View Point

Renewable Energy, Energy Conservation, and US Rangelands

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On the Ground

- Depletion of conventional oil and natural gas reserves, rising world demand for fossil fuels, and changing geo-political conditions necessitate that the United States aggressively develop both renewable and nonrenewable energy along with increasing energy conservation and efficiency. This will affect how rangelands are used, create income opportunities for ranchers, and expand employment opportunities for professional range managers.
- Air and ground water contamination and increased earthquakes could be serious environmental challenges from expanded development of unconventional fossil fuels. Renewable energy development involving wind, solar, and biomass also have environmental hazards. Rangeland managers in the future must be prepared to minimize and ameliorate environmental damage from different types of energy developments while optimizing energy production with traditional rangeland uses.
- In our view, government policies encouraging energy conservation could significantly reduce rangeland losses to urban and ex-urbanization, dependence on foreign oil imports and carbon emissions. They would also extend the longevity of fossil fuel reserves providing a hedge against possible failure of renewable energy sources to meet future needs.

Keywords: rangeland, renewable energy, energy conservation, ecosystem services, geopolitics.

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In the December 2014 issue of ***Rangelands*** we examined issues relating to the effects of energy development on rangelands and ranchers in the United States, emphasizing conventional and unconventional fossil fuels.[1] Although we briefly mentioned renewable energy resources and energy conservation, many important details relating to their significance in US energy security and their importance to rangelands and ranchers were not discussed. Since publication of the article, which focused on unconventional fossil fuel development in the United States, there has been a crash in oil and natural gas prices, increased information on shale oil and gas reserves, stiffening environmental resistance to shale oil and gas development, bans or restrictions on shale development in certain localities, increased information on the environmental/human health effects of fracking/horizontal drilling, and release of the Environmental Protection Agency (EPA) report on fracking. In this view point article, our objective is to consider how renewable energy development and energy conservation might affect rangelands and ranching in the future. We provide an update on shale oil and gas information.

The Case for Renewable Energy Development

The case for aggressive development of renewable energy sources centers around the eventual depletion of nonrenewable fossil fuels (oil, natural gas, coal) and that they minimize the threat of catastrophic global warming by reducing fossil fuel use. However, we previously reviewed studies showing that renewables in general are inferior to fossil fuels in their energy output to input or energy return on investment values and are therefore a more costly source of energy than fossil fuels.[1] There is much uncertainty and deep controversy over the adequacy of fossil fuels, especially oil and natural gas, to meet global and national energy needs over the next 30 years. Already the US Energy Information Administration (USEIA) has made major downgrades of unproved natural gas reserves for the Marcellus formation in Pennsylvania and Monterrey formation in California.[2,3] A detailed analysis by geologist David Hughes of the seven tight oil basins and seven gas basins that account for 88% of current shale oil and gas production was released in November 2014.[3] The report casts strong doubt on the optimistic shale oil and gas scenario between now and 2040 presented by the USEIA. Hughes disputes conventional wisdom that the shale boom will last for decades, that high-quality shale plays are ubiquitous, that emerging plays will always fill the gap from declining production of existing plays, and that domestic oil and gas production in 2040 will be near current levels.[3,4] Very importantly, Hughes strongly challenges the belief that technological advances improving capability and efficiency in oil and gas extraction can compensate for the increasingly difficult geology of remaining oil/gas resources.[3,4] Overall Hughes projects the US tight oil production at a little more than half and shale gas production at one-third of USEIA[2] estimates for 2040. According to Hughes, this means that the United States should use its temporary fossil fuel bounty to develop a sustainable energy policy based on increased energy conservation, improving energy efficiency, and rapid transition to renewable energy sources.

Hughes' report has high creditability because his methods involved well-by-well calculations for shale oil and gas fields throughout the United States and his previous work caused the USEIA to downgrade its estimates of recoverable oil from the Monterrey shale formation in California by 95%. After reading various reports by the USEIA, the International Energy Agency, and other sources, we believe that there is great uncertainty regarding the magnitude of remaining fossil fuel resources, how long they will last, and development of improved technologies to extract them. However, we have little doubt that the adverse economic consequences of greatly overestimating the future capability of oil and gas resources to meet future needs could be catastrophic. Therefore, we consider it a prudent hedge to begin gradually implementing Hughes' recommendations regarding energy conservation, energy efficiency, and transition to renewable energy as a hedge against potential catastrophe. Global warming, environmental/human health concerns, and financial problems relating to development of unconventional fossil fuels are additional reasons we believe Hughes' recommendations have merit.

Update on Shale Oil and Gas Development

Oil prices have dropped by more than 50% since July 2014 as a result of an increase in US tight oil production, a slowing world economy, increased oil output from Saudi Arabia, and a strengthening US dollar. Lower oil prices are reducing drilling activity for shale oil, but it is uncertain as to how much this may eventually depress production and what the effect will be on oil prices. Policies of the US Federal Reserve Bank since 2008 to stimulate the economy involving extremely low interest rates and quantitative easing have been blamed in part for the world oil glut.[5] These policies have resulted in heavy borrowing by various shale oil producers to expand their output.[3–5] Apparently most shale oil producers need oil prices above $70 per barrel to be profitable.

