials, rather than shallow-rooted annuals.

This vision suggests an open range, where instead of growing cattle feed on a farm for animals living in a distant feedlot, herds of bison, elk and antelope, plus some longhorns, roam the plains standing in their food, and tilling the soil with their hooves. In the fall roving combines with sleeper cabs would work their way south, harvesting grains not eaten.

Once rigid distinctions between wild and domestic are blurring as cities discover the value of green. Restored shorelines and rivers attract residents, businesses and visitors. In some cities food gardens are encouraged, in vacant lots, on rooftops and as a public garden. Invariably vegetables plus wild plants attract native species of birds, butterflies, deer, raccoons and other critters. Several coyotes now reside in San Francisco, having arrived a few years ago via the Golden Gate Bridge.

Much of the high plains stretching from West Texas to Montana has become de-populated, leaving 6,000 ghost towns just in western Kansas. In 1987 Frank and Deborah Popper of Rutgers University proposed a "Buffalo Commons," a vast open range. Their vision may result in a new National Park in western Kansas, as advocated in a Kansas City Star editorial (November 15, 2009) that concluded, "Buffalo Commons is an idea whose time has come."

WATER'S WAY

Thousands of miles of rivers are restrained from their natural functions, often submerged in stagnant reservoirs. They can be fisheries supporting local and migratory populations; they can deliver silt from the mountains to fields in the valleys; they can be habitat for countless birds and small mammals; they can be a heavenly respite from hot summer days; and a stunning lesson in water power when flowing full in winter. The sight and feel of crystal clear mountain waters is mesmerizing, and vital to our spirit. Salmon, having journeyed from the waters off Japan, once passed by this spot in California's Sierra Nevada. One day they will again.

3—Seeking Water, Standing in the Rain

We are water. A river flows through us and all life on planet Earth. It is continuously rising, condensing into clouds and falling back in an endless cycle. We drink the clouds. We are primarily hydrogen and oxygen.

Ecological science goes beyond biological specialization to embrace what binds all life — water, air and light. Instead of seeing a river as water to take, ecologists see it as a civilization of fish, birds and mammals, some year 'round residents plus migrants and visiting tourists, and an annual surge of minerals and nutrients delivered free to floodplain and ocean. It, and us, are in the water cycle.

Despite such contemporary knowledge, and its implications for human survival, much of the world is still drinking from water systems based on a 2,000 year old Roman plan of dams and aqueducts, all designed to get pure water from elsewhere. Yet contemporary US households use only a small fraction for drinking, cooking and bathing, perhaps some for gardening, with the rest used to transport waste from toilets, sinks and washing machines. Ideally it's sent, along with storm drain water, to a sewage treatment plant where it's nearly purified only to be drained to a river or bay.

Over the last few decades several cities, notably Los Angeles, recognized the absurdity of ignoring rain and virtually purifying billions of gallons of "used" water only to drain it away. Now they are building catchment basins and cisterns to capture rainwater, and pumping it underground along with water from sewage treatment plants. Many manufacturing facilities recycle water, and several commercial buildings in the US now recycle water internally as "gray water," radically cutting "virgin" water use. These strategies recognize rainwater is a gift not a drainage problem, and the earth as the biggest reservoir of all.

Most cities receive electricity from power plants that consume water. Existing steam generating power plants use coal, natural gas, oil or uranium to boil distilled water. After the steam has passed through steam turbines, making generators spin, it's condensed to be boiled again. Condensing high temperature steam requires cooling towers, often visible aside power plants. Cold water is used to remove the heat, with heat rising skyward as low temperature steam. That water represents a large portion of the world's freshwater drawn from rivers and

reservoirs — in the US it's about 48% of total water consumption. About two-thirds of the heat generated by the fuel is lost, and provides no value in generating electricity while contributing to atmospheric warming.

Renewable energy sources do not require cooling water. A city using renewable energy only, while recycling water and taking advantage of streets and roofs as a rain collection system, could rely on groundwater replenished by rain. Residents can have ample water with no vulnerability to disaster or sabotage. Power plant water can return to the river, plus that delivered to cities by aqueducts.

Dams and reservoirs are widely viewed as a means of "saving" water, and hydroelectric dams are seen as a means of also generating electricity. There are approximately 75,000 dams in the US, 8,100 are "major" structures exceeding 50 feet in height. The height and form of virtually all dams, canals and levees was derived by engineering guesstimates of the odds of an extreme precipitation event within 100 and 500 years. Unfortunately they had only a few centuries of weather data, and little knowledge of the relationship between groundwater and flooding. No one imagined the climate changing radically, with hurricanes covering half the continental US.

Large-scale hydroelectric dams average about 3.7% of global energy demand as electricity distributed by the grid. Such centralized power plants require investment in massive turbines, generators and high voltage power lines to distant cities.

California was blessed with a vast Central Valley grassland supporting herds of elk and antelope. Europeans converted the landscape to cattle and farms in the 18th and 19th centuries. No one imagined that under the verdant valley was an immense reservoir recharged by floods, and not subject to evaporation during the summer. As dams were built on nearly all rivers — 1916 to 1960 — water otherwise destined underground sat in open reservoirs, where about a third is lost annually to evaporation, a rate increasing as average temperatures rise. Inevitably underground water levels dropped, and so did the land, as much as 20 feet in some places, and it's still dropping.

Restoration of California's primary watershed has already begun. Projects include restoration of salmon runs on one river, islands in the river delta east of San Francisco and several smaller efforts involving creeks, estuaries and lakes.

Restoration of the entire Mississippi River system, covering over 40% of the 48 states, including levee modifications to

protect cities, may seem extreme, even crazy. Nevertheless such comprehensive action may just be inevitable.

According to the Federal Energy Regulatory Commission roughly 700 dams are now slated for removal. Some are dangerously aged, others geologically unstable and still others hold back more silt than water, rendering them useless. In addition, relative to all dams, there is no longer any guide to whether or when a reservoir will dry up, becoming a dead pool so low hydroelectric generators stop and the river downstream ceases to exist, or overtop the dam to cause a catastrophic flood. Dams are a disaster waiting to happen, not a reliable source of power.

Recent flooding along several rivers, worldwide, suggests dams and levees are increasingly inadequate to the task. Flooding on the upper Mississippi in 1993 covered parts of nine states, killed 50 people and cost tens of billions in property losses. It also resulted in federal, state and local agencies recognizing the futility of fighting the river, and moving many small towns to higher ground.

