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Rural Futures Lab

Transitioning to Renewable Energy: Development Opportunities and Concerns for Rural America

RUPRI Rural Futures Lab Foundation Paper No. 2

Adam Blair
David Kay
Rod Howe

Community and Regional Development Institute (CaRDI)
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Since 1990, the Community and Regional Development Institute (CaRDI) has strengthened Cornell's role as a leader in responding to current and emerging needs in community and rural development. Working with Cornell faculty and staff—including Cornell Cooperative Extension's network of county offices—and other state and regional institutions, CaRDI is a center of dialogue and collaboration addressing needs at the local, state, and national levels.

Rural Futures Lab Foundation Papers are intended to present current thinking on the economic drivers and opportunities that will shape the future of rural America. They provide the foundation upon which it will be possible to answer the question that drives the Lab's work—What has to happen today in order to achieve positive rural outcomes tomorrow?

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Executive Summary

Rural America can provide the energy of tomorrow. Indeed, rural communities not only have the opportunity to reemerge as dominant producers of biomass energy where agricultural land predominates, but also of wind energy atop the hills, hydropower throughout the valleys, and solar across the plains and deserts. Abundant natural resources will be a necessary ingredient in the development of more water-, wind-, and biomass-intensive forms of energy. With vision and planning, rural America could even be home to new systems of distributed energy generation, which would lessen the need for costly energy transmission and transportation that is required to move energy to the places it is consumed or efficiently stored for later use.

Renewable energy sources are widely but unevenly distributed throughout the U.S. Biomass resources, for instance, are abundant on the Eastern Seaboard and in the northwest, while the potential for solar energy generation is pronounced in the southwest. These regional disparities, and the fact that given its low power density relative to conventional sources renewable energy often requires abundant open space, highlight the special role of rural America in leading the coming transition to renewable energy. A transition to renewable energy also holds great promise for communities in need of economic development. Often promoted under the banner of the "clean energy economy," investments in renewable energy have spurred significant job growth and local economic activity that cannot be outsourced to other countries.

While the prospect of renewable energy development may be a beacon of hope for many in rural America, policymakers would be remiss to ignore the challenges and concerns associated with a full-fledged energy transition. For one, rapid energy development, like many other industries, has the potential to generate large influxes of population and consequent labor market instability and changes in community character.

Fortunately, rural communities in many states have at their disposal a variety of policies and programs that can be used to foster local renewable energy development while overcoming inherent challenges. Any approach to transitioning to renewable energy sources should, however, acknowledge the limits of centralized, one-size-fits-all policies, and build strategies that adapt to local circumstances. This is best achieved through broad community participation, which is arguably a central tenet of any successful energy transition.

Given our dependence on energy for sustaining modern American lifestyles, it is imperative that policymakers prepare for the opportunities and concerns associated with various energy development scenarios, and work to ensure the availability of one of society's most valued resources.

Building on RUPRI Rural Futures Lab themes, the authors hope to inject a uniquely rural viewpoint into the national discussion surrounding the inevitable transition toward renewable energy. The goal of this paper is to educate policymakers and engaged citizens on the expected acceleration of a transition that has already begun toward renewable energy in the U.S., and the unique implications for rural America. In order to properly inform local decision-making processes, the paper highlights the challenges and concerns that rural communities will face, and strategies for overcoming them.[1]

[1] The authors wish to thank the following reviewers for their valuable comments and insight: Peter Bardaglio, Brian Dabson, Al George, Tristan Fionn Stackig Morris, Megan Carroll, Jennifer Jensen, Tom Johnson, John Martin, Paul Mutolo, Alan Okagaki, and Judith Reppy. Despite the generous assistance of these experts, remaining faults rest with authors.

Introduction

Energy plays an essential and pervasive role in sustaining modern economies and lifestyles. Economic growth; national debt and the balance of payments; climate change; the quality of air, water and land; food security; foreign and military policy; and the distribution of the earth's bounty are all influenced by how we produce and consume energy in the United States.

Americans appear to be on an inevitable cusp of change. Even short-term projections past the economic sluggishness that persists in 2011 foresee increasing oil scarcity leading to increased liquid fuel costs.[2] Such analyses suggest that the systems of commerce, transportation, and land use settlement that evolved under twentieth century conditions of low cost transportation fuels will come under increasing stress. Climate change debates, in particular, are increasingly reshaping the contours of tension between environment, economy, equity, and energy policy.

Awareness of U.S. dependence on imported oil is longstanding. Yet our current transportation system remains overwhelmingly based on oil. Fossil fuels more generally remain the dominant source of energy for our other major consuming sectors: residential, commercial, and industrial. Nevertheless, in recent years, the need to respond constructively to problems associated with our nation's continuing dependence on oil, domestic but polluting coal, and other nonrenewable fossil fuels has again seemed more urgent. Concern about reducing carbon emissions has in particular focused new attention on replacing the leading role coal plays in electricity production.

Renewable energy use is already increasing rapidly and will undoubtedly play a growing role in meeting future energy needs. However, the speed with which this will and should happen is contested, remains contingent, and is in any event policy dependent. In general it is clear that a rapid increase in the supply of renewables is possible and indeed already underway. What is much less clear is how far and fast a truly systemic transition can take place.

The issues and promise of renewable energy are inextricably tied to the parallel issues and promise associated with the alternatives. Though renewable energy is almost by definition the only energy source that is viable in the long run, alternatives are multiple at least through the medium term. They include but are not restricted to conservation, coal, shale gas, other nonconventional fossil fuels, and nuclear power.

Economics and politics push both toward and against these alternatives. Recurrent headlines of energy related disasters abound, ranging recently from the Deepwater Horizon oil spill (offshore oil) to the Massey Energy Company's Upper Big Branch coal mine catastrophe, from the water contamination and flaming faucets in Dimmock, Pennsylvania (natural gas drilling), to Japan's Fukushima Daiichi nuclear crisis. These incidents highlight only the episodic human, economic, social, and environmental costs of fossil fuels and nuclear power. But considered along with the more routine costs that are borne but rarely make headlines, they also highlight the reality that so far the vested economic and political forces of inertia—holding on to our dependence on fossil fuels—have largely prevailed.

[2] See EIA projections at http://www.eia.gov/emeu/steo/pub/contents.html#US_Crude_Oil_And_Liquid_Fuels, accessed June 29, 2011.

Thus, frustrated advocates of renewable energy worry that the perfect moment to make the case for a more balanced energy portfolio approach which gives greater prominence to alternative energy is now being filtered narrowly through the policy lens of reducing dependence of foreign oil. The concern is that this will lead to a green light for exploitation of all domestically controlled fossil fuels without accounting for their full costs, thereby undermining the market for renewables.

The continuing absence of consensus about energy and climate issues at the international and national levels has led to federal public policy that lacks coherent direction and forcefulness. This only increases the responsibility of U.S. institutions and governments at the state and local levels to lead in addressing the nexus of energy-related issues. Already at the community and regional levels, multiple approaches to energy conservation, renewable energy production, and new forms of fossil fuel extraction are being implemented and debated, with many other proposals waiting in the wings. The slow and inconstant response of federal policies has been accompanied by small but notable production shifts toward regionally significant place-dependent domestic renewables (especially wind, but also solar and biomass, with hydropower holding steady). Similarly, it is increasingly evident that energy transitions and policies have important dimensions that are uniquely local in nature.

Though an energy transition will have deep implications for the entire country, it raises unique opportunities and concerns for rural America. From the perspective of energy production and particular places, the opportunities and concerns will vary depending on the energy sources that are economically abundant and most cost effective in each region.

The prime opportunities for rural America amid a transition to renewables include various forms of regional economic development. In some ways reminiscent of its production history with mineral fuels and agriculture, most renewable energy development is land intensive and location dependent in a way that points to rural America's revitalized potential as an energy exporter. A renewables-centered export economy would be based on a more sustainable, long term foundation than has been experienced in the past by rural boom and bust economies based on nonrenewable fuels.

Regional economic development may also be spurred insofar as regionally produced and lower cost energy can be used to lower the relative cost of doing business in rural places. Energy-intensive goods and services that are produced in rural places and consumed elsewhere can add to the value of local production and be exported as "embodied" energy, not just raw energy itself. Historically, for example, nearly all aluminum production was, because of its high energy needs, located near low cost hydropower. Improved export potential is not the only way rural energy production can provide an economic boost. Substituting local production for energy or energy intensive products (e.g., food, chemicals, cement) that would otherwise have to be imported can strengthen energy producing rural economies.

As society transitions away from fossil fuel dominance, change will also pervade the entire calculus of low cost fossil fuels that has shaped existing residential, commercial, and industrial location patterns. The center of gravity between rural and urban places will likely rebalance. As some rural places become more attractive for energy production, others will become increasingly attractive and valuable based on their existing non-energy assets—including their natural amenities and ability to produce food.

The relationship between transport costs and rural vitality is complex and will change. As the costs of transporting people, goods, and services increase, some communities currently dependent on low cost exchanges with population centers may decline. However, economic geographers and others have

shown that higher transport costs often favor the dispersion of industry and commerce and population into smaller clusters in rural areas (Kilkenny, 1998; Krugman, 1991). They note that the historic growth of large urban centers was in no small part facilitated by the advent of low cost transportation.

In order to strengthen the very places where much of our domestic sources of renewable energy will likely come from—rural America—there is a need for a national dialogue about what an energy transition will mean for our rural communities and their relationship to urban places. Such a dialogue should complement a coordinated initiative of applied research, outreach, partnership building, policy analysis, and community leadership training. We need to increase the energy literacy of the general populace while improving the technical, energy-related skills of those living in rural communities. We need to build the capacity of local government officials to assess the impacts of various energy development scenarios. We need to engage with, provide resources to, and support the organizations and institutions that coordinate and guide communities. In all, rural communities (and their urban, state, and federal counterparts) must learn how to manage many different energy transitions wisely and effectively.

The ultimate goal of research and education efforts should be to increase our collective understanding of the connections between energy technologies and key social, economic, and environmental issues. Such an understanding would support a broad range of decisions spanning business investments; individual and community planning; environmental management and mitigation; and the development of effective regulatory programs and tax policies. Interdisciplinary and systems approaches should not only facilitate the achievement of energy transitions, but also support those individuals and groups who will make the important decisions through political processes.

Renewable energy resources

Types of renewable energy resources

Renewable energy[3] comes from sources of energy that are naturally restored within human as opposed to geologic time scales. These resources are generally accessed by tapping into "flows" of energy, a small fraction of which is used to generate useful power or heat. Renewable energy sources tend to have relatively low energy density (see inset on next page) compared to fossil fuels, and are thus less economical, which is a major challenge for the roll-out of many renewable technologies. Also, full capture and exploitation is impossible—and probably undesirable on a global scale for environmental reasons—as these sources are in a natural flux. Examples of renewable energy sources include the following (NREL, 2011):

- **Solar**: sunlight, or solar energy, can be harnessed in a variety of ways, including directly for heating air or water used in buildings. It can also be captured directly to generate electricity.
- **Wind**: electricity is increasingly generated using wind turbines.
- **Biomass**: the organic matter that makes up plants is referred to as biomass, and can be used to produce electricity, liquid fuel sources, or chemicals.
- **Geothermal**: derived from the earth's internal heat, geothermal systems can tap the underground heat source and use it to produce electricity or for the heating of buildings.

[3] See Appendix A for more definitions and explanations of our energy system as a whole.