Environmental resistance to fracking in America may become a serious impediment to expanding shale oil and gas production in the future.[3,6] In the November 2014 election, American communities voting on oil/gas fracking bans were evenly split (four against, four in favor). New York has banned fracking, whereas Pennsylvania voted to replace a highly profracking governor with one taking a moderate approach. It is noteworthy that the residents in Denton, Texas, which is the birthplace of fracking and one of the most fracked areas in the United States, voted to ban fracking. However, unfortunately for Denton, the state of Texas subsequently banned fracking bans. The debate on fracking centers on positive economic benefits (jobs, lower energy costs for consumers, stronger US economy, increased tax revenues, increased landowner income, more local business income) versus quality-of-life negatives (environmental pollution, more noise, community disruption, earthquakes).[3,6] Human health issues regarding polluted water and contaminated air are the major concerns people have about fracking.[6,7] Actual scientific reports evaluating human health hazards from fracking have been lacking but initial findings of a major investigation by the EPA were released in June 2015.[7] The EPA found no evidence of widespread systemic effects on drinking water resources in the United States. However, the agency did report that fracking has repeatedly contaminated drinking water, which runs contrary to oil industry denials. A recent investigative book titled ***The Real Cost of Fracking*** documents the effects on small farmers in Pennsylvania and strongly warns that fracking poses a dire threat to the air we breathe, the water we drink, and even our food supply.[6]

According to a new report released from the US Geological Survey, fracking operations appear responsible for a dramatic increase in earthquakes in eight states.[8] Although fracking itself can cause earthquakes, most of these earthquakes are primarily from the injection of byproduct wastewater from fracking operations into underground wells, which can activate subsurface faults. Although Oklahoma, Texas, and Ohio have received the most publicity, Alabama, Arkansas, Colorado, Kansas, and New Mexico are also at risk for more and bigger earthquakes. Damage to buildings from the increased earthquakes is the major economic concern, although financial estimates are lacking to date. The increase in earthquakes has been most dramatic in Oklahoma. Before 2008, the average number of earthquakes greater than the magnitude of 3.0 in Oklahoma was two or three per year compared with more than 300 in 2014.[9,10]

Most of the increase in world oil production since 2006 has come from the United States and Canada, primarily in the forms of shale and tar sand oil.[2–4] Because this unconventional oil is expensive to produce, much of this added supply may disappear from the market if oil prices remain below $70 per barrel for several months.[3–6] This could cause several of the highly leveraged shale oil companies to go bankrupt. Various major and minor oil companies have instituted large-scale budget cuts in both conventional and unconventional oil exploration and development projects. There is concern that these cuts will eventually result in a global oil shortage, with prices skyrocketing above $130 per barrel.

Overview of Renewable Energy Development

Although much progress is being made in development of renewable energy sources (primarily wind, solar, and biomass), there have not yet been any major breakthroughs that will drastically reduce our dependence on fossil fuels. The USEIA estimates total renewable energy will provide 12% of US total

Figure 1. Wind turbines on rangeland in southern California. Wind power now provides about four percent of electricity needs in the United States.

needs in 2040 compared with 9% in 2015.[2] Fossil fuels are projected to provide about 80% of energy needs in 2040 versus 82% in 2015.[2] Nuclear power is likely to remain constant, accounting for 8% of total US energy consumption. Wind and biomass are estimated to account for most of the 3% increase expected in the importance of renewable energy. Many advocates for renewable energy are much more optimistic, however, believing renewable energy could provide 20% or more of US energy needs and perhaps 30% to 40% of those for the world by 2040. In the next section, we evaluate the status of wind, biomass, solar, and other renewable energy sources.

Wind Power

Wind power development has had strong advocacy among environmental groups because it is widely distributed, plentiful, clean, and requires relatively little land.[11,12] Despite heavy subsidization and reductions in turbine costs, the cost of wind power is marginally competitive with fossil fuels as a source of electricity. Although wind power has experienced a boom, growing from 1.3% in 2008 to 4% in 2014 in production of the nation's electricity (Fig. 1), future growth is in doubt because of the US government suspending wind power subsidies on January 1, 2014.[12] On the positive side, improved wind turbine technology is reducing wind farm construction costs. These improvements involve longer, lighter turbine blades, increasing turbine productivity, and higher storage efficiency. Wind turbines without blades are being developed.

There are several impediments to wind power becoming a major energy source. Despite wind having potential to provide the world with unlimited energy, the materials used in wind turbines, especially iron, would become a major constraint if the United States decided to rely on wind as its primary source of electricity.[13] The problem with iron is that the higher grade/more easily extracted sources are being depleted. Wind power generation also requires high amounts of copper, which is becoming costly because of depletion of easily extracted reserves.[13] Wind farms are expensive to build and every time federal tax credits have been removed, wind farm construction falters.

Because wind velocities can be highly variable on an hourly, daily, seasonal, and to a lesser extent annual basis, wind power must be combined with a costly back-up power source typically involving fossil fuels or hydropower. Therefore, incorporating wind power into a grid as the primary electricity source is a significant engineering and financial challenge. Storage batteries that can be placed on individual wind turbines are being developed, but their capacity and cost-effectiveness are in doubt. Combining solar and wind power systems is a promising strategy to combat the intermittency problem with both energy sources. To some extent, they complement each other as windy days typically have cloud cover, whereas sunny days are often still. A cost often overlooked in financial analyses of wind power is the need for periodic maintenance and replacement parts for the turbines.