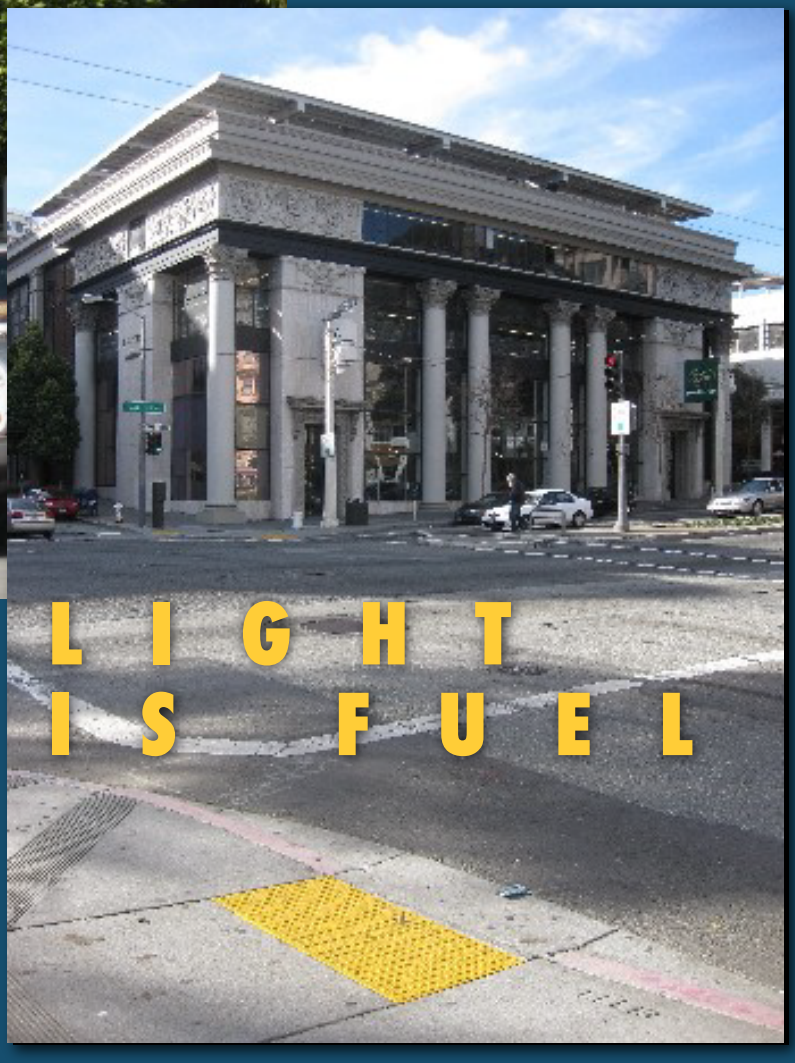
While difficult to prove in pure economic terms it would seem rivers are worth more alive than dead, in relation to sequestering carbon dioxide and exhausting oxygen, plus fish, fiber, wood, wild berries, rice and other plants that thrive in riparian wetlands and flood plains. Culturally rivers can be the common thread linking countless communities. They can even support houseboat communities traveling the river.

Ecological restoration represents an unprecedented new trend. Never before has a civilization recognized it was destroying the ecological foundation of its economy, and taken action to restore what was almost lost. It is now a maturing global movement, embracing a vision of restored landscapes, and proving that ecological diversity is vital to human health.

San Francisco Bay is regaining tidal salt marshes; geese already lower their flaps and touch down on a “new” wetland where B-52 bombers once landed. Oysters are being reintroduced to New York Harbor, where a large segment of the Bronx River was recently restored, causing beavers to show up on their own. Dams on Washington’s Elwha River were recently removed, and all five species of salmon returned to their former spawning grounds. LA is planning restoration of all 31 miles of the Los Angeles River right through downtown. The concrete ditch, as seen in countless car chases, will become a living river. Coyotes will be able to saunter from the Hollywood Hills down to Long Beach for some fish.

This installation is typical for a modest urban home. Including cells on the remainder of the roof this would be sufficient to power the home. In most cases the installation can be done in a few weeks.

Photovoltaics are innocuous. This building is the Jaguar dealership on Highway 101 in San Francisco. It was designed as a Packard dealership in 1926 by Bernard Maybeck, a famous local architect. In 2008 it gained a second roof of photovoltaics generating a large portion of the building's electricity, equal to the demands of 80 average homes. It also keeps cars parked on the roof cool in the midday sun.



4—Standing in the Energy of Light

In the seventies energy innovators viewed oil, coal and natural gas as unsustainable, while nuclear tech was costly, inefficient and fraught with risk. In their future three imperatives were paramount: reduce waste by buying higher efficiency, focus on sustainable energy and emphasize clean tech. Existing tech didn't fit the bill.

In the early 1980s an infrastructure revolution was triggered by innovators in telecomm and computing: the personal computer. The high-tech revolution didn't stop at merging typewriters, adding machines and televisions, because its most fundamental innovations, the silicon-based microprocessor, magnetic storage systems and operating software, were applicable to all sorts of things. This ongoing revolution has already transformed photography, printing and filmmaking via digitized media; is now doing the same to the lighting business; and will transform the energy biz within the next two decades.

Three spectacular innovations grew from the semiconductor branch of the high-tech tree, and characterize the work of many visionaries: photovoltaics, light-emitting diodes and charge-coupled devices, a.k.a. "PVs," "LEDs" and "CCDs." PVs receive light and generate electricity, LEDs receive electricity and generate light, and CCDs receive light and generate an electronic image.

Transformation of the simple light bulb typifies the trend. LEDs, using the same wattage, deliver four times more light compared to fluorescent bulbs, and up to 20 times more than a typical incandescent bulb. They also last much longer, take up less space and can be used at all scales, from tiny to powerful searchlights, and they are equally viable for flat TV screens, offering resolution approaching reality. A glass door with a "view" that looks real will soon be real.

Digital cameras use CCDs to capture the light and translate the data into specific wavelengths of color, so each pixel is precisely calibrated by the photons it receives. This function is similar to how the eye works. The results are available instantaneously, and can be transmitted in their original form and color managed for exceptional accuracy.