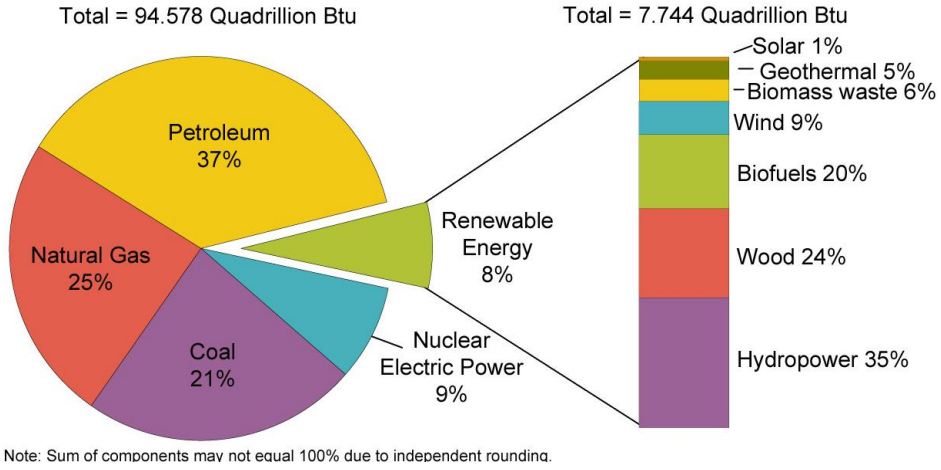
- **Ocean**: the ocean absorbs heat from the sun that can be used for energy. Also, the movement of tides and waves produces mechanical energy that can be harnessed to generate electricity.
- **Hydropower**: flowing water can be stored behind dams and used to generate electricity.

What is energy density?
The ratio between the mass of an energy source and the amount of energy it is able to provide is referred to as *energy density*. Generally, non-fossil fuels are less energy dense, meaning they require more handling and larger storage space (Smil, 2010).

What is power density?
Power density is the rate of flow of energy per unit of land area. The harnessing of most renewable energy sources is a process low in power density compared to fossil fuels, meaning that less land is required per unit of energy produced (Smil, 2010).

Renewable energy supplies about 8% of total U.S. energy consumption (see Figure 1). Hydropower accounts for a third of all renewable energy sources. Wood makes up 24% and biofuels 20%. A small fraction of energy consumed in the U.S. comes from wind, biomass, geothermal, and solar energy. However, wind energy growth has been especially vigorous in recent years[4] and is projected to continue to grow rapidly over the next several decades.

Figure 1. U.S. Energy Consumption by Energy Source, 2009



Source: U.S. Energy Information Administration, *Annual Energy Review* 2009, Table 1.3.

Renewable energy and electricity generation

About 40% of all fuels burned generate electricity, and renewable energy already plays an important role in generating electricity. Hydroelectric generation alone comprises most (nearly two-thirds) of this renewable generating capacity and accounts for somewhat less than a tenth of all U.S. capacity. Hydropower capacity varies from year to year depending on annual water availability. Solar, wind, geothermal, municipal solid waste, and biomass fuels such as landfill methane gas, wood byproducts, and crop and forest residues fuel other renewable electric generation. Of these, wind and biomass are the next most important renewable sources of electricity after hydropower. The U.S. Energy Information Administration (EIA) projects that public subsidies will help lift the share of renewably-generated electricity from 9% in 2008 to 17% of total U.S. electricity generation in 2035. Led by wind

[4] Consumption nearly quadrupled between 2005 and 2009. See http://www.eia.gov/emeu/aer/renew.html

and hydroelectric power, renewable energy will be the fastest-growing source of electricity generation overall through 2035.[5]

While there is enormous potential for increased use of renewable energy in electricity generation, there are also important limitations. The current electric grid is not designed to handle large increases in renewable energy, and heavy investment in a revamped grid will be necessary.[6] According to a Congressional Research Service study, one of the most difficult related issues will be deciding which customers pay will pay for building and operating new transmission lines that cross state boundaries (Kaplan and Vann, 2010). Moreover, wind and solar plants are necessarily variable in their supply because they occur as inconstant flows, and the means for capturing and storing their energy in large quantities are still quite limited. Given this reality, the National Academy of Sciences (2010, p.10) has concluded that the development and deployment of advanced storage technologies will have to "play an important role" in enabling the use of intermittent renewable electric power.[7] Otherwise, increased use of intermittent renewables will most likely continue to need to be accompanied by backup generation capacity with the ability to be rapidly engaged and disengaged. Presumably, during any transition to renewables, these and other innovations such as increased use of distributed energy systems will be implemented in some mix.

Many in the wind industry expect natural gas generators, particularly using relatively efficient combined cycle technology, to fill this role,[8] and the EIA cites several advantages including, "fuel efficiency, operating flexibility (it can be brought online in minutes rather than the hours it takes for coal-fired and some other generating capacity), relatively short planning and construction times, relatively low emissions, and relatively low capital costs."[9] Another solution to the intermittency problem could involve a smart grid infrastructure that allows electric loads to be balanced over a broad geographical area, along with strategic management of energy demand to at least partly follow and compensate for intermittent supplies.

The geography of energy supplies: Rural implications

Energy sources of different types are widely but unevenly distributed across the rural U.S.[10] The implications of energy source choices are thus highly significant for rural America, and will be experienced differently in different parts of the country. Biomass resources are more abundant in the east, south, and northwest, while solar potential is greatest in the southwest. Hydropower is already a

[5] See http://www.eia.gov/energy_in_brief/renewable_energy.cfm and https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2009/LLNL_US_Energy_Flow_2009.png

[6] One study estimates costs ranging from $49 to $80 billion to deliver Great Plains wind power to the East Coast. A Department of Energy study of wind power similarly estimated transmission expansion costs of $60 billion by 2030. A third study of transmission funding requirements for all purposes from 2010 to 2030 estimated $300 billion would be needed. (Kaplan and Vann 2010, p. 1)

[7] A more pessimistic analysis suggests problems arise at significantly lower than 20% penetration (cf. Trainer 2007, p.21). Other studies suggest higher penetration is possible with significant but achievable operational changes (NREL, 2011).

[8] One example is Michael Skelly of Clean Line Energy Partners and former head of development with Horizon Wind Energy. See Michael; Skelly, Promises and Challenges of Renewable Energy, Clean Line Energy Partners, October 13, 2009, accessed June 30, 2011 at http://environment.harvard.edu/events/video/archive. Horizon Wind Energy is currently ranked third in the United States in terms of net installed capacity (http://www.horizonwind.com/company/about.aspx, accessed June 30, 2011).

[9] See http://www.eia.gov/oiaf/ieo/electricity.html.

[10] See http://www.nationalatlas.gov/articles/people/a_energy.html for a collection of maps displaying the geographic distribution of energy resources.

major resource in the eastern and western states, coal in the Appalachian and Rocky Mountain States. Wind power resources are most concentrated in the center of the country, in the Plains states; among renewable sources, relatively favorable economic, technological and regulatory and other policy forces have promoted wind power most rapidly in the recent past. Some states, such as Texas, are rich in multiple energy sources including both renewables like wind and fossil fuels like oil and natural gas. In contrast to its earned reputation as an oil state, Texas has also emerged as a leader in renewable energy development.

Energy development policy, along with the distribution of natural resources and market forces, has great influence over the geography of renewable energy production. At the international level, aggressive policy support explains why Germany leads in solar electricity generation and installed wind capacity, and China in the production of solar panels and wind turbines.[11] Research in the U.S. shows that a policy favoring renewable energy—state-level renewable portfolio standard requirements—is the major factor that determines where new renewable electric generating capacity will be built during the next twenty years. Chupka et al.'s (2008) "most likely" modeling scenario (absent federal carbon policy) predicts that the Midwest will see the greatest investment in new capacity (primarily wind and biomass), with the least in the West. Notably, though the predicted total need for new capacity in the Northeast is much lower than in any of the other regions, the proportional contribution of renewable power is predicted to be greatest there.[12]

Among the more general regional influences on the viability of renewable energy are the costs of fossil fuels and their competition with renewable energy. Because of the costs of electricity transmission and of fuel transportation from source to market, regional price premiums for various energy sources exist. The comparison between the costs and benefits of alternatives therefore has a regional cast. Moreover, as noted above, there is great concern in the renewables industry about existing limitations of the electricity grid in moving large quantities of renewably generated electricity, and especially wind and solar power, from parts of the country in which they are most abundant to distant urban centers of consumption.

Other regional issues include the ability of different energy sources to complement or supplement each other on the electric grid (e.g., hydro and wind, solar and natural gas) and many subsidy and tax policies affecting renewable fuels. Collectively, these effects, primarily associated with the ultimate pace and scale of adoption of renewable energy in overall energy portfolios, will influence both local and regional economic development prospects for renewable energy as well as the associated local and regional environmental and social implications.

Finally, because concentrations of renewable energy resources tend to be distributed across rural areas in parts of the country that are distant from urban centers of demand, transmission issues are key to the future of renewable energy development, and to both rural and urban areas. A seminal U.S. Department of Energy (2008) report showing that wind energy could provide 20% of the nation's electricity needs by 2030 serves as a good case in point. In order for large-scale wind generation to be successful, the report identified at least one primary barrier: developing transmission infrastructure. The power industry has

[11] See http://www.nationmaster.com/graph/ene_ele_sol_pro_pub-energy-electricity-solar-production-public, http://www.nationmaster.com/graph/ene_win_ene_ins-energy-wind-installation, and http://www.nytimes.com/2010/01/31/business/energy-environment/31renew.html , accessed 7/24/2011.

[12] See also Chen et al. (2009) for a detailed analysis of state renewable portfolio standards.

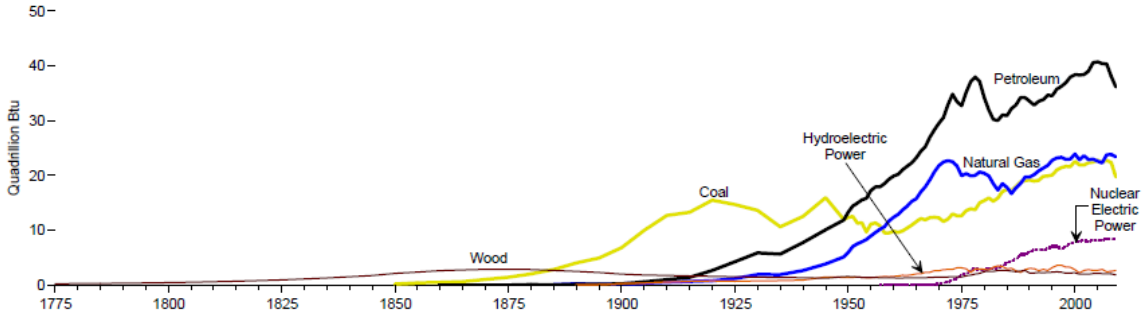
argued that the current transmission and permitting system is too balkanized and needs reform and centralization to foster "planning for an electric transmission system with the needs of the entire country in mind rather than the local fixes that compose the patchwork of today's transmission system."[13] The political ramifications of these kinds of shifts in authority are highly charged.

Transitioning to renewable energy

A history of energy transitions

America has undergone several dramatic and rapid transitions in the way it has met its energy needs since the industrial revolution.[14] For many decades, the trend was toward ever cheaper and more convenient forms of energy. With the dawn of the industrial age, the first era of renewable energy was eclipsed as wood was surpassed in importance by coal consumed in the U.S.[15] Coal's tenure as the king of fuels was, however, relatively brief. National coal consumption began to turn down by 1920 and the consumption of oil and natural gas eclipsed that of coal shortly after the end of WWII (see Figure 3).[16] Though the use of liquid and gaseous hydrocarbon fuels increased unabated, by the 1950s it seemed that yet another shift was approaching. Uranium and the attendant generation of nuclear power promised to hold center stage as our dominant energy resource.