Additional problems with wind farms involve loss of esthetic values in natural landscapes (rangelands) and the associated increase in power transmission lines.[14,15] People living close to wind farms often complain about the noise and loss of sleep.[15] Wind farm construction can adversely affect birds, especially raptors.[14,15] One positive aspect of wind power development is that it has become an important source of income for many private land ranchers. They typically receive $3,000 to $5,000 annually per active wind turbine.[16] According to reports, livestock ignore wind turbines and graze normally, but this needs better evaluation.[17] The wind industry in the United States generates thousands of jobs and wind farms provide important tax income to ranching communities.

In the past couple of years, wind power has become more competitive with coal as a source of electricity. This has led to the view that it must now stand on its own without subsidies. The counter view is that subsidies have accelerated wind power development at a time when critical materials such as iron and copper are still readily available and affordable. Ten years in the future, both fossil fuels and essential metals may be much more expensive which could make wind power development far more costly than now.

Biofuels

Biofuels can include all types of plants, but sugar cane, corn, palm oil, and algae show the greatest potential to supplant fossil fuels at a meaningful scale. The USEIA projects biofuels will provide 2% of total US energy needs by 2040.[1] Some high-fiber plants that grow on rangelands, such as switchgrass (***Panicum virgatum***), cottonwoods (***Populus sp.***), and hemp (***Cannabis sp.***), have potential as biofuels through use of bacteria to convert cellulose into ethanol. However, without expensive treatment, the cellulose does not readily ferment into ethanol. Researchers are aggressively working on this problem and there is hope that eventually various kinds of plant residues from rangelands, forests, and farmlands can be economically converted to biofuels.

Algae has received a lot of hype as a fossil fuel replacement, but it has several constraints that cause it to be at best a biofuel of the distant future.[18,19] Some of the problems in commercial algae production involve selection of the right algae species, sensitivity to temperature swings, competition from bacteria, and competition with other algae species.[18,20] Unfortunately, the high oil algae have low resistance to viruses, which necessitates growing them in closed, regulated systems without exposure to open air. All the inputs in terms of equipment, structures, nutrients, harvesting, and processing are costly.[18,21] Another problem is that large amounts of phosphorus are needed.[19] This nutrient is expensive and its depletion poses a major threat to world food production.[20] By some estimates, oil prices would have to reach $500 or more per barrel for algae to be a viable fuel alternative.[18] Hopefully, future breakthroughs eventually will make algae a competitive fossil fuel replacement.

Several energy experts doubt biofuels will ever become a major supplier of US or world energy requirements.[4,11,15,22] Low energy output-to-input ratios; high land requirements; large reduction in cropland for food production; destruction of wildlife habitat; and need to use large inputs of other critical resources such as water, natural gas, phosphorus, and potash all constrain biofuels as a fossil fuel replacement. Presently, almost one-third of the US corn crop is used to produce ethanol, which accounts for 3% of US oil consumption.[11] Sugarcane and palm oil plantations are replacing large areas of rain forest in countries such as Brazil and Indonesia accentuating global warming, loss of biodiversity, and displacement of indigenous species.[11,23,24] Because of soil erosion and nutrient depletion, sustainability of these biofuels operations is uncertain. Another likely problem is that some potential biofuels could also become invasive species. Under these conditions, there is strong doubt that biofuels will provide more than 3% or 4% of world energy needs by 2050.

Solar Power

Almost unlimited solar energy is available for conversion into electricity, but there are many constraints on its development as with wind and biomass. The positives for solar power are that it involves no direct atmospheric pollution and facilities have low maintenance and no fuel cost.[11] The negatives are high costs for materials and installation, large-scale need for transmission lines, intermittency of sunlight due to cloud cover and night, and energy sprawl.[11,15]

Solar installations have required high levels of government subsidization for economic feasibility.[11] Because of bolstered government renewable energy initiatives, solar energy development has increased rapidly under high oil prices such as in the 1970s and presently. Over the past 5 years, solar power production in the United States has grown >50% per year but it still accounts for <1% (0.2%) of total energy consumption.[2] Although improvements are steadily being made in solar energy collection and storage, solar electricity is still at best 20% to 50% more expensive than that from natural gas or coal when all costs are considered. There is strong doubt that solar power could ever provide more than 20% of US electricity needs. The major constraint on solar power development is that it requires large amounts of metals like aluminum, copper, and lanthanides that would become scarce and costly if widely used nationally and globally.[13] Fossil fuel depletion is driving up energy costs for finding, extracting, and transporting metals needed for massive solar and wind power expansion. This vicious cycle of higher energy, metals and installation costs limits solar power as a major fossil fuel alternative.[13] The most promising use of solar energy is that harnessed from home rooftops and converted into electricity for daytime lighting, refrigeration, television, computers, electronic gadgets, and so on. Potentially, this could meet 15% of US electricity needs.[11] Without some major breakthroughs regarding storage for night use and substitution of less expensive materials, however, solar power use will probably be limited to sunny locations for individual homeowners and businesses. Another drawback to solar power is that photovoltaic panels must be cleaned about once a month as dirt accumulation diminishes their output.[11] In desert areas, water availability and this added maintenance cost further limits large scale solar development.[11]

Significant progress has been made in lowering the cost of solar panels and improving storage of captured solar energy using lithium batteries, as summarized by De Decker.[25,26] Even with these improvements, though, solar energy will probably provide only 5% to 10% of total US energy needs by 2050 (Fig. 2).