These technologies represent not just a higher quality of energy, light and image, but a staggering reduction in the resources required. LED bulbs require a fraction the materials of conventional bulbs, and since they last longer the

material turnover is reduced. Digital cameras bypass the entire process of negatives and prints, along with the chemicals and paper required; a fact that demolished the film industry. The transformation of the recording industry is attributable to waves of new tech. The "stereo" of 1970 — components plus record albums — weighed as much as a person. It was replaced by devices that weigh ounces, cost a tenth the price, use a fraction the energy, fit in one's palm, and can carry the music of a lifetime, plus movies, pictures and books. Now it's also your phone, camera and hand-held computer too. Now you can buy a song without even leaving your chair.

Without doubt the most profound new technology to emerge from the technological ferment of the last few decades is the photovoltaic cell. They are based on Albert Einstein's quantum theory of light, published in 1905. He defined light as packets of energy he called "photons." Light is energy, and solar light we receive on Earth, at about 92 watts a square foot, permeates nearly all life on Earth. The sun produces 23,000 terawatts annually, people use a mere 16 terawatts — 16,000,000,000,000 watts. The sun delivers more energy to Earth in one hour than all humans use in a year, and one year's input of solar energy is more than could be generated by all the coal, natural gas, oil and uranium available and consumed to date. We cannot see photons raining down on photovoltaics and triggering a flow of electrons — electricity. We cannot see light nor stare at its source, but we can see by its presence in reflection.

By the mid-80s a loose group of US and Japanese high-tech start-ups, plus major oil companies, dominated the photovoltaic business. By 1998 big oil had dropped out and the Japanese lost the initiative. China now dominates PV manufacture, though US, Japanese and European producers are still in the game.

Photovoltaics are rapidly altering the energy business. PVs already power all satellites, plus thousands of navigation lights, railroad signals, billboards, streetlights, remote pumps and telecomm facilities. Somewhere north of 10,000 backwoods homes, and a small but rapidly growing number of commercial buildings, are wholly PV powered, using batteries for power storage. A larger number of homes and commercial buildings receive most of their power from the sun, with grid connections as back-up. Photovoltaics are also becoming building components; roofing, tiles and soon clear windows.

PVs are a new class of device that demolish the notion that it takes a power plant to "make" electricity. Existing power

plants are the focus of energy systems that involve millions of tons of steel, copper, concrete and other materials to extract fuel from the earth, transport and burn it to generate steam, which drives generators producing electricity distributed by wire to customers. Photovoltaics reduce all that to photons and electrons silently streaking about in a film thinner than paint.

PV tech is primarily silicon, identical to that used for semiconductors in computers. Silicon is a metal derived from common quartz found in beach sand — also the source of glass. PVs are produced as crystal wafers, or as thin coatings on metal or glass. One type of PV is "printed" on paper-thin steel — megawatts instead of newspapers.

Light is the fuel. Light tends to be equitably distributed and never fails to arrive at dawn. The cost is primarily a fixed finance cost for the PV system, plus depreciation and maintenance — like washing panels occasionally. They last at least 30 years with a slight reduction in output over time. No fuel cost means no vulnerability to commodity prices or interruptions in supply. PVs applied to a roof will save money by extending the life of the roofing, and some types of PVs are designed to function as roofing.

For over three decades PVs have been gaining efficiency while declining in price. Photovoltaic sales have grown about 30% annually for decades. Growth in the last few years exceeded that of cell phones. As of 2014 the European Union receives about 2.6% of its electricity from PVs, while photovoltaics account for roughly 1% of total world demand for energy. Worldwide all forms of renewable energy, excluding large-scale hydroelectric dams, account for about 6% of total electrical demand. Overall investment in renewable energy has grown from $277 billion in 2010 to a projected $1.2 trillion in 2014.

In the US rooftop solar systems are being installed at the rate of one every four minutes. Worldwide growth in renewable energy output has reached extraordinary heights; PVs hit 77% in 2011, nearly doubling in output. In 2012 PV growth subsided to the still astonishing 40%, while renewable energy overall is growing at 21%, or doubling every 3.5 years.

Wind energy has reached similar levels of growth, primarily in the production of massive three-bladed turbines for offshore and open prairie environments where wind is uninterrupted. The largest turbine is 220 meters tall (720 feet) and can generate eight million watts. Notably Kansas is becoming a center of wind energy, as are several other prairie regions in the US and world. A few ranches in western Kansas

The San Francisco Public Utilities Commission office building, completed in 2010. Compared to conventional building this structure uses far less energy and water overall, and generates up to about 10% of its electricity from renewable sources.

ENERGY TODAY

Sun shades on the building's south side (bottom) are translucent photovoltaics, while on the north side (top) four "eggbeater" wind turbines are almost constantly spinning in the prevailing winds off the ocean. If the roof and other wall panels were photovoltaic the building could generate all the electricity required.

host a cluster of wind turbines, with bison herds grazing below the massive blades.

If all renewable energy averaged a 40% growth rate, doubling every 1.7 years, renewables would supplant all natural gas, oil, coal, nuclear and large-scale hydroelectric power, for buildings and transportation, within 15 years. At that point the world energy economy would represent an investment of roughly $120 trillion — including nearly everyone.

Unlike any other form of energy technology photovoltaics are uniquely viable at all scales, from powering a radio on a bumble bee's back to a cell phone to a high rise. They can be linked in a micro-grid to serve several buildings or recharge vehicle batteries. Kenyan village residents now buy a 20 watt PV panel and a car battery to recharge cell phones and light a bulb. As their income increases they can add more panels, sufficient for a fridge, computer and more lights. Suburbanites worldwide can buy panels covering half their roof and run the whole house. Add neighborhood-scaled wind or in-stream hydroelectric generators in areas with less sun, plus solar-thermal power for heavy industries, and renewable energy can power civilization.

Batteries are the most common means of storing electricity, while hydrogen is emerging as a complementary solution. "H" is the primary constituent of us, the sun and all *hydro*-carbon fuels. Hydrogen can be obtained by using electricity to power an electrolyzer that splits water into hydrogen and oxygen. The hydrogen is stored in tanks. As needed hydrogen is recombined with oxygen in a fuel cell, producing electricity and pure water vapor — steam, which can be condensed and endlessly recycled. This system is an earthbound version of the system used on every manned space flight and space station.

What do these new energy technologies suggest? All the components for a new energy-water system exist. Taken together, using batteries for small devices and light vehicles, with hydrogen for structures and heavy vehicles, the tech makes it possible to power a city within its own boundaries.