Figure 3. Primary Energy Consumption by Source, 1775-2009



Source: EIA http://www.eia.doe.gov/emeu/aer/pdf/perspectives_2009.pdf

All of these actual or anticipated shifts appeared within the course of a single century, indeed within the plausible span of a single lifetime. Each was associated with new paths of economic diversification and growth, greater energy production efficiencies, and lower energy costs. Then, during the 1970s, the driving momentum of the energy century faltered. The promise of nuclear power became the problem of nuclear power, a dynamic which has only been re-emphasized by the earthquake and tsunami-induced nuclear disaster in Japan. At the same time, a globalizing marketplace highlighted the geographical disparities between energy supply and demand. The OPEC petroleum producer's cartel achieved previously unattained economic strength.

[13] See Appendix B for more information on the impact of energy prices. Also see http://www.aep.com/about/transmission/docs/EnablerforCleanEnergy.pdf, accessed May 3, 2011.
[14] See http://www.eia.doe.gov/emeu/aer/pdf/perspectives_2009.pdf.
[15] According to Schurr and Netschert (1960, p.47), declining BTU's of fuel wood consumption were overtaken by the increases in coal consumption between 1880 and 1885.
[16] Schurr and Netschert, p.36.; http://www.eia.doe.gov/emeu/aer/pdf/perspectives_2009.pdf.

Subsequently, as oil prices began a series of rapid increases, an unprecedented process of energy supply reshuffling began. For the first time, sources of energy that were declining in importance (like coal) were revitalized. And—of enormous significance—the changing pattern of energy supply was for the first time not founded on lower cost energy. Nor was it founded on the growth of major new economic uses of energy and improved material well-being that low costs enable—coal had fueled the industrial revolution,[17] oil the automobile/transportation revolution, and the dawning nuclear age had pointed toward universal electrification. The energy solutions and lifestyles of the future will almost certainly be driven in response to more costly energy supplies and the incentive for greater efficiencies in energy use.

Smil (2010, p. 105) addresses this issue in his recent book on the history of and prospects for an energy transition to renewables. He observes that the history of energy transitions is "long, complex and not easily amenable to simple judgements [sic]" or crisp conclusions. Nevertheless, he considers the upcoming transition to be distinctively problematic: "lessons of the past energy transitions may not be particularly useful for appraising and handicapping the coming transition because it will be exceedingly difficult to restructure the modern high-energy industrial and postindustrial civilization on the basis of non-fossil—that is, overwhelmingly renewable—fuels and flows." What is needed is "an unprecedented and persistent commitment to rapid change."

Smil is not alone in his barely suppressed doubt that vested short-term interests at all levels, ranging from the individual to the powerful political and corporate, will support such a commitment. Jacobsson and Johnson (2000, p. 638) note similarly in their study of the adoption and diffusion of renewable technologies that, "There are a multitude of forces which favour an incumbent energy system, forces which are likely to reinforce one another in a process of cumulative causation. The inducement mechanisms need to be strong enough to overcome these failures and set in motion a process of cumulative causation which works in favour of the new technology, as has happened in the Danish case of wind turbines."

How long will it take to transition to renewables?

No one can answer this question definitively. But it is clear that a critical factor to consider in energy transitions is the importance of the pace and scale of change. How rapid do careful observers anticipate a transition might be, and under what conditions? A recent report by the National Academy of Sciences (2010, p. 6) projects that favorable circumstances and policy would likely allow renewables to more than double in importance and generate up to 20% of the nation's electricity needs by 2020 (a more rapid transition than in the EIA projection cited above). To reach further, beyond a 50% supply sometime after 2035, would be feasible but require both "scientific advances… and dramatic changes in how we generate, transmit and use energy."

Despite the apparent authority behind these predictions, others provide starkly contrasting, though not necessarily mutually incompatible, windows into the future. Thus glass-half-full analysts have suggested that a plan to supply, "100% of the world's energy, for all purposes" by wind, water and solar resources

[17] More strongly, Allen has recently argued that the ability of the industrial revolution to take root actually hinged on the fact that energy (coal) was cheap and labor expensive in Britain. "The famous inventions of the Industrial Revolution were responses to the high wages and cheap energy of the British economy. These inventions also substituted capital and energy for labour. The steam engine increased the use of capital and coal to raise output per worker. The cotton mill used machines to raise labour productivity in spinning and weaving. New technologies of iron making substituted cheap coal for expensive charcoal and mechanised production to increase output per worker." (See http://www.voxeu.org/index.php?q=node/3570 and a fuller exposition in Allen, 2009.)

by 2030 does not face 'an insurmountable hurdle'" (Jacobsen and Delucchi, 2009, p. 58), while a glass-half-empty analyst cautions more forebodingly that, "renewable energy [alone] cannot sustain a consumer society" (Trainer, 2007).

Almost by definition, much more change is possible over longer time periods—counted in generations, amortization and investment lifecycles, forest regeneration timelines, and the like, than can occur over time frames measured by the return on investment timeframes of private sector investors or the election cycles of the public sector. The debate over the effects of energy use and greenhouse gas emissions is but one salient example: complex energy and climate systems simply cannot be transformed wholesale overnight, no matter how strong the will to do so.

On the other hand, many familiar and important social, technological, and economic changes have happened relatively quickly. There are many examples of rapid adoption and diffusion of technology, for example, generally driven by a combination of technological improvements, markets, and policy (including security policy) forces. A post-war sampling includes microcomputers, automobiles, telephones, cell phones, and the Green Revolution in agriculture. Infrastructure examples include the Internet, the interstate highway system, rural electrification, and rural broadband. Yet the continuing lack of adequate access in many rural areas to broadband, and the long time frame and focused policy it took to fully electrify rural areas, strike cautionary notes for rural America. Experience suggests that attention needs to be also paid to the relation between rural public policy and private sector investment. This caution is also a salient reminder that energy transitions tend to be uneven, raising a variety of equity issues about divisions between regions, rural and urban places, and rich and poor.

Lund (2010) provides another perspective on pace and scale issues for renewable energy adoption and diffusion. His review of historical work on energy transitions suggested that 50-100 year time periods were required for "radical" energy source share shifts at a global scale. His own empirical models predict that, under assumptions favorable for growth, photovoltaic, wind, and nuclear technologies could meet 15, 25, and 41% of global electricity needs by 2050, respectively. He concludes that technologies currently in development might move into a role as a mainstream energy source over about a half-century time frame. In any event, among the most important determinants of a renewable energy transition timeline will be the timelines for the electric grid to adapt to the various issues of reliability and location posed by renewables, and the not unrelated ability of the vehicle fleet to be economically and practically redesigned away from its dependence on oil.

Finally, it should be reiterated that there is a fundamental difference between changes that are driven by desirable economic factors (increased efficiency, product improvement, lower costs) versus those that are responding to the opposite. The most rapid diffusion occurs through private markets when the advantages are obvious and the costs are falling rapidly; often assisted to some degree by public policy.[18] For a transformation that will be fundamentally driven by rising economic and environmental costs, there is fairly widespread agreement that transformations are likely to be much more difficult.[19]

[18]Montalvo (2008) discusses a complex landscape of factors that affect the diffusion of "clean technology" that includes government policy, economic risk, market trends for green goods and service brands, communities and social pressure, attitudes and social values, technological opportunities and technological capabilities and organisational capabilities.

[19]One model for systemic behavioral and institutional change motivated largely by concerns about increasingly recognized environmental costs might be the transformation of solid waste management in the U.S. In response to economic, environmental, educational, regulatory and other policy incentives, the proportion of municipal solid waste that was recycled increased slowly from 5.6% in 1960 to 9.6% in 1980, then jumped to 28.6% in 2000 and 33.8% in 2009 (EPA 2010).

The admonition of Schurr et al. (1979) is sobering in the extent to which it still resonates: "During the… years this study was in progress, energy commanded the attention of the U.S. public and the country's leadership as never before. Yet despite its front and center position on the domestic (and international) political stage…The country is not much closer to a national consensus on energy than it was before the feverish activities of the past several years."

Rural opportunities & concerns

Given its abundance of natural resources and expansive open space, rural America has the opportunity to play a central role in the next energy transition. In one display of federal leadership, the rural development arm of the U.S. Department of Agriculture (USDA) has demonstrated a commitment to making renewable energy sources commercially viable to rural America through a variety of funding opportunities in the form of payments, grants, loans, and loan guarantees.[20]

Renewable energy development has important implications for rural America not least because of the fact that a transition to non-fossil fuels rests on less energy-dense sources whose larger mass requires more handling and larger storage spaces (Smil, 2010, p. 112). Renewable energy sources as a rule yield less energy per unit of land area by an order of magnitude or more in comparison to fossil fuels.

Table 1 shows the number of acres typically required per megawatt of generating capacity for different kinds of renewable and nonrenewable electricity generating technologies. Fthenakis and Kim (2009, p. 1471) have shown that energy dense fossil fuels tend to economize on land "transformation" per unit of electric output. Among the renewable sites studied in that paper, photovoltaic installations were among the most "land efficient" (roughly comparable to natural gas), and biomass among the least. However, the actual nature of the land transformation or utilization for energy production is very different for each of the generation processes (Jacobsen 2009; Lovins 2011).

Table 1. Electricity Generation Footprints

Wind farms	40-60 acres per megawatt
Geothermal	1 acre per megawatt
Solar photovoltaic	10 acres per megawatt
Solar thermal	6 acres per megawatt
Gas turbines	0.4-2 acres per megawatt
Coal (including mine)	0.4-20 acres per megawatt

Sources: Alternative Energy: Facts Statistics and Issues Paula Bernstein 2001, Generating Electricity from Renewables: Crafting Policies that Achieve Society's Goal, https://wpweb2.tepper.cmu.edu/ceic/pdfs_other/Generating_Electricity_from_Renewables.pdf

Some renewable-energy sources (photovoltaic or windpower-plants) can be located on low quality lands or lands used for multiple purposes (e.g., grazing, shading, rooftops of existing development). Some of the larger impacts (e.g. temporary dirt roads for construction access) are short term and can at least in theory be reversed, while some of the more permanent impacts are relatively small in area (e.g.,

[20] U.S. Department of Agriculture, Rural Development, "Energy," http://www.rurdev.usda.gov/Energy.html, accessed May 2, 2011.

foundation pads for wind turbines). Moreover, precisely because renewable energy is not depletable, no new land is required to continually renew the feedstock as is the case for fossil fuels. On the other hand, in order to continue supplying energy over time, renewable energy installations typically require a permanent disturbance of the landscape.

Producing renewable energy in rural America

Rural America currently plays a relatively small role in national energy production, despite its historic dominance, particularly in the agriculture sector, during the early 1900s. As of the early-2000s, the agricultural sector provided between only 0.3 and 0.5% of energy consumed nationally, but the quantities of ethanol, biodiesel, and wind-generated electricity have been growing rapidly (Eidman, 2005, p. 31).[21] Indeed, there is enormous potential for rural, agricultural communities to supply several sources of energy as conventional fuels are depleted. Moreover, many renewable technologies may prove suitable for energy production on a much smaller scale than has been the case for fossil fuels.