Presently, the future of large-scale solar development is uncertain as a result of cheap natural gas prices and the 2016 presidential election. We recognize that if large-scale solar development receives more nationwide emphasis, as is occurring in California, that effects on rangelands, water, and wildlife will become much more significant. Presently, information on environmental effects from solar development is limited, however, much can be learned from California.

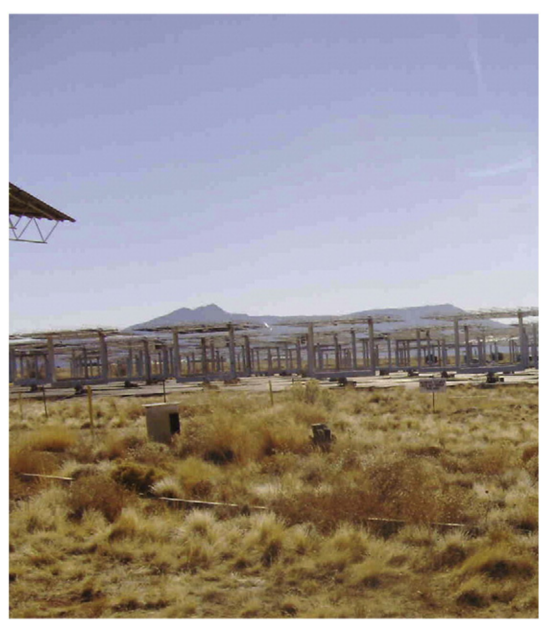

Figure 2. Solar energy development on central New Mexico rangeland. Lowered costs for solar panels and improved battery storage in the past few years have caused solar power development to rapidly increase. It now provides >1% of US electricity needs.

Other Renewable Energy Sources

Hydropower, geothermal power, tidal power, and fuel cells are other important renewable energy sources, however, at present none can solve problems relating to fossil fuel depletion and carbon emissions. The United States currently obtains about 3% of its energy from hydropower, and it provides 5% to 6% of world energy needs.[2] In the United States, the potential for more hydropower is small as nearly all the best sites for harnessing this resource have been developed.[11]

There are important drawbacks to hydropower from dams, such as disruption to the ecology of rivers; harm caused to fish populations; and inundation of large areas, displacing people and wildlife.[11] Further dam building lacks public support in the United States, and some dams that block fish migrations are being torn down. Silting is reducing electricity output of several large dams. Because of these factors, the role of hydropower may actually decline in America's energy future.

Geothermal power can be expanded, but it will be primarily a local source of energy.[11] Capital costs for exploration and drilling can be high and there are environmental drawbacks. Toxic chemicals and greenhouse gases can be by-products from geothermal development. Over time, significant losses in power production and land instability problems have occurred for some geothermal developments. Although geothermal production can be increased, it will at best contribute only 2% to 3% of total US energy needs in 2040.[2]

Tidal power comes from harnessing the energy of ocean tides into mini-dams for electricity generation. Tidal power does not require massive capital or a fuel source and produces no pollutants.[27] The main problem is that only a few good sites are available, so it is unlikely to be a significant contributor to US or world energy needs.[27] Optimists have touted fuel cells with hydrogen as the energy provider as a primary solution to world energy problems. The major problem with this method is that hydrogen is not readily available in pure form and must be derived from natural gas or water.[24,27] The dream is to split hydrogen from seawater using solar energy.[24] However, major technological improvements and cost reductions will be needed to make this economically feasible.[24,27] Even without the problem of hydrogen production, fuel cells are quite expensive to manufacture.[24,27] The infrastructure for a fuel cell economy would be quite costly even if hydrogen could be cheaply synthesized.[24] At best, a fuel cell/hydrogen economy is 40 to 50 years away.[24]

In closing this section, we recognize that we have not discussed every possible energy alternative such as nuclear fusion, small nuclear reactors, and river turbines as well as problems relating to the electrical grid in the United States. For readers wanting more inclusive coverage of energy challenges and solutions, see Abraham[11] and Bryce.[15]

Energy Conservation and Efficiency

The surest, quickest approach to reducing use of fossil fuels is to increase energy conservation, but this lacks the support of US citizens. The basic problem is that energy conservation involves lifestyle and taxation changes that run somewhat contrary to the "American Dream" of unlimited material abundance, high emphasis on consumption versus saving, and a view that technology can solve any problem.[22,27,28] Most energy conservation approaches that can drastically reduce fossil fuel use involve some kind of restriction on mobility or consumption taxes. Per capita oil use in Europe is only about half that of the United States because Europeans live in smaller homes; many live in high-density, multilevel apartments; they live closer to work, schools, and shopping; they drive small, fuel-efficient cars; they drive less for pleasure; they use less heating and air conditioning; and they heavily tax energy consumption. Gasoline taxes are high throughout Europe, and nearly all major roadways involve periodic tolls. Mass transit involving buses, subways, and trolleys is well developed in European cities. Trains rather than planes and cars are commonly used for transit among European cities and countries.