Most homes, apartments and small commercial structures can be "solarized" within weeks to a few months. New insulation and windows are upgraded, skylights added, even "light pipes" transmitting sunlight to basements. Photovoltaics are installed on a portion of the roof, plus water and hydrogen storage tanks in the basement or foundation. Each structure or cluster of buildings, would receive electricity and heat generated by photovoltaic and solar thermal technology

via windows, wall panels and roof systems. Some of the electricity and heat would be used directly, with the remainder powering an energy-water appliance that incorporates an electrolyzer and fuel cell, and replaces furnaces, water heaters and air conditioners.

This appliance would use electricity generated while the sun was shining to split water into hydrogen and oxygen, with oxygen vented to atmosphere and hydrogen stored in tanks, aside a cistern storing rainwater captured by the roof. As needed, during the night or over cloudy periods, this appliance would recombine hydrogen with oxygen in a fuel cell, producing electricity, heat and pure water. Most of the water would be recycled in the energy system. Water used for drinking, cooking, bathing and toilets can be purified by local biological treatment facilities that mimic a marsh, and produce flowers, fish and pure water. The water can be stored underground or returned to a cistern. Groundwater functions as the reservoir to replenish losses by leakage and evaporation. A city can be its own power plant and reservoir.

This potential appliance could be mass produced in all sizes, viable for every kind of structure from adobe villages to steel high rises. The same basic format can also be replicated on large scales. For example, a solar thermal plant with hydrogen storage could power a steel mill. In cities a local grid would be needed to balance gas, electricity and/or water use in cities, as some structures would generate more than they need, others less. The larger grid, with its long distance transmission of electricity by wire, as well as gas pipelines would be unnecessary. Overall this emerging energy-water strategy is far more viable worldwide because it requires far less technology, is modular and could be purchased incrementally by all people.

After the transition to a 100% solar home the first thing residents notice is how quiet it is. If the latest lighting tech is used, combined with skylights, they will also notice how warm the light is at night, and how bright the interior is in the day, with no lights needed; many residents won't need reading glasses anymore. Everyone would feel more secure knowing their energy and water is far less vulnerable to natural disasters, distant wars or terrorists at a keyboard. Security lies in knowing everyone else has clean power and pure water.

RAILWAY REVIVAL

Many Americans assume railways are archaic. Yet railways remain the most efficient application of money, materials, energy and space, for freight or passengers, and the only viable means to relieve pressure on highways This four-car train might be carrying about 240 passengers equal to 200 cars on the parallel interstate. Each car would require 60 feet of lane and 5 parking spaces, or roughly 264,000 square feet for all cars. The train covers 8,500 square feet, or three percent the land area. All the cars might total 30,000 horsepower, while the train requires only 3,000 – 10%. Trains go faster too.

Rail is the most sophisticated steel made; produced almost continuously since the 1840s. Ties are increasingly concrete, using rail clips rather than spikes driven into oak. Steel wheels are guided and supported by the rail. The area of contact is about the size of a dime, so friction is extremely low.

5—Riding by Light

Once President Eisenhower signed legislation in 1956 it took only 15 years for the US to build 40,000 miles of interstate highways. The nation has been busy filling them up ever since, creating a collar of traffic congestion now strangling every city, costing billions of dollars in wasted fuel and time, while pumping billions of tons of greenhouse gases into the atmosphere.

After buildings transportation is the second largest consumer of energy and resources. Today all planes, trains, ships and cars burn fossil fuels, except electric passenger trains that draw power from the grid, and thus rely on a mix of coal, natural gas, nuclear and renewable energy.

Energy conservation has been advanced by hybrid cars. Electric scooters are available, and selling by the millions, primarily in Asia. Harley-Davidson recently (2014) built a prototype electric motorcycle. Riders testing the new bike loved zero to sixty miles per hour in four-seconds performance; not silent operation or a 50 mile range on a three hour charge. Electric cars are selling well, at over 100,000 now in use, and the industry is poised to grow. Plain old bikes are selling very well, even in the US, where bike path networks are steadily growing.

Two decades ago General Motors and Toyota, began multi-billion dollar research efforts to develop a "fuel cell" to replace internal combustion engines and make electric cars viable. Initially the fuel cell filled the van it powered, now it's a box with a fan under the hood. Now there are fuel cell powered buses in regular service in several cities, and GM, Honda, Toyota, Nissan, Ford and a few other companies intend to launch fuel cell electric cars in California — 2015-16.

Unlike battery electric cars, such as the excellent Tesla, which require time to recharge for a range of about 200 miles, hydrogen-electric cars can recharge the tanks in a few minutes, yielding a range in excess of 300 miles. Compared to batteries hydrogen fuel cells are more viable for heavy energy users — trucks, locomotives, ships and planes. Boeing has built small fuel cell-electric planes, and Burlington Northern Santa Fe Railroad operates a fuel cell locomotive.

In the 1980s planners in city and suburb realized highways could not be systemically expanded. Besides, excessive reliance on cars in the US has already resulted in more than half the land of many cities being paved, thus destroying

half the city to get to the other half. In seeking alternatives planners reviewed all options, only to return to railways. Trains remain the most efficient, costing less than half the money, using a fifth the land, and consuming a third the energy compared to cars. Compared to buses rail service attracts more votes and passengers.