Ethanol

Ethanol production began in the late 1970s and was a result of diminishing fossil fuel supplies and a rapid increase in oil prices. The industry was also given a major boost with the passage of the Clean Air Act Amendments of 1990 and the provisions requiring a reduction in carbon monoxide levels found in conventional petroleum-based fuels (Eidman, 2005, p. 34). In 2004, the production of ethanol accounted for approximately 12% of U.S. corn use (USDA, 2004). In addition to bolstering farm prices and income, ethanol production has the potential to lower U.S. trade deficits and create new jobs in rural communities (USDA, 2002). However, the subsidized production of corn ethanol has been contentious on several grounds,[22] not least of which is whether or not ethanol production is in fact a net energy producer. As summarized by Tilman et al. (2009) other issues center on the indirect land-use effects of certain biofuels that can lead to extra greenhouse gas emissions, forest and biodiversity loss, and higher food prices.

New technologies are in development that would produce ethanol from cellulosic biomass, the woody part of plants, on a commercial scale (Eidman, 2005, p. 39). When large-scale rollout of these technologies becomes feasible, they will allow for the production of ethanol from agricultural and forest products like corn stover, wheat straw, switch grass, and waste wood. According to DiPardo (2000), an ethanol production process called enzymatic hydrolysis has the greatest potential for commercialization. Hydrolysis involves the conversion of cellulose into glucose, and then the fermentation of glucose and other sugars into ethanol (Eidman, 2005, p. 40).

Biomass gasification

Biomass and other solid fuels can produce energy through gasification using low-temperature pyrolysis. This approach captures the off-gases from the heat-driven decomposition of wood or grasses to produce heat, electricity, or biofuels. Some promising gasification technologies claim high process efficiencies even in medium and small scale systems suitable to many rural and agricultural contexts. By utilizing the waste heat of the system, which is possible in this power range, system efficiency can be very high. Moreover, a byproduct of these systems is biochar, a stable form of carbon which has been shown to have both beneficial agronomic properties and persist for long time periods as a stable carbon

[21] According to another estimate by the Congressional Research Service, agriculture- and rural based energy production accounted for about 0.7% of total U.S. energy consumption in 2006. (See http://www.nationalaglawcenter.org/assets/crs/RL32712.pdf, accessed May 3, 2011.)

[22] For example, as of June 2011, the Senate had voted 73-27 in favor of eliminating the $6 billion a year in ethanol subsidies.

component of soil. According to a leading biochar researcher, "this technology has the potential to provide an important carbon sink and to reduce environmental pollution by fertilizers," (Lehmann 2007, p. 381).

Biodiesel

Many U.S. farmers have acted as strong advocates for the development of biodiesel—a vegetable oil-based fuel—because of its promise for creating new markets for agricultural commodities (Eidman, 2005, p.43). Energy security and clean air legislation has also contributed to biodiesel's future potential as a substitute for petroleum-based diesel fuel. Oils derived from materials like soybean, corn, peanut oil, animal fats, and used cooking oil can be converted into fuel through a process called transesterification (Eidman, 2005, p. 43). Algae is another promising source that uses both land and water very efficiently; though not yet commercially viable, algae cultivation is also relatively environment-benign. Biodiesel can be used in diesel engines in its pure form (B100) or as a blend with conventional diesel fuel.

Wind power

Many rural landowners have invested in private wind turbines while others have leased the rights to place turbines on their property. There are several advantages of electricity generation from wind over other renewable resources. First, wind holds the potential for electricity generation without emissions. Windmills can also be built within a relatively short time. Furthermore, wind power (like other renewable fuels) provides the consumer with a security buffer against the unforeseen costs of emissions regulations and fluctuating prices that are characteristic of fossil fuel generation (Eidman, 2005, p. 46).

Wind power also has benefits unique to rural America. Though wind energy has run into stiff opposition in many quarters even in rural areas, lower population density and abundant open space can limit the extent to which "not in my backyard" responses to the location of large wind turbines are an issue. Also, the open terrain and often elevated landscapes found in many rural areas are most suitable for wind power generation, as wind speeds tend to be higher and more consistent.

Methane

The production of electricity from methane produced through a process of anaerobic digestion of manures has also become an option for rural renewable energy development. The Energy Information Administration (2004) projects a significant increase in electricity generation from different types of waste gases; possibly comprising 0.5% of total U.S. generation capacity by 2025. Studies suggest that the conversion of methane gas into heat and electricity may provide a way for large livestock operations to not only limit their use of finite energy resources but to deal with a major social problem—odor (Eidman, 2005, pp. 48-49). Methane capture would also address an important environmental issue, as methane is a powerful greenhouse gas emitted in quantity from the manure handling systems that are common on large dairy and hog operations.

Altman et al. (2007) among others have presented encouraging case study evidence on the cost savings, financial feasibility, and regional economic impacts of anaerobic digestion and other rural biomass energy generators. However, methane digesters on the whole have not been widely adopted in the U.S. because of high capital costs. Key and Sneeringer (2011) cite an EPA report listing only 157 methane digesters operating on U.S. livestock farms. They suggest that a policy that offered modest payments to producers to reduce greenhouse gas emissions through use of digester technology "could increase the number of livestock producers who would profit."

Energy conservation and alternative generation systems

It is important to realize that at every stage of an energy system—from exploration to end use—work must be done and energy expended. During the energy conversion process, some of the energy content of a raw energy source is unavoidably (but also some avoidably) consumed or lost as waste heat or light (Chiras, 2010, p.278). As graphically displayed in a chart produced by the Lawrence Livermore National Lab,[23] only about two-fifths of the energy that is converted from primary sources in the U.S. is actually put to use providing useful energy services. Nearly all the energy that is not put to work is from oil consumed in cars and from heat that is lost in the process of generating electricity.

This highlights the critical importance for the future of targeted conservation and efficiency measures in the production of energy. For example, in conventional electricity generating plants (fueled mostly by coal and distantly followed by nuclear and natural gas), about two-thirds of the energy in the primary fuel is lost—vented as heat—right at the power plant.[24] Alternative systems (e.g., combined cycle and combined heat and power or CHP) reuse some of their waste heat for additional electricity production and are often able to capture some of the heat for process or space heating applications in nearby facilities. Conservation and efficiency measures are critical to consider in the development of future technology, regardless of the fuel used.

The compatibility of renewable energy with smaller scale distributed generation systems offers a promising alternative to producing and distributing renewable energy within rural communities themselves. Distributed energy generation systems[25] differ from conventional centralized electric energy systems by generating electricity and/or heat from many small energy sources at or near the point of use. Distributed generation is most frequently considered in the context of electricity production, but need not be restricted to that form of energy. Distributed generation can employ multiple fuels, either alone or in combination.

Distributed energy systems predated the integrated electric grid. During the first modern "energy crisis," Amory Lovins (1977, p.39) promoted an updated version of distributed generation he called "soft energy paths" that would rely on energy technologies "matched in scale and in geographic distribution…and in energy quality to end-use needs."[26]

Several studies have predicted that large fractions of new electric generation capacity, and in particular generation fueled by renewable energy, would be distributed or decentralized (Ackerman et al., 2001; Lasseter, 1998; Grubb, 1995). A variety of small scale systems are increasingly available in commercial and residential applications.[27] A few examples of distributed generation systems employing various primary fuels include residential and commercial-scale solar, small to medium scale wind and biomass

[23] See https://flowcharts.llnl.gov/.
[24] See, for example, http://www.eia.doe.gov/cneaf/electricity/chg_stru_update/chapter3.html#N_3_.
[25] See http://www.newrules.org/energy/rules/distributed-generation-local-plans and http://www.localpower.org/ for more.
[26] Distributed generation is only one element of what Lovin's Rocky Mountain Institute now calls the "end use/least cost approach". Rather than meeting increased demand for heat or electricity by increasing supply, this approach starts with a fundamental question: "How much energy, of what kind, at what scale, and from what source, would do each desired task?" See http://rmi.org/rmi/End-Use%2fLeast-Cost+Approach , accessed July 24, 2011.
[27] Home Depot, for example, in several windy states recently began offering residential wind turbines designed to produce "up to 400 kw hours" in low wind per month at an estimated installed cost of $6,000. See http://www.naturalhomeandgarden.com/green-home-building-and-remodeling/residential-wind-power-home-depot.aspx, accessed 7/25/2011.

installations, onsite backup generators, cars, solar powered roadway lighting, and district energy/heating systems. Morris (2007) suggests that because feedstock costs dominate (60-75%) biofuel technology production costs, most plants are large and located in corn and oilseed states to minimize costs of feedstock transportation, whereas the advent of commercial cellulosic ethanol would open the possibility for more and smaller facilities to be located closer to the consumer.

District heating systems typically cogenerate both heat and electricity from a variety of primary fuels and then provide heat and power to multiple consumers located nearby (in the "district"). These systems can dramatically improve energy production efficiencies to levels significantly exceeding 80% (Rosen et al, 2005). These efficiencies are gained through a design that utilizes the high temperatures of fuel combustion to generate electricity and the lower post-generation temperatures for heating purposes. Because proximity is especially important for heat delivery, district heating systems are particularly suited to compact, dense, land use development patterns. These patterns are more naturally inherent to and complementary with urban areas, but because they are feasible at many different scales they can also be employed in less urbanized village or commercial and industrial contexts.

Johnson (2007) has suggested that rural America will benefit from a renewable, especially biofuel, based economy because of "the double dividend of distributed energy… [that] turns remoteness on its head." The double dividend is earned because rural fuel producers can avoid the extra costs of transporting fuel into rural areas and then (assuming a relative cost advantage for locally produced renewable transportation fuels) reduce the costs of shipping all rural goods and services elsewhere. Rural production of distributed energy, especially if it meets local needs first, also has the potential to loosen some of the links that tether rural places to the vagaries of footloose multinational energy corporations and foreign governments. Distributed generation is an important ally of relocalization.

Distributed systems also tend to foster the greater overall system stability and security against disruptions that are inherent to the use of a wide variety of networked but geographically dispersed and complementary components. As pointed out by Van Hoesen and Letendre (2010), rural areas are at higher risk of extended disruption by being on the periphery of energy networks with characteristically remote infrastructure and low customer densities. Distributed systems also are much more likely, but not of necessity, to use local and/or renewable resources (local can include nonrenewables, too). Potential efficiencies in cost are associated with the decreased need for both the fixed capital and other variable costs associated with transmission. Further efficiencies are possible with the enhanced ability of dispersed generation to employ combined heat and power (CHP) units. CHP captures the routinely significant quantities of waste heat and puts them to work locally. The high efficiencies of CHP units imply both reduced costs and lower polluting emissions.

Potential disadvantages counterbalance some of these advantages. These include incompatibilities across different system components and the need to overcome institutional barriers especially in regard to the need to interface with the electric grid and regulated utilities. Other major barriers, especially for nonutility generators, include lack of access to capital and related financing issues.[28] Distributed systems

[28] The International Energy Agency (2002) concludes that larger plants can take better advantage of economies of scale, i.e., the capital cost per kilowatt of individual distributed generation is higher for distributed units. More recently, Karger and Hennings (2009) repeat the IEA report's conclusion that distributed systems also tend to have poorer fuel economy (though not true if used in CHP mode) and use a more limited selection of fuels. Focusing on photovoltaic systems, they note that a number of

also face a highly diverse set of localized risks and barriers, each associated with the specific alternatives among a wide array of generation contexts, fuels and technologies.[29] Insofar as a major driver of distributed generation fueled by renewables will be rising fuel prices, it is important to understand that distributed generation will be stimulated as a response to price impacts that are likely to be seen as having negative effects on many rural communities. As costs for transport and freight rise, the profit margins of most farmers will be squeezed. However, this cost impact would generally be smallest for producers with local markets, such as ethanol plants, livestock operations, or processing plants (Doane Advisory Services, 2008).