So far, no high-profile politician or president since Jimmy Carter (1977–1980) has advocated energy conservation in the United States. The delayed gratification of energy conservation is a hard sell for a society used to getting things immediately and at low cost. Because energy is still relatively cheap in the United States, the energy conservation benefits of less dependence on foreign oil, more contained energy prices in the future, more time to develop alternative energy, reduction in atmospheric pollution, less congested cities, less time spent in long commutes, and a simpler, more efficient lifestyle do not resonate politically. Major health benefits could result from these changes, as people would walk and bike more often and possibly eat more food from home gardens and local farms. A large reduction in the loss of rangeland and farmlands to urban and ex-urbanization is a major indirect benefit from energy conservation geared toward changing transportation and community structure.[29] However, reducing agricultural land losses to urbanization does not seem to be of much concern to most political leaders.

We roughly estimate that a switch to more fuel-efficient cars and electric vehicles could drop US oil consumption from nearly 19 million barrels per day (mbd) to 16 to 17 mbd within 10 years. In making this estimate, we assumed a 30% increase in fuel efficiency of the automobile fleet. Transportation accounts for about 70% of oil consumption in the United States. Aggressive development of mass transportation in major cities coupled with opportunities and incentives for high-density living in or near city centers could drop oil consumption another 2 to 3 mbd.[29] Generally, urban planners and energy experts agree that the low-density, car-dependent, suburban lifestyle that quickly developed in 1950s America is unsustainable.[28,30] Unfortunately, converting to high-density intercity living will be costly, slow, and economically painful. Both home and car ownership are key parts of the "American Dream."[30] Unlimited immediate mobility with one's own car and spacious living in one's own home define the American lifestyle.[30]

We do recognize that US population growth will to some extent nullify the benefits of increased energy conservation. By 2050, it is projected that the US population will increase by

33%, adding 100 million people,[2] making increased energy conservation even more essential. A recent report by the National Research Council recommended that policies favoring compact development should be encouraged at federal, state, and local levels.[29] The report projected that a major shift to compact development could reduce US fossil fuel use by ≥ 20% and significantly curb carbon emissions.

We doubt any major switch to high-density living in mid- to high-rise apartments coupled with mass transit by buses, trains, or subways will occur in the western United States until it is forced on Americans by an extended energy crisis in which oil prices more than triple ($150 per barrel) and gas is not always available at the pump. Zoning laws will have to be changed to allow high-density, high-rise apartments and to permit integration of housing, schools, businesses, and shopping. These changes are not popular with most state and local governments, especially those in the West.[30] Although the benefits of high-density living are not well appreciated by most Americans, there is a new trend developing in this direction.[30] Apparently, many young people and some aging baby boomers near or at retirement are showing preferences for the simplicity, convenience, and lower living cost of condominiums and well-designed apartments close to or in city centers. Several cities scattered across the United States are now revitalizing their centers to accommodate this trend.

Home prices in suburban and exurban areas on the edge of the large cities took some of the biggest hits in the real estate bust of 2008 and have been the slowest to recover.[30,31] Large numbers of unoccupied and partially constructed homes now occur in many outlying suburban and exurban areas in the western United States. At gasoline prices >$3 per gallon, living costs are too high for many people if they must make several long commutes for various daily activities (work, shopping, schools, health care, entertainment).[30] Some long-term planners believe that as oil prices rise, there may be a significant trend for many suburban and exurban areas to revert back to rangeland and farmland. Salvaging materials in abandoned buildings and implementing alternative uses for these lands could be potential new enterprises. Detroit, Michigan is at the forefront of this reversal, but several other cities such as Chicago, Cleveland, and Saint Louis are drifting in this direction.[30] If gasoline prices reach $10 per gallon within the next 10 years as some energy experts expect,[32] large-scale abandonment of exurban communities throughout the western United States might occur. Abandoned exurban housing is already a problem in several western states such as Arizona, Nevada, and Colorado.[28,30,31]

In addition to the high fuel and automobile costs for low-density exurban living, indirect costs for infrastructure installation and maintenance in terms of highways, roads, bridges, power lines, water lines, and natural gas lines are also substantially increased on a per dwelling basis.[28,30,31]

Energy Efficiency

Energy efficiency improvement involves reducing the amount energy wastage in lighting, home heating and cooling, and operating various appliances and electronic products. We also put electric cars in the energy efficiency improvement category. Various improvements in energy efficiency discussed previously potentially can reduce electricity use by ≥ 50% over the next 20 years.[33] Some examples are improved light bulbs, smart lighting involving motion sensors, and improved insulating materials for buildings. Although many energy efficiency improvements have occurred over the past 30 years involving appliances and insulation, total US energy use has risen about 28% as a result of an increased number of households and more appliances and electronics per household. Because electricity is still relatively cheap in the United States, Americans have typically responded to efficiency improvements by increasing electricity consumption.[11] To curb electricity consumption, a major increase in electricity cost will need to occur in response to fossil fuel depletion. Higher taxes on energy consumption can be used to lower energy demand and pay for improving the electrical grid, maintaining highway infrastructure, and light rail development. Some advocates of higher consumption taxes suggest they be offset by reduced income taxes so overall taxes are not increased. Although consumption taxes can be a powerful incentive to increase energy conservation and efficiency, their implementation is politically contentious and therefore this alternative may not be viable in the United States.