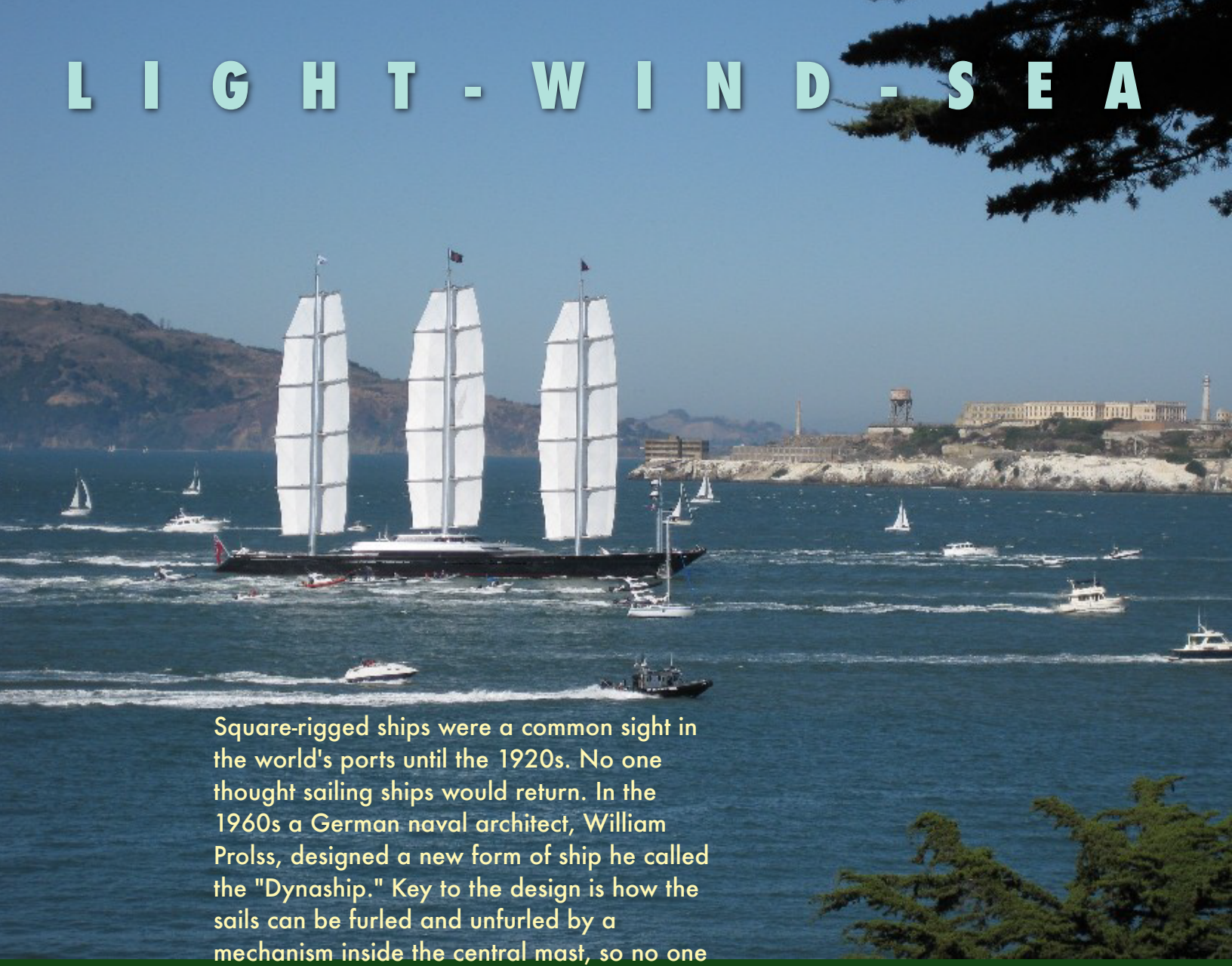
Since the 1970s over 50 US cities have built new railways, from regional subway systems in the SF Bay Area, Washington DC and Atlanta, to commuter trains, streetcars and light rail systems. Meanwhile the freight railroads are carrying more than ever on 175,000 miles of railway routes — the largest system in the world. Simultaneously nearly all developed nations have been restoring, revitalizing and expanding railways.

China is laying thousands of miles of track a year. Only a few percent of China's citizens have cars and already new urban superhighways are jammed. Since each car demands four or five parking spaces, plus road space, one car for every household of three people would translate to over 30,000 thousand square miles of parking and highways. Too many cars do not increase mobility, they strangle it.

Where does the new path lead? Electric car sales will grow exponentially, as will battery and hydrogen recharging stations powered by renewable energy. Meanwhile the US will have no choice but to fix aging highways, while adding track to existing routes and building new railways. Developing regions will grow their road network somewhat, often in concert with railways. Rail access will encourage pedestrian-oriented development around stations, in turn increased use of bikes and small "city-cars." Railways powered by sun and wind will "seed" new infrastructure outwards from every station.

Airplanes will be quieter, faster and not prone to fire or explosion, often including large windows. Ships will convert to all electric power, using fuel cells in place of diesel engines. Hydrogen would be generated at shore facilities, and on-board by photovoltaic paint covering the exposed hull. Many cruise ships will be sail-powered, in part to achieve near silent performance — just the sound of wind and water.

L I G H T - W I N D - S E A



Square-rigged ships were a common sight in the world's ports until the 1920s. No one thought sailing ships would return. In the 1960s a German naval architect, William Prolss, designed a new form of ship he called the "Dynaship." Key to the design is how the sails can be furled and unfurled by a mechanism inside the central mast, so no one need climb the rigging. It can all be managed by one person from the bridge. By the late 1980s a few cruise ships were built with several masts carrying triangular sales, and they sail today. Then Tom Perkins, a Silicon Valley venture capitalist, decided to build a Dynaship. It was launched in 2007 as the "Maltese Falcon." She is known to be fast and luxurious. Here the 298 foot yacht is sailing into San Francisco Bay for the only time. Mr. Perkins later sold the yacht to a charter firm in Europe. There will be other sailing ships of this design, and with the addition of photovoltaic sail fabric, plus fuel cell system, the ship could stay at sea indefinitely, until the passengers are tired of fish for dinner and one another over dinner.

6—Changing Climate In the Air

Three greenhouse gases — carbon dioxide, methane and water vapor — are present in excess of what the planet's plant life can absorb. Excessive carbon dioxide, absorbed by the warming ocean, turns seawater acidic, causing coral reefs to slowly die. Methane is worse than CO2 because it reflects more heat, and methane emissions are growing from melting permafrost and fracking to an unknowable degree. Water vapor will fall back as rain, methane will decay in decades, but CO2 will remain for centuries unless reduced by human actions. Ice sheets are ominously melting, a process some scientists believe is unstoppable.

Adaptation is not an option. Human consumption of fossil fuels has set in motion ecological changes that are unfolding unpredictably and compound at bookie's interest rates: one change triggers two, which triggers four, which triggers eight as ecosystems and economies unravel. Well within this century ecological changes could reduce the global population by disease, malnutrition, floods, fires and war. Tragically the Syrian civil war may have been caused in part by a drought that dried up rivers and wiped-out farmers, followed by a lack of government assistance.

The ocean is a primary means of absorbing carbon dioxide. Phytoplankton that live on the ocean's surface consume up to half the carbon dioxide produced by humanity, but they have declined due to ocean warming and a 40% decline in oxygen absorbed by the sea since 1950, which roughly parallels a similar decline in atmospheric oxygen, presumably due to deforestation and desertification. In some regions too little oxygen in seawater, plus urban and industrial pollution, has resulted in ocean "dead zones" absent of life. Too little oxygen in the atmosphere can starve the brain of oxygen, and some studies suggest this may be a factor in Alzheimer's disease.