Potential economic and community development benefits for rural America

A transition to renewable forms of energy holds great promise for rural communities in need of economic and community development. Investments in renewable energy have the potential to create quality jobs and industries (the opportunities for rural jobs in energy conservation and efficiency are even more widespread), helping to close the gap left in the wake of declining employment levels in agriculture and manufacturing.

Local economic development benefits of renewable energy are associated with the observation that:

1. Renewable technologies tend to be labor intensive in various stages of their production cycle,[30]
2. Some also tend to keep more dollars in the local and rural economies by making greater use of local inputs, and
3. Essentially all renewable technologies are flexible and adapted to use in applications at multiple scales (e.g. measured in kilowatts as well as megawatts of capacity), and hence in many decentralized contexts (NREL 2007).

Consequently, renewable projects are often associated with shorter project development and construction timelines, lower up-front capital costs (see Goldemberg, 2004), and greater community acceptance of facility siting, though barriers on all of these fronts can still be significant.

Some forms of renewable energy generation have particularly strong local economic "multipliers". In other words, they are particularly suited to keeping dollars circulating in local and regional economies because they a) tend to employ workers who are or become long term residents, and b) tend to purchase more of their inputs at both the initial and ongoing or operational stages from local and regional businesses. Due to the locally sustainable nature of the renewable energy feed stocks, associated jobs—and especially those associated with fuel supply and ongoing system operations and maintenance—tend to be less geographically footloose and more rooted in rural communities for the long term. Similarly, networks of businesses in the supply chain for renewable energy production can become established and grow without concern that the purchaser of their product is likely to relocate due to resource depletion. Thus, the economic benefits to host communities in rural areas are more likely to be stable over time.

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studies have concluded that while system operating costs in particular are very low, high capital costs have prevented more than niche market penetration.

[29] See http://www.eia.doe.gov/cneaf/electricity/chg_stru_update/chapter3.html#N_3_ .

[30] For example, solar photovoltaics, like many conservation measures, require significant local labor in the installation stage; biomass in the feedstock growing, harvesting, transporting and processing stages.

Sustainable rural job creation potential is enhanced in particular by renewable technologies with a requirement for inputs that can only be economically produced in quantity in rural areas, such as forest and field sourced biomass. Capital-intensive renewable industries with "free" fuel input flows such as wind, water, and solar produce fewer direct jobs in rural areas. Rural areas, with some isolated exceptions, are unlikely to have the material or labor infrastructure necessary to host the production of the capital goods themselves (wind turbines, solar panels, etc. which, as noted elsewhere, are often not even made in the U.S. at present). The construction and installation phases associated with these technologies can provide a significant stimulus to rural economies and provide good jobs, but these phases are by definition of limited duration at a given site.

In some rural places with multiple energy resources, renewable energy has the potential to supplement, and either displace or eventually replace, rural jobs currently dependent on fossil fuel extraction. Though many jobs have historically been created in rural areas by the extraction and processing of nonrenewable fuels, renewables can often be better job creators, especially in terms of raw job creation numbers[31]. Recent reviews of existing data suggest that the renewable energy sector is a more prolific job supporter per unit of energy generated/delivered or dollar invested (Wei et al., 2010; Kammen et al., 2004). Wei et al.'s recent analysis of fifteen studies of the clean energy sector found that solar photo voltaics were estimated to create the most direct employment[32] per unit of energy output. Goldemberg's (2004) international comparison similarly concludes that photovoltaics create the most fuel production plus power generation jobs per unit of energy produced. In that study, photovoltaics were followed by biomass for ethanol (from cane sugar), wind, and woody biomass.

A simple "jobs per kilowatt-hour produced" comparison is not the only or necessarily even the most appropriate window through which to view job creation effects of the renewables industry. More policy oriented analysis using economically sophisticated methods have pointed out a variety of complex systemic interactions that should be accounted for. For example, policies that support renewable energy investment typically also raise the cost of energy above what energy customers would otherwise pay (e.g. portfolio requirements that require the purchase of renewably generated energy even if it costs more, or feed in tariffs that require higher payments to renewable energy producers).

In one such study, Hillebrand et al. (2006) attempt to quantify two opposing impacts: the stimulus effects of subsidy-driven increased investment in renewable technologies versus the contractive effects resulting from an increase in the cost of producing power. In their Germany-specific scenario of increased investment in a broad portfolio of renewable technologies led by wind, solar photovoltaics and biomass[33], they find a strong positive impact on jobs in the short run (especially in sectors producing investment goods; services; wholesale, retail and transportation goods; and construction). However, these impacts dissipate over time and, on an economy-wide basis, even turn slightly negative (with modest job losses in production goods; wholesale, retail and transportation and services that collectively outweigh the modest persistent job gains in the investment goods and construction sectors).

[31] This is a subject in which some evidence exists, but in which more empirically based comparative studies are needed.

[32] Defined in this study as jobs in construction, installation and manufacturing, operations, maintenance and fuel processing required to create and operate the facility.

[33] The scenario also accounts for compatible changes in fossil fuel consumption, and in particular shift from combined cycle gas turbines for the base load towards more flexible gas turbines more suited to temporary power generation during peak times (and times with poor wind).

Unfortunately, the few general equilibrium studies along these lines do not appear to have been spatially articulated in ways that enable conclusions about the distribution of job gains and losses along the rural/urban continuum. One might speculate, however, that the job creating impacts associated with renewable energy development would be more focused on rural places than would the economy-wide negative price effects of higher energy prices. Insofar as rural areas are able to benefit by consuming at lower cost renewable energy produced locally, they could escape even further from the negative price effects.

Labor force development and the clean energy economy

Driven by concerns about energy and climate change, as well as a need to create jobs and better compete in the global economy, American government and business leaders are increasingly seeking to cultivate new industries in what is now referred to as the "clean energy economy." Charged with "[generating] jobs, businesses, and investments while expanding clean energy production, increasing energy efficiency, reducing greenhouse gas emissions, waste and pollution, and conserving water and other natural resources" (Pew, 2009, p. 5), this new economy is composed of the following categories:

1. clean energy;
2. energy efficiency;
3. environmentally friendly production,
4. conservation and pollution mitigation; and
5. training and support.

The category of clean energy is particularly important for the purposes of this paper, and can be further broken down into three sectors of the economy: energy generation, energy transmission, and energy storage. As seen in Table 2 (next page), a variety of positions—commonly known as "green jobs"—are created through the development of clean energy sources. According to Pew (2009, p. 12), clean energy jobs, businesses, and investments are required to "have a positive net energy yield, reduce greenhouse gas emissions compared with other sources of energy, and be produced and distributed in a sustainable and safe manner." Unfortunately, we are not aware of any empirical data which indicates which of these occupations are most likely to benefit rural residents, though some speculation seems safe (photonics engineers are less likely to be located onsite than the solar power plant technician).

In 2007, Pew (2009, p. 15) counted approximately 89,000 jobs in the clean energy sector (i.e., energy generation, transmission, and storage). In contrast, the traditional energy sector (i.e., utilities, coal mining, and oil and gas extraction) employed approximately 1.27 million workers in 2007, or 1% of national employment.[34] Six out of ten jobs in the clean energy sector are related to energy generation. In fact, 62.5% of all energy generation jobs in 2007 were in the solar industry, while wind power generation accounted for 9.7% of total energy generation jobs (see Figure 4).

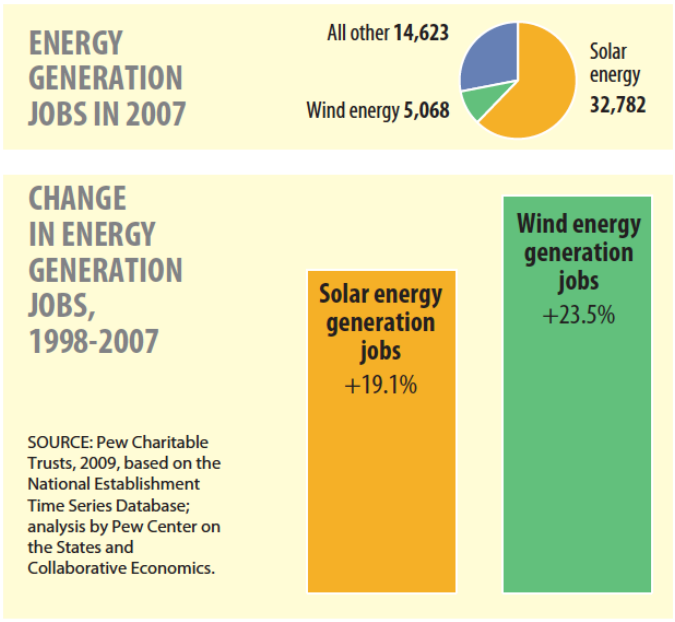
[34] U.S. Bureau of Labor Statistics, Current Employment Statistics, http://www.bls.gov/ces/, accessed April 27, 2011.

Table 2. Clean Energy Employment Sectors

	Sub-segment	Examples of Occupations
Energy Generation	Energy consulting	Electrical engineering technicians
	Energy management (software, services, devices)	Computer systems analysts
	Biomass (hydrogen, other, waste-to-energy)	Power plant operations technicians, process engineers
	Geothermal (geothermal drilling, generation, development, hardware)	Operating engineers and other construction equipment operators, drilling engineers (Geothermal)
	Hydro	Plumbers, power plant operators
	Marine and tidal	Mechanical engineering technicians
	Hydrogen	Mechanical engineering technicians, chemists
	Multiple	Solar and wind system installers
	Other (combined heat/power, hydrogen production, natural gas, on-site systems, waste heat, renewable energy providers)	Plumbers, electrical engineers
	Research and testing	Electrical engineers
	Solar (material feedstock supplier, PV: thin film, PV: polysilicon, concentrated PV, BIPV, solar thermal, solar installers and contractors, equipment sales and distribution)	Photonics engineers, solar power plant technicians
	Co-generation	Mechanical engineering technicians, boiler process engineers
	Accessory equipment and controls (solar, wind)	Electricians
	Other generation equipment	Mechanical engineering technicians
	Wind (consulting, water pumping systems, wind plant operators and developers, turbine and tower manufacturing, equipment sales and distribution)	Electricians, wind turbine service technicians
Energy Transmission	Cable and equipment	Electrical power-line installers and repairers
	Services (power monitoring and metering, power quality and testing)	Electricians, power distributors and dispatchers
	Transmission (sensors and controls, Smart Grid)	Electrical and electronic equipment assemblers
Energy Storage	Advanced batteries (Li-Ion, NiMH, advanced PB-acid, charging and management, nickel zinc, other technologies, thin film, ultra capacitors, multiple)	Electrical and electronic equipment assemblers, tool and die makers
	Fuel cells (methanol, PEM, solid oxide, systems Integrators, zinc air)	Electro-mechanical technicians
	Hybrid systems (flywheels, heat storage, hydrogen storage)	Mechanical engineers
	Uninterruptible power supply	Electrical engineers

Source: Pew, 2009, p. 43

Figure 4. Clean Energy Generation Jobs in 2007; Change in Energy Generation Jobs, 1998-2007



Source: Pew, 2009, p. 18

Energy transmission jobs, or those dealing with the distribution and delivery of energy, accounted for one of every nine jobs in the clean energy sector, while the remaining 31% of jobs were in the energy storage segment (Pew, 2009, p. 18). Despite its relatively low share of employment nationwide, Pew's research shows that between 1998 and 2007, total employment in the clean energy economy grew by 9.1%, while national employment grew by only 3.7%.