Examples of how energy demand is reduced at price thresholds deemed unaffordable have been previously provided.[11] When gasoline prices rapidly increased to $4 per gallon in the first half of 2008, gasoline demand began to level off, sales of gas-guzzling vehicles declined, and sales of fuel-efficient cars increased. However, when gasoline prices fell sharply in fall and winter 2008–2009, this situation reversed as Americans lost their incentive for fuel efficiency. Both Rubin and Steiner provide thought-provoking insights into how American lifestyles might change in regard to rising energy costs.[32,34]

Vehicle fuel efficiency plays a critical role curbing oil use because transportation accounts for 70% of oil consumption.[11] Both electric cars and major increases in fuel efficiency have much potential to combat rising transportation costs. Presently, 23 miles per gallon (mpg) is the average fuel efficiency for US automobiles, but new cars and light trucks are mandated by Congress to have a fuel efficiency of about 28 mpg. The goal is to increase fuel efficiency to 54.5 mpg for new cars and light trucks by 2025. Although small "smart cars" that get in excess of 40 mpg are available from Europe, in general most Americans still prefer larger vehicles because they can afford gasoline at $3 to $4 per gallon.

Electric cars and hybrid electric cars have not yet become popular because they are more expensive than conventional cars by roughly $10,000. Savings in gasoline costs do not yet compensate for higher car costs with electric vehicles. With straight electric cars, keeping the battery charged and periodically replaced is both time consuming and expensive. Electric cars with cheaper lead batteries typically have a 40- to 50-mile cruising range, whereas those with the new, more expensive lithium batteries now have a maximum range of ≥ 200 miles. Various improvements are occurring in batteries for electric cars involving increased cruising range, shorter charging times, and longer life. Nevertheless, it seems probable that Americans will switch to more fuel-efficient gas cars before widely adopting electric cars or hybrids. In the near future, substantial increases in fuel efficiency of gas cars (60–80 mpg) are quite possible and could long delay widespread electric car use.

Other potential problems relating to widespread electric car/hybrid use are excessive stress on the electrical grid, higher electricity costs due to increased demand, supply/cost issues for both lead and lithium used in electric car batteries, and copper depletion (hybrids and electric cars involve much higher amounts of copper than gas cars).[15,32,35] Presently, sales of electric cars and hybrids account for nearly 4% of sales of new cars in the United States. By some estimates, this number may reach 8% to 10% by 2020, with optimists projecting 33% to 35% by 2030. It seems probable that by 2030, electric car use will become common for short-range trips (<50 miles) but their use for long-range travel will be limited unless major breakthroughs occur that reduce their cost and improve battery capability.

Concluding Thoughts

Without major improvements in energy conservation and energy use efficiency coupled with major breakthroughs in renewable energy development, it is doubtful that development of unconventional oil and natural gas sources alone can avoid a very painful energy shock that could devastate the US and world economy.[4,22] Presently, the world economy involves extreme globalization, specialization, intercountry dependency, and complexity that depends on heavy use of abundant cheap energy in the form of fossil fuels. To conserve energy, some level of movement back to self-sufficiency, balanced trade, and more localized living seems essential. In the United States, this will mean major lifestyle changes that involve expanding mass transportation to reduce car use, shifting from income to consumption taxes, and changing development patterns from low-density sprawl to more compact, high-density communities where schools, shopping, and housing are in close proximity.[22,28,34]

In terms of national security, we consider it critical that US rangelands and farmlands be kept as working landscapes to meet multiple needs (food, water, wood, energy, recreation, wildlife, ecosystem services) and protected from urbanization and fragmentation as much as reasonably possible. Although US agricultural land losses to development have declined since 2007, they still remain too high for sustainability. Between 1982 and 2010, when the real estate bust occurred, the United States lost 46.6 million acres of agricultural land (1.66 million acres per year) to development.[36] Roughly 21% (10.03 million acres) of this land was rangeland. Annual rangeland losses averaged about 358,000 acres per year. Since 2007, annual loss of total agricultural land to development in the United States has been reduced to nearly 800,000 acres with rangeland losses probably accounting for approximately 160,000 acres of this total.[36] The United States (Alaska not included) is about 1.95 billion acres in size and about half of this area can be classified as rangeland assuming most forest land is grazable. About 5.8% of the land in the United States is considered developed compared with 3.6% in 1982.[36] Loss of rangeland to housing development has dropped significantly since 2007, although this varies by state and information is lacking.

Changing demographics, increased living costs, and tighter credit all account for the slow change from population dispersal into the rangelands back into the urban areas and cities.[30,31] We believe a trend is now beginning within rangeland landscapes in the United States for people to prefer to live in towns and villages as opposed to ranchettes and low density ex-urban developments. This is in response to stagnant incomes coupled to rising fuel, electricity, food, school, and health care costs. An important factor as this trend develops may be an aversion to energy developments that is possible for compact high-density communities but not practical for homes scattered through working rangeland and farmland landscapes with various kinds of energy developments. Homeowners who live in areas newly affected by shale oil and gas development (and also wind farms) typically experience reduced property valuations and often complain about adverse effects on their health from the increased noise, dust, human activity, and bad odors.[7,37,38]

In contrast with recent decreasing rates of rangeland loss to ex-urban development in the western United States, a new study reported a sharp increase in rangeland loss to gas and oil drilling across central North America between 2000 and 2012.[39] According to the study, rangeland and forestland loss across the region (which includes the central provinces of Canada and U.S. central states) grew from <150,000 acres in 2000 to approximately 1.5 million acres in 2012. In terms of forage production, it was estimated that the total amount of animal unit months lost from rangeland conversion, was "more than half of annual available grazing on public lands controlled by the U.S. Bureau of Land Management" (p .401), the largest holder of public land in the western United States. Unfortunately, because land reclamation has lagged behind the rate of expansion of oil and gas drilling, Allred et al.[39] predict that loss of critical rangeland ecosystem services will likely be "long lasting and potentially permanent" (p.401).