The climate change cure does not necessarily require any new technologies, just the acceleration and elaboration of innovations begun decades ago. Three major initiatives are required: decrease greenhouse gases by conservation; develop renewable energy; and restore ecosystems to their highest level of ecological productivity in order to sequester carbon dioxide and methane, and increase the proportion of oxygen.

Conservation of energy is the first initiative. The Rocky Mountain Institute,

founded by Amory Lovins, a globally recognized energy visionary, modified a typical suburban home, using the latest insulation techniques and appliances, and discovered the home can be comfortable year 'round with no furnace or air conditioner. They also managed a recent upgrade of the iconic Empire State Building, reducing energy costs by more than a third. Other commercial buildings have been modified to reduce energy consumption by 80% plus.

In transport hybrid cars, regular and electric bikes, plus buses in some cities, and rail transit or intercity trains where available, are all popular options. In many communities the fastest and most convenient option is one foot in front of another — lunch is fuel.

Significantly the US has reduced carbon dioxide emissions about 10 percent since 2005. This was largely accomplished voluntarily by citizens and businesses making choices to invest in cleaner tech.

Renewable energy is the second initiative. Increasingly competitive renewable energy prices set the stage for exponential increases in production, lowering prices still further and feeding more sales. Meanwhile innovations now in the lab will result in tech that generates more electricity using even less stuff. As renewables take over greenhouse gas production will decline. Meanwhile use of hydrogen fuel cells will clean freshwater as the energy system filters out chemicals, heavy metals and radioactive particles.

Restoration of lands and waters is the third initiative, and it is the most significant public investment. Farming is a self-funding business that might require some community or government assistance. By comparison restoration of a watershed can be a long-term investment crossing all local and regional boundaries and requiring the involvement of many businesses, agencies and local groups.

An ecosystem is a natural economy. It is built on a web of relationships that facilitate the exchange of information, nutrients and waste between members of the community. Much like building a human economy the restoration of an ecosystem involves symbiotic relationships, where arrival of one species favors two more, who in turn attract five others. While the economic implications of ecological restoration may take awhile to fully manifest this resurgence of life can happen with astonishing speed, as if former residents were just waiting for an excuse to flourish.

A web search for "Mississippi River Restoration" will yield a few million hits listing plans and projects from the Twin Cities to the Big Easy and the Gulf Coast.

Riparian woodlands and flood plains are often the focus, restoring both would increase sequestration of carbon dioxide, while functioning as nurseries for fish. Presuming invasive species are killed such a strategy can trigger steady growth in native fish populations. As locks, dams and levees are removed the river will do its work and move accumulated silt downstream, where much of it will rebuild barrier wetlands south of New Orleans. At the very least restoration efforts will blunt the impact of a rising sea.

Ecological restoration on so large a scale raises as many scientific questions as it answers. Wetlands, for example, both produce and sequester methane, and the balance represents a complex interaction. Replication of what was is not possible, but arriving at a new balance of native and imported species is possible. The only guide in defining a restoration strategy is relatively recent natural history.

Ocean life is now starved for nutrients because thousands of rivers have been dammed. Releasing rivers would result in floods bearing nutrients and minerals, including naturally produced salts. Would this not reduce acidity, while causing a population explosion in river, estuary and coastal fisheries? Growing fisheries would represent a sizable and sustainable "new" industry.

SHORELINE WEALTH

A tidal wetland along Tomales Bay north of San Francisco. The straight embankment Is a railroad grade abandoned 84 years ago; the trestle that crossed the inlet is long gone. The embankment reduces the flushing action of tides. This is typical of thousands of miles of shorelines, where railways, highways or levees have devastated tidal estuaries , beaches and seasonal wetlands. If the railway were to be rebuilt it could be on a bridge with widely spaced piers. The fill can be removed to reestablish full tidal flow. Such ecosystems are the vital nurseries for fish, so the volume of fish living in the sea is directly related to the area of wetlands.

7—Profit by all Measures

Profit is a matter of survival. Animals, plants and people must have sufficient resources to survive winter, so all store more than enough greens, seeds, carrion, fat or cash, so come spring they're still here. The drive to survive and the ingenuity required to prosper permeates nature and business, where profit is a basic measure of survivability. No profits is like running out of firewood before the last winter storm. At least bankruptcy is preferable to freezing to death.

Many people will cite the pursuit of profits as the cause of all the world's ills, and dismiss solar energy or any such innovation, believing corporations oppose innovation they cannot control. But the ubiquitous corporate "they" are not of one mind. They are continually vying with one another for influence over external forces in a never-ending effort to survive in a business world no one can comprehend. There are century-old companies that still think they run the world, companies driven by lying sociopaths and companies displaying every behavior from breathtaking brilliance to tragic ineptitude. Given technologies changing weekly, global capital markets moving trillions of dollars per second, and a world where the weather is more unpredictable than ever, control is a fairy tale.

By comparison infrastructure is a haven of stability and certainty, where returns on investment may be modest, but dependable because infrastructure is the foundation of civilization. Every cultural, industrial and agricultural institution arises around the basics — the road, and parallel wire, pipe and cable — and so infrastructure generates a "profit" in the form of activities it makes possible. Private investors receive a financial profit on an infrastructure investment, while customers who use the service receive a financial profit in savings, plus a social profit in improved quality. Everyone cares about profits, by all measures.

The notion of economic, environmental and social profits is often characterized as the "triple bottom line." As employees, shareholders and customers adopted a more holistic view of business, many companies created policies that acknowledge economic, environmental and social profits. They recognize that high financial profits are worthless if social profits, measured by enraged customers, are low. Angry customers are a liability.

If a business is to sustain a profit and survive it must be disciplined about

costs and liabilities. Increasingly businesses tend to view pollution and reliance on non-sustainable resources as liabilities.

In the 1940s Henry Ford and his friend, the botanist George Washington Carver, built test cars using soy- and hemp-based plastic parts. They even powered a car on hemp oil. Today Ford Motor Company has rediscovered plant-based materials with an eye to reduce costs and reliance on petrochemical plastics. Five million Ford cars now have soy foam seats, and the company recently built an electric concept car molded in plastics made from corn. Such a car would produce no pollution, use no petroleum products and little energy-intensive metal, and could be easily recycled.