Investment, clean energy, and local ownership

Most renewable energy projects require public subsidies to "level the playing field"[35] and compete in the market place.[36] The average retail price of electricity in the U.S. is a bit under ten cents a kilowatt hour, though the price varies by sector and location.[37] The table of renewable energy production costs that is reproduced in Appendix C makes clear the tendency of hydro and wind power and some biofuels to be among the most competitive renewables under current market conditions.

Pew (2009) confirms that despite a number macroeconomic and financial challenges, the U.S. clean energy sector is successfully attracting private sector venture capital. Venture capital investment in clean technology grew after 2005, crossing the $1 billion threshold in that year and achieving a cumulative total of about $12.6 billion during the three following years. In 2009, both U.S. and European

[35] This is a general concept referring to policies that would attempt to achieve rough parity for the subsidization of fossil fuels. For example, the Environmental Law Institute (2009) estimated that subsidies to fossil fuels totaled approximately $72 billion between 2002-2008, while subsidies for renewable fuels totaled $29 billion over the same period. Making a related point, Delucchi and Murphy (2008) estimated that were there no oil in the Persian Gulf, then US combined peacetime and wartime defense expenditures might be reduced in the long run by roughly $27–$73 billion per year (in 2004 dollars).

[36] See for example REN21 (2010, p.11), which summarizes policies including subsidies that have increasingly been adopted to promote renewable energy by dozens of countries, states, provinces, and cities during the past 15 years, and especially during the period 2005–2010.

[37] See http://www.eia.gov/cneaf/electricity/epm/table5_6_a.html, accessed July 3, 2011.

additions to electricity generating capacity from renewable sources such as wind and solar exceeded additions from conventional sources like coal, gas and nuclear, a result that held on a global basis as well.

Most recently, Pew (2011) reports that worldwide investment and financing of clean energy rebounded from the global recession: a 30% increase brought total investment to a record $243 billion. To broadly contextualize this world figure, Jacobsen and Delucchi (2009) roughly estimate that a total worldwide conversion to a wind, water and solar system over 20 years would involve construction costs "on the order of $100 trillion worldwide", or $5 trillion annually, not including transmission.

Pew (2011) also reports that U.S. investment in clean energy rebounded more than 50% to $34 billion. Despite the substantial increase, the U.S. slipped from second to third place in clean energy investment. U.S. venture capital dedicated to clean technology (mostly energy related) sectors grew rapidly since 2009 in numerous subsectors (solar and transportation investments, followed by smart grid and alternative fuels investments, led in growth rates), but these investments are very heavily concentrated in solar and transportation (PWC, 2011). Within the world's largest economies overall, nearly half of private clean energy investment was in wind in 2010, but growth in small scale and residential solar was most pronounced. Solar energy investment overall grew at 53% annual growth rate.

The reality is that these investment totals, while significant and growing, pale in relation to both estimated need and other investments in just public infrastructure. The cumulative construction cost of the interstate highway system through 1995, for example, was estimated to be $452 billion in 2010 dollars (Cox and Love, 1996). The American Recovery and Reinvestment Act of 2009 committed $275 billion just to contracts, grants, and loans.[38]

Considering energy infrastructure that in some cases includes and in others competes with renewable investment capital, a recent report (Chupka et al., 2008) estimates that by 2030, the U.S. electric utility industry will need to make a total infrastructure investment of $1.5 trillion to $2.0 trillion, averaging as much as a hundred billion dollars a year. A DOE study (see Kaplan and Vann 2010, p. 1) pegged the investment necessary to scale up wind energy to be $60 billion for transmission alone. The Aspen Environmental Group (2010) similarly cites an industry study that foresees expenditures on new natural gas pipelines ranging from $106-$163 billion, and up to $348 billion if coal-fired generation must be replaced with natural gas due to policy changes at the state and federal levels. The latter figure, it should be noted, does not include costs of around $335 billion for the natural gas generation facilities themselves. More generally, a 2009 report focusing attention on the needs for basic investment to modernize neglected infrastructure in the U.S. calculated five-year annual investment needs of $87 billion per year as a baseline, and high-end needs of $148 billion per year (Heintz et al., 2009). Finally, to put all of these numbers in a different perspective, total gross fixed capital formation of the U.S. for 2009 (essentially the sum of private sector investment in capital) totaled $2.12 trillion.[39] Current investments are still small in relation to what is needed for large scale transition, and there is a mix of competing and complementary infrastructure demands on available capital which will be prioritized in private markets primarily by profitability.

Because most renewable energy projects will be located in rural areas, the opportunity for rural communities to benefit from overall investment in renewable energy for rural areas is evident. Whether

[38] And another $512 billion in tax benefits and entitlements; see http://www.recovery.gov/Pages/default.aspx.
[39] See http://data.worldbank.org/indicator/NE.GDI.FTOT.CD.

rural places can turn this opportunity into sustainable economic development is less clear. The concern is whether money that flows into the community is likely to be "sticky" or whether it flows right back out again. This local versus nonlocal benefit issue is as important for the investment/profit equation as it is for the job creation and supply chain issues considered in previous sections. Calling for a policy which views renewable energy development less as an energy security issue with agricultural implications and more as a rural development issue with energy security implications, Morris (2007) makes a forceful argument on these grounds that "local ownership of renewable energy production is key." Though not strictly a rural or energy production example, it is worth noting in this context that the world's largest producer of crystalline silicon photovoltaic modules recently announced it would build its first manufacturing plant in the U.S. in the outskirts of Phoenix, Arizona. Suntech Power Holding Co. Ltd. thereby became the first Chinese clean tech company to set up manufacturing facilities in the U.S. (PWC, 2011). It will not be the last.

Access to capital of any kind for small towns and rural areas tends to be limited. Venture capital in particular is concentrated geographically as well as by industry sector. Well over half of total U.S. venture capital investment ($23.3 billion in 2010) occurs in New England and Silicon Valley, while more than two thirds of this investment goes to the software, biotechnology, industrial/energy, medical devices, and IT service sectors.[40] Barkley and Markley (2001) summarize several characteristics of nonmetro areas that restrict access to such funds:

- their tendency to be concentrated in low-tech, low growth sectors;
- the smaller size of rural investments resulting in higher relative fund management costs;
- the reluctance of many rural businesses and entrepreneurs to sacrifice ownership control;
- higher costs for identifying or creating deals and higher time and transportation costs for conducting due diligence and monitoring the investments; and
- lack of fully developed business infrastructure and human capital.

Because of these barriers, the authors identify three types of nontraditional venture capital programs that have successfully served small market areas: public venture capital funds; publicly assisted, privately managed venture capital funds; and community-level equity funds. The current and potential role of these kinds of mechanisms to promote access to venture capital in rural areas for renewable energy in particular does not appear to be well researched or widely understood.

Public ownership is perhaps the most obvious approach to public, and in some contexts local, control of investment and profit. Although clearly from another political era entirely, it is worth first invoking the famous example of the federally owned Tennessee Valley Authority's (TVA) involvement in renewable energy and its multiple missions of regional economic development, electricity generation, flood control and other water management issues.[41] Still the nation's largest public power company, the TVA started by building large hydropower dams, then diversified its mix. TVA now generates about 60% of its power from fossil fuels, 30% from nuclear power, and about 10% from hydropower. However, TVA has increased its commitment to rural energy as noted in recent publicity: "The Tennessee Valley Authority's successful strategy to balance consumer demand for renewable energy through Green Power Switch

[40] PricewaterhouseCoopers/National Venture Capital Association Moneytree Report Data accessed 7/29/2011 from https://www.pwcmoneytree.com/MTPublic/ns/nav.jsp?page=notice&iden=B

[41] See http://www.tva.com/, accessed 7/29/2011.

with renewable generation from the Generation Partners initiative placed 10 local power companies among the top providers of solar power in the region and nation in 2010."[42]

Rural electric cooperatives[43] are another New Deal legacy that remain vital in rural areas and are central players in the economic development, environment, and energy mix for rural areas. The National Rural Electric Cooperative Association serves more than 900 not-for-profit rural electric cooperatives and public power districts in 47 states. These rural institutions provide retail electric service to more than 42 million consumers and account for approximately 12% of electricity sales in the U.S., with the electricity demand growth rate in their territories about double that for other electric utilities. Most of them are consumer-owned local distribution systems, but they also include 66 generation and transmission cooperatives that supply wholesale power to their distribution cooperative owner-members.[44] Rural distribution co-ops collectively depend on hydropower for about 10% of their needs, and on other renewables for about 3%.[45]

In theory at least, the ability to implement efficiency measures (thereby selling less electricity) and increase use of renewable energy could be easier for nonprofit organizations than it is for investor-owned utilities (Wilson et al. 2008). The rural co-op movement has turned fairly aggressively to energy efficiency ("the fifth fuel") as a way to meet increased demand with an emphasis on keeping electricity prices affordable.[46] Co-op interest in renewable energy is also increasing cautiously as utility-scale projects have become economically viable in some regions of the country. However, like others focused on centralized utility-scale renewable electricity generation, the rural co-operatives highlight as significant barriers the lack of "high-voltage transmission infrastructure to move it from the rural settings in which it is generated—the Great Plains and desert Southwest—to the urban, suburban and exurban markets in which demand is growing" and "the political will to designate the transmission corridors necessary to take full advantage of the sun and wind with which we are blessed."[47]

New approaches to economic development

Economic development scholars (cf. Zheng and Warner, 2010; Shaffer et al., 2006) have noted the evolution of economic development theory and practice over the years away from "smokestack chasing"

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[42] See http://www.tva.com/news/releases/julsep11/renewable_growth.htm, accessed 7/29/2011.

[43] Our focus here is on rural electric cooperatives, but municipal electric utilities are another common form of consumer owned utility, many with similar characteristics. They tend to be small and numerous. There are 1,848 municipal utilities out of 2,100 total public utilities including federal state and county districts. Municipal utilities cover roughly the same share of the retail market as rural coops (both around 10%). However, only 3% of the municipal utilities in 56 large cities account for over half of their sales. About 32% of all municipal utilities own generation capacity, though nearly 2/3 of these own a total of 25MW or less (Wilson et al. 2008). The many small municipal utilities would are of most relevance for rural and small town places.

[44] See http://www.nreca.coop/about/Pages/default.aspx , accessed 7/29/2011.

[45] See http://www.nreca.coop/members/Co-opFacts/Documents/Distributioncoopfuelmix.pdf, accessed 7/29/2011. Coal accounted for 58%, nuclear 17% and natural gas 12% of the overall mix.

[46] For example, a consortium of twenty electric cooperatives of South Carolina (serving 1.5 million consumers and 70% of the state's land mass), has plans to avoid the dramatically higher costs of next generation nuclear and fossil fuel plants with a pilot program targeting a 10% reduction in residential energy use statewide through weatherization and replacement of resistance heating and inefficient heat pumps. The program will involve certified home energy audits, cost effectiveness evaluation, loan processing, in-home contractor work, post-retrofit audits, and on-bill payments. Based on anticipated federal financing, the program is expected to defer the need to pay for half of a nuclear plant. Legislation has passed the house and is pending in the Senate to authorize a national program based on the South Carolina pilot. See http://www.eesi.org/resp , http://www.newpartners.org/2011/docs/presentations/thurs/NP11_Smith-Energy.pdf, and http://www.nreca.coop/press/Testimony/Documents/RESPA_Final_Bruce_Graham_Testimony0711.pdf, accessed 7/1/2011.