We believe that planning, regulation, and monitoring of energy developments will become an increasingly important part of range management especially on public lands. So far, estimates are lacking on how much rangeland in the United States is being annually affected by different types of alternative energy developments, but they are needed along with future projections. Relative estimates of how much land is affected by different types of energy development for equivalent amounts of power have been provided previously.[40] Nuclear power development affects the least amount of land followed by coal, photovoltaic solar, natural gas, wind, and corn ethanol.[40] Corn ethanol, the most land-intensive of all energy alternatives, has a 144 to 1 ratio compared with nuclear power. For wind, the ratio is near 45, for natural gas near 10, for solar near 8, and for coal near 6. No doubt vast areas of rangeland landscapes will be affected by "energy sprawl" from wind turbines, solar panels, substations, power lines, and roads if wind and solar power are heavily emphasized as future power sources.[15,40] How these developments will affect other rangeland uses is an important question for rangeland researchers. A recent study provided a useful framework to evaluate the effects of energy development on rangeland ecosystem services.[41]

According to the USEIA, the United States can meet its energy needs until 2040, but the cost of fuel for transportation, heating, electricity, and so on will probably be substantially higher than it is in 2015.[2,3,42] After 2040, it appears both the conventional and unconventional reserves of oil and natural gas will be severely depleted leaving coal as the primary remaining fossil fuel, with reserves that might last another 50 to 100 years.[3,22,27,28] However, this is mostly low-grade coal that burns dirty, exacerbating global warming problems unless there is very expensive carbon capture and sequestration.

Although an in-depth analysis of the connections between energy policy and climate change goes beyond the scope of this article, there is broad consensus among climate scientists that, regardless of current and future mitigation efforts, additional warming of the planet is inevitable.[43] Predicted changes in climate for western US rangelands will vary regionally and will likely include higher temperatures, altered precipitation regimes, and increased frequency of extreme weather events (e.g., droughts).[44] In general, the Southwest and southern Great Plains (Texas) are predicted to become warmer and drier whereas the northern Great Plains and the northwest are predicted to become warmer and wetter.[45] Therefore, region-specific adaptation strategies will be required. A recent paper provides a nuanced analysis of the complexities of developing location-specific adaptation policies.[45] There appears to be a high degree of variation in ranchers' capacity to adapt to climate change driven by differences in age, sex, and beliefs, among many other factors. Briske et al.[45] not only propose broad categories of adaptation strategies that include minimization of adversity in the south and optimization of opportunity in the north, but also argue that differences in capacity of ranchers and managers to implement adaptation strategies need to be specifically addressed in government intervention programs.

In our view, the shale oil and gas will buy valuable time to develop alternative renewable energy resources and to restructure our economy so it is much less fossil fuel dependent. At the same time, we believe we need to strongly consider changing our basic economic model that is based on endless exponential growth of population, consumption of natural resources, and debt.[22,28,46] Properly managed rangelands can sustainably and harmoniously provide food, fiber, and ecosystem services, but they have a finite capability to provide these essential components to human life.[46]

References

1. Holechek, J.L., and M.N. Sawalhah. 2014. Energy and rangelands: a perspective. ***Rangelands*** 36:36-43.
2. [USEIA] US Energy Information Administration, 2014. Annual energy outlook 2014. Report DOE/EIA-0383. Washington, DC, USA: United States Department of Energy Information Administration. [247 p.].
3. Hughes, J.D. 2014. Drilling deeper. Santa Rosa, CA, USA: Post Carbon Institute [315 p.].
4. Hughes, J.D. 2015. Revisiting the shale oil hype: technology versus geology. Resilience [Available at: http://www.resilience.org, Accessed 15 May 2015].
5. Berman, A.E. 2015. Saudi Arabia's oil-price war is with stupid money. Resilience [Available at: http://www.resilience.org, Accessed 21 April 2015].
6. Bamberger, M., and R. Oswald. 2014. The real cost of fracking. Boston, MA, USA: Bacon Press [230 p.].
7. [U.S. EPA] United States Environmental Protection Agency, 2015. Assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources (external review draft). Washington, DC: US Environmental Protection Agency [EPA/600/R-15/047].
8. Pantsios, A. 2015. 8 states dealing with huge increases in fracking earthquakes. EcoWatch [Available at: http://eco-watch.com, Accessed 28 April 2015].
9. Ramsey, N. 2014. New study links Oklahoma earthquakes to fracking. MSNBC [Available at: http://www.msnbc.com/, Accessed 11 May 2015].
10. Pantsios, A. 2015. Confirmed: Oklahoma earthquakes caused by fracking. EcoWatch [Available at: http://eco-watch.com, Accessed 11 May 2015].
11. Abraham, S. 2010. Lights out. New York, NY, USA: St. Martin's Press [254 p.].
12. Couronne, I. 2014. Blown away? US suspends wind power subsidies, for now. Yahoo News [Available at: http:news.yahoo.com, Accessed 16 January 2014].
13. Leeb, S. 2009. Game over. New York, NY, USA: Grove Press [245 p.].
14. Subramanian, M. 2012. The trouble with turbines: in the wind. ***Nature*** 486:310-311.
15. Bryce, R. 2010. Power hungry. New York, NY, USA: Public Affairs Books [394 p.].
16. American Wind Energy Association, 2009. Annual wind industry report, year ending 2008. [27 p.].
17. Buller, E. 2008. Capturing the wind. Uinta County Herald [Available at: http://www.uintacountyherald.com/, Accessed May 15, 2015].
18. Wurts, W.A. 2010. Farming algal fuels: economics challenge process potential. ***Global Aquaculture Advocate*** 13:71-73.
19. National Research Council, 2012. Sustainable development of algae biofuels in the United States. Washington, DC, USA: National Academic Press [258 p.].
20. Cribb, J. 2010. The coming famine. Berkeley, CA, USA: University of California Press [248 p.].
21. Pate, R., G. Klise, and B. Wa. 2011. Resource demand implications for U.S. algae biofuels production scale-up. ***Applied Energy*** 88:3377-3388.
22. Hall, C.A.S., and K.A. Klitgaard. 2012. Energy and the wealth of nations. New York, NY, USA: Springer Books [407 p.].
23. Brown, L.F. 2012. Full planet, empty plates. New York, NY, USA: W. W. Norton & Company [144 p.].
24. Smith, L.C. 2010. The world in 2050. New York, NY, USA: Dutton [322 p.].
25. De Becker, K. 2015. How sustainable is PV solar power? Resilience [Available at: http://www.resilience.org, Accessed 15 May 2015].
26. De Becker, K. 2015. How sustainable is stored sunlight? Resilience [Available at: http://www.resilience.org, Accessed 15 May 2015].