Nature doesn't waste anything and evolution favors economy in action. Ford's actions reflect a longstanding drive to achieve efficiency, an imperative now transforming the science of materials. Steel is now up to five times stronger than steel of 1950, and that means far less is required — a Golden Gate Bridge today would be one-fifth the mass. Airplanes are increasingly made of carbon-composite materials to achieve lighter weight and reduced fuel consumption. New materials like "graphene" seem to defy logic. Made of graphite, as used in any pencil, graphene is diamond strong, conducts electricity efficiently, yet can be so thin it's transparent and flexible. It suggests a smart phone as thin as paper and clear when not in use. Far less resource consumption can reduce costs, yet offer exceptional quality. Less can be more.

Reducing liabilities can also have a direct affect on profits. Organic farmers can assure customers their products are not leaving them, nor their community with the liability of potential cancer or poisoned watersheds. Plus, the produce is more nutritious and tastes better. These values contribute to profits. Whole Foods, a major supermarket chain, makes a few more pennies in an industry where three cents on the dollar is a good year.

Growth, as routinely expressed by corporate and government representatives, is also cited by critics as a root cause of excessive resource consumption and climate change. They often assume population, profits and economic growth are inextricably linked.

Companies are driven to sustain profits and reduce costs by increasing efficiency and decreasing resource consumption. This imperative has resulted in a fourfold increase in automotive efficiency since the 1970s, a change that benefited customers in lower fuel costs, and because higher quality cars are kept

about three times longer. All kinds of companies have achieved dramatic reductions in resource use, and even zero waste. In only a few years DuPont transformed several truckloads of solid waste per day into products sold to other companies — a cost became revenue. Resource consumption in all kinds of industries has declined dramatically over the past two decades, yet many companies still grew by increasing their market share, in part because they became more efficient. Population had nothing to do with it.

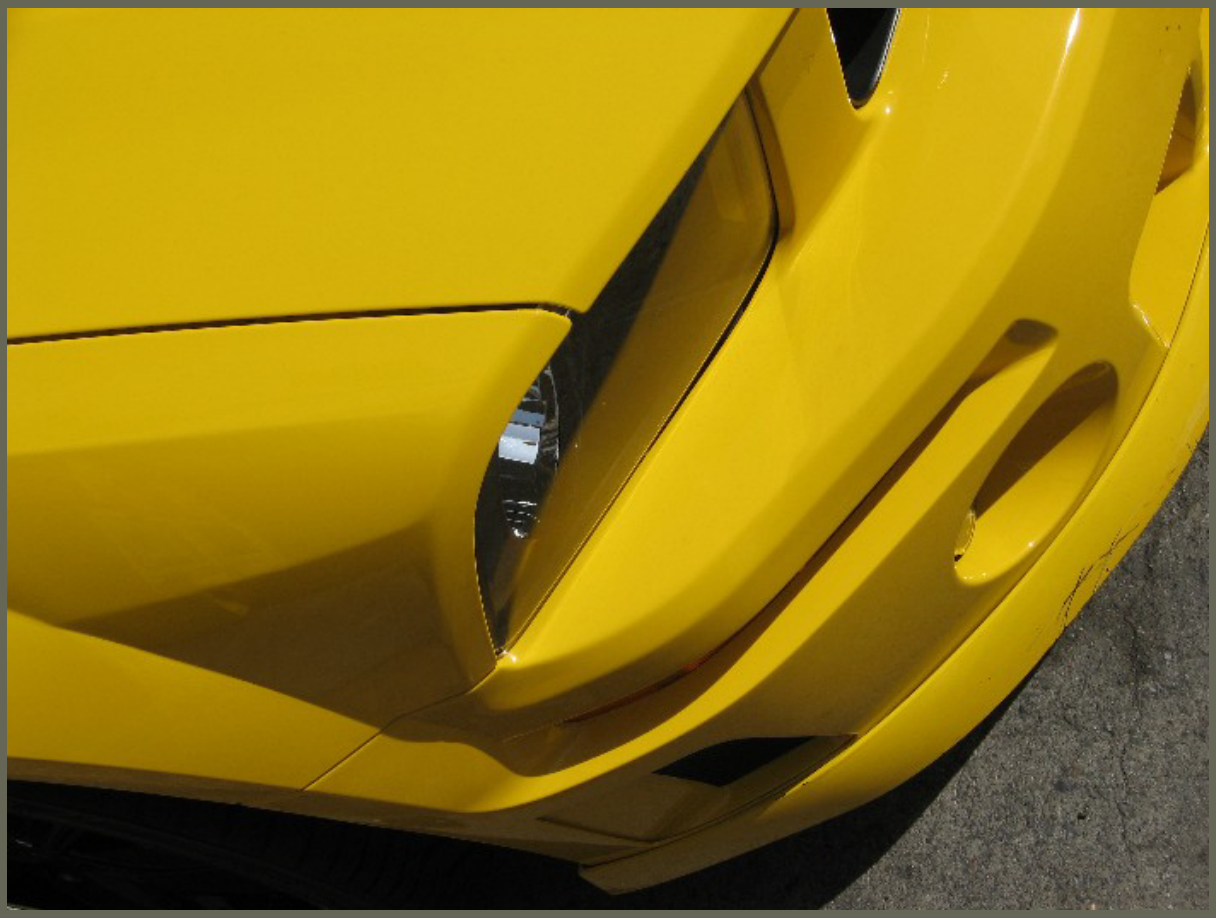
Economic growth can happen with no change in population. One town might experience economic growth by the success of a local industry, which may attract new residents, but with no change in regional population. Populations migrate, causing growth in one area and shrinkage in another. Technologies change, causing whole industries to grow at the expense of older industries. Many communities are constrained by resource limits and cannot accommodate more people, others simply decide to stop growing. Japan's population has been shrinking for several years.

Paradoxically the only way to stabilize world population may be to grow the economies of developing nations. As quality of life trends up birth rates tend to trend down. The critical first step is human rights, especially woman's rights, paralleled by availability of capital via micro-loans and regular banks allowing purchase of clean energy and pure water, plus lighting, telecomm and refrigeration tech, which leads to education, improved nutrition and a higher likelihood children will survive. Quality prevails over quantity.

Infrastructure is designed to change the world. The contemporary notion that all people regardless of income should have access to clean water, energy and sewage disposal systems, was attempted by the Romans 2,000 years ago. Today it's widely accepted that infrastructure must be equitable — everyone has the basics. But by accidents of history, and a heavy dose of colonialism, a third of the world's population remains lacking, left to rely on archaic tech and scrounging.

For the first time modern infrastructure is accessible to developing regions without government programs that may take decades. An infrastructure revolution has already begun, via cell phones, photovoltaics and car batteries purchased by residents in thousands of villages and remote towns.