[47] See http://www.nreca.coop/about/Documents/NRECA_Annual_Report_2010.pdf p. 2, accessed 7/29/2011.

and toward more multi-layered, place-based "community economic development" approaches. Such approaches emphasize the role of institutions, social and cultural factors, and governance and decision-making capacities in addition to the more traditional focus on export markets and advantages in land, labor, and capital resources. These additional considerations open the door to more strategies for economic development in rural areas, but they also draw attention to challenges in rural institutional and governance capacity which often parallel their lack of critical mass in economic arenas (e.g., skilled labor force, industry clustering, marketing potential).

This evolution in theory and practice has been summarized in one recent review as a shift away from "the pursuit of mobile capital to cultivation of local economic assets," with increasing attention being given to the economic, environmental, and equitable "triple bottom line" concepts undergirding sustainable development (Carley et al., 2011, p. 284). Significantly, Carley et al. argue further that intensifying national concern about climate change, energy price volatility, and insecure foreign energy supplies has set the political and economic stage for a converging relationship between energy and economic development policy. Their exposition of "energy based economic development" enumerates specific goals:

- Increased energy self sufficiency,
- Increased energy diversification,
- Energy focused economic growth, and
- Development more broadly conceptualized as enhanced collective well-being.

The importance of both rural communities and renewable energy resources to the attainment of these goals is evident. In particular, the emphasis on the "cultivation of local economic assets" is highly compatible with the distributed energy generation systems discussed previously. Moreover, these issues engage directly with the history of research on rural economic development which has long highlighted the importance of the interplay of three determinative "facts of life": (1) natural resource advantages or endowments, (2) economies of concentration or agglomeration, and (3) costs of transport and communication (Irwin et al., 2010).

Also notable are the parallels that many of these goals share with those underpinning the growing support for local and regional food systems as enumerated by Jensen (2011). Jensen highlights as motivating tenets of the local and regional food movement concerns about community-based economic development ("buy local"), food security and its relation to social justice, food safety and its relation to the "shorter supply chains of regional production systems," and enhanced environmental sustainability and sense of community through increased localization. While the goals of Carley et al.'s energy based economic development cannot be mapped precisely onto these terms, it is not a stretch to see support for local and regional energy systems stemming from motivations to "buy local," improve energy security and social justice, shorten "supply chains of regional production systems," and enhance environmental sustainability and sense of community through increased localization.

Challenges and concerns of rural energy development

The challenges involved in transitioning to renewable energy are considerable, and they require unique approaches and solutions in rural America. Concerns policymakers will confront include unstable economic growth; those related to the preservation of social ties and effective community development; and issues related to the interaction between water and energy.

Volatility and change

As energy transitions take place, rural communities must be prepared for the economic volatility associated with certain energy development scenarios. While energy development is often celebrated for its job creation and economic development potential, there are less well-considered concerns that communities must address related to rapid population growth and increased employment. Rapid change of any kind, especially if it is not under the control of those affected by it, has been understood to be a mixed community blessing by sociologists from at least the time of Durkheim in the late 19th century.

Though most research into the well-known rural boom and bust phenomenon has looked at the cycles associated with depletable resources where there is an inevitable eventual bust, renewable energy development is not exempt from significant ups and downs. The energy sector overall exhibits at the very least the volatility of overall economic growth, and the renewables sector in particular is vulnerable to the political tug of war over energy policy and changes in policy direction. Other factors familiar to farmers such as weather and land and food policy can cause additional variance in renewables markets. It is also noteworthy that oil prices and crop prices tend to be correlated to no small degree because of the extensive fossil fuel inputs involved in modern agriculture.

In any event, rural communities are not always ready to handle influxes of people and economic activity, and "booms" can potentially result in negative effects to society and local economies (Brookshire and D'Arge, 1980). Furthermore, small towns and rural areas may be more likely to experience consequences of economic impacts that would be less noticed in a large, metropolitan area (Besser et al., 2008, p. 580). Despite these challenges, small town and rural municipalities may have a more comprehensive understanding of the local ramifications of economic booms, given their relative smaller size and lower level of complexity (Besser et al., 2008, p. 580-581).

Fortunately, economic volatility is somewhat predictable, meaning local governments can counteract the negative effects associated with boom-bust cycles by taking certain precautions. Indeed, tax incentive, workforce training, and land banking programs can all be implemented in response to harbingers of volatility such as an undiversified economy, limited access to capital, a poorly educated, low-skilled workforce, and limited greenfield availability (Kasarda and Irwin, 1991; Malizia and Ke, 1993; Spelman, 2006).

A recent study of western states by Headwaters Economics (2011, p. vi) underscores both the importance and variability of local, regional, and state governance capacity to respond effectively to the challenges posed by economies that depend heavily on volatile energy markets. They suggest somewhat paradoxically that, "Predominantly rural areas with high levels of drilling and limited economic diversity may be the most overwhelmed by the buildup phase of an energy boom, but also are the places that ultimately may see the greatest long-term fiscal gain from energy development."

Regional economic stability and diversity

In preparing for local economic development generated by energy transitions, it is also important to consider the relationship between economic stability and diversity. Stability can be defined as the absence of variation in economic activity over time. Diversity, however, refers to differences in economic structure, or variety of economic activity (Malizia and Ke, 1993, p. 222). Economists have hypothesized that more industrially diverse areas should experience more stable economic growth and lower rates of unemployment than less diverse economies. This can essentially be explained by the notion that a diverse economy has a wide variety of industries that help to smooth out macro-level

fluctuations experienced by any individual industry. Employment gains in some industries, in other words, mitigate employment losses in other industries, moderating region wide unemployment.

In terms of the actual effects economic diversity has on growth and stability, results are mixed. Some researchers (Tress, 1938; Rodgers, 1957; Attaran, 1986) find no correlation between economic instability and diversity, while others (McLaughlin, 1930; Vining, 1946; Leser, 1949; Kort, 1981) observe a positive relationship between diversity and stability. This may be a result of a theoretical inconsistency of jointly pursuing economic growth (which is generally achieved through specialization), and diversity—two competing goals (Wagner and Deller, 1998).

At a more fundamental level, the most convincing research concludes logically enough that the most stable economies are based on the most stable employers. Diversity only helps if the mix of sectors includes stable sectors, or as noted above in some cases if additional sectors balance each other counter-cyclically. The web of economic diversity in predominately rural regions is almost by definition likely to be thinner than in areas with greater population concentration. In the context of this paper, the most important question related to stability is likely to be whether or not renewable energy production complements or competes with other rural economic mainstays such as tourism, agriculture, mining, and public sector employment. It may well be that incremental growth in renewable energy would be largely complementary, but it is not hard to imagine that conflicts in rural areas (consider transmission lines, logging trucks, turbine noise, etc.) will increase as the scale of renewable energy development becomes increasingly significant.

Water and energy

The relationship between water and energy is intimate, multifaceted, and important. It is of special significance in rural areas, which serve as sources/sinks/regeneration sites for many kinds of water and energy resources. Insofar as fossil fuel consumption contributes to greenhouse gas emissions, any changes in climate, weather patterns, and precipitation are causally linked to energy consumption.

Similarly, energy extraction practices that alter forestation or land use practices can have feedbacks that affect precipitation patterns and water supplies regionally. In addition, significant amounts of energy can be consumed simply in moving or treating water for irrigation, household use, industrial use, and for treating sewage and wastewater. Here, however, our attention is focused more on the extent to which the demand for energy leads to the demand for water in energy production. In some locations, energy and water development can provide complementary resources to support the nation's needs while stimulating economic development. In areas where water is scarce and water-intensive energy resources are abundant, conflicts will inevitably arise.

Indeed, various elements of the energy production process affect both water quantity *and* quality. Oil and gas exploration and production, for instance, not only use water-intensive drilling and fracturing processes, but can potentially impact surface and groundwater as well. The transport of energy through pipelines, similarly, can affect surface and groundwater quality through persistent minor leaks or more sudden spillage incidents. The production of renewable energy can also leave its mark on water. Crops used for producing biofuels and ethanol require water for growing and refining, while water is subsequently needed in the treatment of refinery wastewater. The amount of water used or affected by the production of solar and wind power is negligible; a nominal amount is used for cleaning solar panels and windmill blades.

Connections between water and energy production are particularly important to rural America, given the geographic diversity of energy production potential (i.e., solar in the Southwest and biomass in the Northwest). The likelihood and extent of future water shortages is also regionally specific, and should factor into any energy development scenario planning.

While certain regions of the U.S. may hold great potential for a specific type of energy development, the water-intensiveness of each production process must receive equal consideration. The societal costs and benefits of water shortages versus reliable energy supply must also be weighed.

Moving forward: Energy policy & planning

Rural America can provide the energy of tomorrow. As future public policy integrates environmental concerns with those regarding economic development, it is essential that *people*—the primary actors—become part of the policy formation process.

The federal government has for quite a few years lacked the consensus necessary to provide strong leadership on energy and climate policy (Carley, 2011). Unlike European Union member states that have aggressive renewable energy targets for 2020, the U.S. has no federally defined targets (Delmas and Sancho, 2011). It appears that the assertions of a 2005 General Accounting Office (GAO 2005, p. 33) report are still relevant: "While the United States does have, and has had, a series of energy-related programs and tax policies, calls for a 'national energy policy' persist."

Nevertheless, some new federal energy legislation has emerged out of concerns over the price volatility and political implications of America's ongoing dependence on foreign sources of energy (Campbell et al., 2009). Many federal energy programs had their beginnings during the 1970s, but have been redesigned by more recent legislation, including the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, and the American Reinvestment and Recovery Act. The Department of Energy (DOE) is responsible for most renewable energy research, development, demonstration, and deployment, but programs also operate under the auspices of the Departments of the Treasury, Agriculture, Transportation, Labor, and Housing and Urban Development (Campbell et al., 2009, p. 1).

Green jobs legislation

A series of federal programs and policies have emerged over the past several years that promote job creation in the clean energy economy. Among these is the Green Jobs Act of 2007. In addition to establishing renewable energy and energy efficiency job training programs, the Green Jobs Act created a research program to study energy-related workforce trends. Programs receive $125 million a year, and are administered through the U.S. Department of Labor (Hanke and Sauer, 2009, p. 4).

In 2009, the job training programs established by President Bush received additional funding totaling $1.2 billion through President Obama's American Recovery and Reinvestment Act (ARRA), or stimulus package (Hanke and Sauer, 2009, p. 4). ARRA was not only expected to create over 500,000 green jobs[48],

[48]Based on reports filed by recipients of ARRA funds (probably not the most accurate measure), 571,383 full time equivalent jobs (not necessarily all "green") were funded directly by ARRA during the first quarter of 2011. The Congressional Budget Office estimates, based on macroeconomic modeling, that between 1.2 million and 3.6 million full time equivalent jobs are likely to have been supported by ARRA in 2011 (CBO 2011).

but also to accelerate the implementation of smart grid technology and devote funding to a variety of energy efficiency efforts around the country (Hanke and Sauer, 2009, p. 4).