27. Heinberg, R. 2005. The party's over. 2nd ed. Gabriola Island, BC, Canada: New Society Publishers [306 p.].
28. Kunstler, J.H. 2012. Too much magic. New York, NY, USA: Grove Press [245 p.].
29. National Research Council, 2009. Driving the built environment: the effects of compact development on motorized travel, energy use, and CO_2 emissions. Report 298. Washington, DC, USA: National Academic Press [286 p.].
30. Gallagher, L. 2013. The end of the suburbs. New York, NY, USA: Portfolio/Penguin [261 p.].
31. Whitney, M. 2013. Fate of the states. New York, NY, USA: Portfolio/Penguin [260 p.].
32. Steiner, C. 2009. $20 per gallon. New York, NY, USA: Grand Central Publishing [275 p.].
33. Brown, L.R. 2008. Plan B 3.0. Mobilizing to save civilization. New York, NY, USA: W. W. Norton & Company [398 p.].
34. Rubin, J. 2009. Why your world is about to get a whole lot smaller. New York, NY, USA: Random House [286 p.].
35. Leeb, S. 2011. Red alert. New York, NY, USA: Business Plus [239 p.].
36. United States Department of Agriculture-Natural Resources Conservation Service, 2010. Summary report: 2010 National Resources Inventory. Washington DC, USA: U.S. Government Printing Press [163 p.].
37. Bateman, C. 2010. A colossal fracking mess. Vanity Fair [Available at: http://www.vanityfair.com/, Accessed May 20, 2015].
38. Heinberg, R. 2013. Snake oil. Santa, Rosa, CA, USA: Post Carbon Institute [151 p.].
39. Allred, B.W., W.K. Smith, D. Tidwell, J.H. Haggerty, S.W. Running, D.E. Naugle, and S.D. Fuhlendorf. 2015. Ecosystem services lost to oil and gas in North America. ***Science*** 348:401-402.
40. McDonald, R.R., J. Fargione, J. Kiesecker, W.M. Miller, and J. Powell. 2009. Energy sprawl or energy efficiency: climate policy impacts on natural habitat for United States of America. ***PLoS One*** 4:1-11.
41. Kreuter, U.P., W.B. Fox, J.A. Tanakzy, K.A. Macabo, D.W. McCollum, J.B. Mitchell, C.S. Duke, and L. Hidinger. 2012. Framework for comparing ecosystem impacts of developing unconventional energy resources on western rangelands. ***Rangeland Ecology and Management*** 65:433-443.
42. [USEIA] US Energy Information Administration, 2011. International energy outlook 2011. Report DOE/EIA 0484. Washington, DC, USA: United States Department of Energy Information Administration [233 p.].
43. IPCC (Intergovernmental Panel on Climate Change), 2013. The physical science basis: contribution of Working Group I to the Fifth Assessment Report [Available at: www.ipcc.ch/report/ar5/wg1/, Accessed 16 July 2015].
44. Polley, H.W., D.D. Briske, J.A. Morgan, K. Wolter, D.W. Bailey, and J.R. Brown. 2013. Climate change and North American rangelands: trends, projections, and implications. ***Rangeland Ecology & Management*** 66:493-511.
45. Briske, D.D., L.A. Joyce, H.W. Polley, J.R. Brown, K. Wolter, J.A. Morgan, B.A. McCarl, and D.W. Bailey. 2015. Climate-change adaptation on rangelands: linking regional exposure with diverse adaptive capacity. ***Frontiers in Ecology and the Environment*** 13:249-256.
46. Holechek, J.L. 2013. Global trends in population, energy use, and climate: Implications for policy development, rangelands management, and rangeland users. ***The Rangeland Journal*** 35:117-129.

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