Consider a major nuclear power plant complex. It might cost about $12 billion over five years to build a plant generating 1,000 megawatts. In that time,



NEW CAR ART

Cars are as much practical machines as a works of art. Like any work of art cars express the cultural attitudes of the times. The mechanics of cars have also changed, once focused almost entirely on personal power, designs now express efficiency, practical features and safety. For most people cars are pragmatic mobility, at best expressing something of the owner's taste.

Cars are becoming electric. This results in a radical reduction in moving parts. Electric motors have one moving part. Electric cars don't need radiators, transmissions and differentials, nor cast iron engine blocks. This simplification of the entire propulsion system changes not just auto design, but the design of factories, the investments they represent, and the entire supply chain.

the 200,000 homes the nuclear plant would supply could be transformed into solar homes for less than half the cost at a rate of five homes per hour. If solar systems were installed at current rates in US — 15 installations an hour — it would take about two years to equal the nuclear plant's ultimate output.

Development of new infrastructure has long been driven by local initiatives rather than massive government programs. But climate change, being unprecedented in global scope, causes politicians, pundits and the public to assume it will require an astronomical sum to fix it, coupled with big government programs and complex global treaties. Treaties and national programs are helpful in establishing standards and funding for interstate and international infrastructure, but the task doesn't require massive power plants, new grids or dams.

Paradoxically new infrastructure is more a matter of changing components and subtracting resources. Houses don't need to be new, just modified. Commercial vehicles needn't be all new, just the engine and drivetrain. Railways need new track on existing routes, some all new routes and locomotives, but not all new railcars. River restoration may involve heavy earthworks to protect a town from floods, but much of the work is about removing impediments so the river can function. We don't need new land, we only need to restore "used" land to maximum ecological productivity in wild species, or use new modes of farming to restore soil and produce more with less by emulating nature.

Climate change is a challenge to human creativity, but it's not insurmountable. Innovators aren't waiting. New infrastructure is happening now, as grassroots, corporate and government efforts all over the world. Many national governments are sponsoring projects, although US federal infrastructure investments have generally declined. As a result most recent investments in US infrastructure represent state and local funds, plus private investments.

For many years the US has been averaging about 3% of gross domestic product on infrastructure, roughly $540 billion, while the world averages about 7%, or $1.3 trillion if the US met the global average. This lack of critical investment is attributable to general ignorance, plus a federal budget drained by wars and the production of weaponry. Federal money is lavished on an infrastructure of fear, expressed by drones, missiles and security cameras, not on new infrastructure that would reduce fear.

Financing infrastructure may seem daunting given the billions required to

build stuff, but large numbers are misleading unless presented in context. Unlike any other business infrastructure is pervasive by definition. It must serve millions of people, so projects often cover large areas and cost in the many billions, yet the cost per person may be very small. For example, doubling the 175,000 mile US railway system and fixing highways might cost $3 trillion over 15 years. Annual debt service would reach $150 billion — a 40 year loan at 4% interest. That translates to about $1.25 per capita per day, with $.75 privately financed, covered by revenue from railway services, $.25 by user fees, covered by gas taxes and local property assessments, and $.25 is covered by sales taxes. Few people would even notice the expense.

Everyone would notice the benefits, in saved time and money by passenger trains and less highway congestion. Many businesses would notice lower shipping costs. If railways shift to renewable energy everyone would also know they represent a massive reduction in carbon dioxide and water vapor. Railway savings would exceed the cost — a public profit.

Seek profit by all measures to all people. Ecology and economy are inextricably bound, for without the work done by nature there would be no fishing industry, no lumber business and no agriculture. If we look at nature as a business it's currently saddled with unnecessary costs that have constrained production, compromised quality and killed product lines. The business climate is lousy and getting worse. Why? Because one species wastes natural resources. They sold the assets, rather than live on the interest, leaving an excess of carbon dioxide on nature's balance sheet.

Nature is not apart from humanity's quest for economic, cultural and ecological values. There is ample evidence that people are inherently attracted to nature, and feel tranquil in the natural world. Human economy and spirit relies on nature, so the restoration of atmospheric balance by restoration of land and waters is the most fundamental and abiding investment. Visions of utopia invariably include a generous dose of nature.

Much is said about peace and war, little about the roots of either. The roots of peace are the technology of wires, pipes, rails and concrete — the stuff that connects us. These things are not mere engineering for convenience, but links that facilitate our economic and social lives. Absence of quality infrastructure sets the stage for conflict over resources; presence of infrastructure sets the stage for sharing resources. Sharing is not a political ideal, it's a fact of every breath we take.

First there must be mobility, so people can visit other places and get to know one another. Many people might view tourist travel as a leisurely pastime not a serious industry. Yet tourism is one of the world's largest industries and undoubtedly it has had a significant affect in reducing global conflict. Billions of people over two centuries have experienced meeting the "other" from a faraway place, perhaps over dinner or drinks, and feeling a sense of delight in realizing how much they shared. Millions of others did more than shake hands. According to modern genetic research the biggest shift in human genetics was triggered by railways beginning in the 1850s. National conflicts are less likely when businesses, friendships, love affairs and families cross all lines.

Perhaps the best strategy to cope with conflict in the Middle East is to build common infrastructure. The region desperately needs a shared experience, where everyone is at least sharing the technology of today. Significantly the region is developing new railways.

The true "profit" lies in knowing the planet's vital signs are improving, as carbon dioxide counts drop and oxygen counts rise. This profit is visible in forests and grasslands exploding with life; farmlands resembling gardens and laced with wild corridors; and restaurants serving a greater diversity of produce, fish and meats — wild and domestic. There's a profit in reduced health care costs by better nutrition, less pollution and fewer car accidents; in the empowerment of countless communities via renewable energy and pure water; in the pride of good jobs doing vital work; and in fewer conflicts due to a rising quality of life.

The task is to invest in improving infrastructure and quality of life for all. In the process climate change can be reversed and life can flourish. All the necessary technology exist today, and as each new challenge arises it's likely the tools and people to meet that challenge will arrive, just as a small group of innovators emerged decades ago to create a new future. Their vision was about the deepest bond all people share, the obligation to protect the land and the waters of home. They arrived right on time.

Beyond the oft-criticized new age language of the human potential movement there is a profound idea: potential. It means a latent capability possessed by everyone that may manifest in the future. New infrastructure, for the first time ever, can deliver water, power, information and mobility to everyone, and in so doing unleash the potential of the world's population.