Energy conservation

Individuals living in the U.S. also have enormous opportunities to reduce their energy consumption and make more efficient use of existing energy systems. It is instructive to consider that Europe's significantly lower per capita energy use can be attributed roughly evenly between energy efficiency and other factors, such as lifestyle (IEA, 2004). Because rural american households consume more per energy per capita than do city dwellers, they have the most to gain economically from conservation.[49]

Energy conservation, in and of itself, has the potential to mitigate climate change and reduce America's dependence on foreign energy sources. Lester Brown, in his popular book titled, *Plan B 3.0* (2008, p.215), suggests that simply replacing inefficient incandescent light bulbs may be the "quickest, easiest, and most profitable way to reduce electricity use worldwide." Significant energy savings can also be achieved through the use of energy-efficient technologies, more efficient building design, and more sustainable transport. Transportation options include such strategies as the use of more energy efficient automobiles, combining more destinations in a single trip, ride sharing, and mode shifts from automobiles to public transit, bicycling, and walking.

One overarching way to evaluate energy efficiency is to consider the energy inputs required to run the economy. Lester Lave (2009) has estimated continued GDP growth through 2030 would, without enhanced efficiency measures, require more than a doubling of oil imports and vast increases in natural gas production to fuel the associated 69% increase in national energy demand. A National Academy panel has provided estimates of the overall potential for the contributions of energy conservation in 2020 and 2030 (2010a).[50] They concluded that by 2030, 30.5 quadrillion BTUs of energy might be saved conservatively (35.8 optimistically). They also found that energy efficiency in buildings offered the greatest possibility for U.S. energy savings.

Finally, there are several indirect benefits of conservation that should be emphasized. Savings in electricity production and use can forestall the need to build difficult to site and costly new power plants.[51] In general, less environmental (air, land, and water) pollution is caused, and high economic, social, and health costs are reduced when less energy is consumed to get the same benefits. One related issue that is often raised in relation to conservation is the so-called economic "rebound effect", or the

[49] See http://www.eia.gov/emeu/recs/recs2001/ce_pdf/spaceheat/ce2-8c_urbanrural2001.pdf and http://www.eia.gov/emeu/rtecs/nhts_survey/2001/tablefiles/table-a03.pdf accessed 8/1/2011. Owners of rural vehicles not surprisingly consumed (in 2001) more gasoline (approximately an additional 90 gallons on average) and spent more money (an additional $100 on average) per vehicle, though they averaged slightly better mileage. For space heating, per capita consumption of "rural" and "suburban" dwellers was statistically indistinguishable. However "town" dwellers consumed significantly more and "city" dwellers significantly less than both. (Survey respondents classified their locations themselves.)

[50] The estimates are assessments of the potential energy savings achievable with the use of energy efficiency technologies, assuming a rapid rate of deployment, but one nevertheless consistent with past deployment rates. See http://books.nap.edu/openbook.php?record_id=12621&page=3.

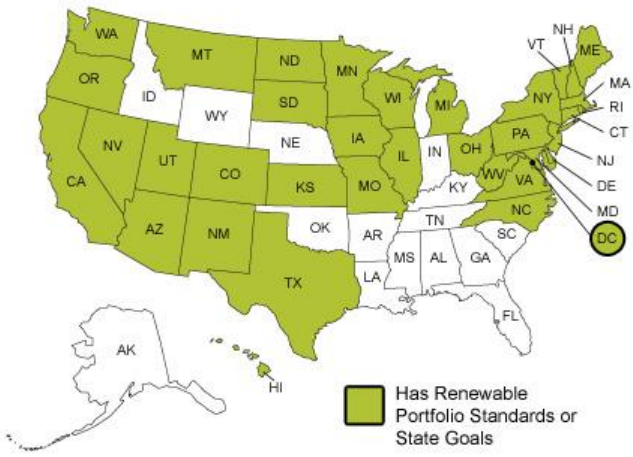
[51] Forestalling new fossil fuel power plants through conservation has in some ways gotten easier. Over the past 30 years there has been a dramatic decrease in the optimal size of electric power plants as natural gas-fired turbines in the range 50–100 MW became economically competitive with older and larger coal-fired plants. Renewable energy installations tend to be even smaller (Sharaboff et al., 2009). Chupka et al. (2008) estimate that "aggressive energy efficiency and demand reduction programs" could significantly reduce a projected large need for new generation capacity. According to their models, such measures drop the forecasted need for new capacity from 214 GW to an estimated 133 GW, a 38% reduction.

paradoxical notion that conservation can actually stimulate increased energy consumption. This economic effect is logically possible if conservation reduces demand for energy so much that the price of energy falls, because a price reduction would indeed stimulate some rebound in consumption. However, while most empirical studies note that there is indeed some detectable rebound, it tends to be very low to moderate in size (Greening et al., 2000).

State-level energy policies and programs

While many energy policies can be universally applied from the federal level, in both urban and rural contexts, location-specific policy development is critical. Indeed, the regional diversity of land uses, natural environments, and policy mechanisms in the U.S. require unique and place-appropriate responses. What follows is a closer look at the most commonly found state-level energy policies and their general characteristics[52]:

Figure 5. States with Renewable Portfolio Standards



Source: Database of State Incentives for Renewables & Efficiency

- **Tax incentives**: Many states provide full or partial tax incentives to both individuals and businesses seeking convert existing technologies or purchase new technologies for the use or generation of renewable energy. Eligible producers often must demonstrate significant investment and job creation.

- **Grant programs**: Renewable energy grant programs are common at the state-level, and often provide loan subsidies to individuals and businesses.

- **Loan programs**: Loans are generally offered to local government, municipal utilities, and independent power producers for the development or upgrade of energy production facilities.

- **Production incentives**: Production incentive programs create an incentive for homeowners and businesses to generate energy from renewable sources, as the managing authority or agency agrees to purchase generated electricity at a competitive rate. This program takes a market approach to renewable electricity generation. The following is a list of organizations offering similar programs:

    - Golden Valley Electric Association (http://www.gvea.com/) – serving Alaska
    - Tennessee Valley Authority (http://www.tva.gov/) – serving Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia

- **Rebates**: Rebates are commonly offered to individual and businesses that generate renewable energy on a per kWh basis.

[52] See ACORE (2010), Carley (2011), or Komor (2004) for more information on state policies and programs.

- **Property-assessed clean energy (PACE) financing**[53]: PACE financing assists home and business owners with covering the fixed costs of installing renewable energy technologies; the financial support is generally repaid through increased property taxes over several years.

- **Public benefit and clean energy funds**: Some states impose a surcharge on residential and commercial electric bills that goes toward funds for energy programs.

- **Net metering**: Many states have net metering policies that allow for the connection between renewable energy generators and public utility power grids.

- **Renewable portfolio standards (RPS)**: The majority of states have some kind of RPS mechanism (see Figure 5), which generally requires electric supply companies to produce a specified amount of electricity from renewable energy sources. In addition to assigning responsibility for meeting certain renewable energy generation goals, RPSs often assign penalties for failing to meet those goals.

- **Covenant restrictions and access laws**: Some states, such as Arizona and Colorado, protect the rights of homeowners to install solar or wind energy technologies regardless of any local covenant, restriction, or condition attached to a property deed.

- **Feed-in tariffs (FIT)**: a feed-in-tariff is an energy supply policy that supports the generation of renewable power, often through requiring utilities to purchase electricity from renewable energy generators, rather than requiring utilities to provide renewable energy to their customers as renewable portfolio standards do. There is evidence that FITs may support more renewable energy development than the RPS model by providing investor certainty (Cory et al., 2009).

- **Green certificates**: Also known as tradable renewable certificates (TRC) or renewable obligation certificates (ROC), green certificates represent the environmental benefits associated with renewable energy generation (e.g., greenhouse gas emissions), and can be traded and valued in a secondary market.

Several states have implemented unique programs that respond to their varied energy needs. In addition, several states have demonstrated their ability to create living planning documents that will guide future energy policy in their respective commonwealths.

- **California**: California's first Energy Action Plan (EAP) was released in 2003, and subsequently updated in 2005 and again in 2008. The EAP places strong emphasis on energy efficiency, citing the stability of California per capita electricity use over the past 30 years while electricity consumption in the U.S. has increased by nearly 50%. This achievement is partially due to some

[53] See http://en.wikipedia.org/wiki/PACE_Financing and http://pacenow.org/blog/. Notwithstanding these measures, on July 6, 2010, the Federal Housing Finance Agency issued a statement that directed lenders Fannie Mae and Freddie Mac not to underwrite mortgages for properties with a PACE assessment. The technical concern was to prohibit loans that have a senior lien priority to a mortgage. The PACE Assessment Act of 2011 has been introduced to the House of Representatives to try to remedy this situation. See http://www1.eere.energy.gov/wip/pace.html and http://pacenow.org/blog/ Web accessed 7/29/2011.

of nation's most aggressive energy savings goals for both electricity and natural gas that were adopted by the California Public Utility Commission (CPUC) in 2004.

In addition to energy efficiency efforts, the California EAP has specifically targeted eight additional areas, including demand response; renewable energy; electricity adequacy, reliability, and infrastructure; electricity market structure; natural gas supply, demand, and infrastructure; transportation fuels supply, demand, and infrastructure; research, development, and demonstration; and climate change (CEC and CPUC, 2005).

California's RPS is a very ambitious mandate that requires all electric utilities in the state to increase procurement from renewable energy resources by 1% of their total annual sales, until they reach a level of 33% by 2020.

- **California Solar Initiative (CSI)**: The CSI will invest over $2 billion over ten years in grid-connected solar energy. The program provides rebates for solar energy development and is funded by ratepayers.
- **Property-Assessed Clean Energy (PACE) Financing**: Under PACE, California authorizes local municipalities to offer special financing programs to property owners
- **Tax incentives**: Expenses related to the design, manufacture, production, or assembly of renewable energy equipment receive full tax exemption in California. Also, certain types of solar energy systems are exempt from property tax requirements.

In addition to these initiatives, an impressive 20% or more of electric utilities in California offer cash rebates to homeowners producing energy wind turbines, fuel cells, or solar panels.

- **Colorado**: Like California, Colorado has an ambitious renewable energy portfolio standard (30% procurement of from renewable energy by 2020). The state also has the fifth largest solar market and the ninth largest wind market in the U.S.

- **Maine**: Maine and the Federal Energy Regulatory Commission (FERC) have streamlined the federal and state licensing process for offshore wind and ocean energy projects, which is the first agreement of its kind on the East Coast.

- **Michigan**: In 2006, Michigan enacted legislation establishing 15 Renewable Energy Renaissance Zones (RERZ) across the state. Renewable energy generation or research and development facilities inside these zones are exempt from the Michigan Business Tax, state education tax, property tax, and local income tax (where applicable).

- **Texas**: Texas boasts great potential in a variety of renewable energy sources, and currently leads the nation in wind power generation. The Texas State Energy Plan, created in 2008 when natural gas prices and demand were peaking, was based on the expectation of increasing costs of electricity due to the inability of natural gas producers to meet growing demand. The Plan attempts to foster competition within energy markets and lower prices for consumers. There is a strong emphasis in the Texas Plan to limit state interference in the electric sector, so as to not "hinder the development and adoption of new technologies" by private companies (Texas, 2008). There is also recognition that residents should be educated in order to make informed decisions about their energy purchasing needs.

Given the emerging shift toward more decentralized energy supplies, local communities—particularly rural ones—have the opportunity to shape future energy systems through land use and economic development policy. Once residents "see the link between policies, their livelihoods, and their children's futures, they become stakeholders in the policy process" (Scriabine and Day, 2000, p. 85). Underlying this assertion are efforts toward greater participation and more empowerment on the part of residents. A healthy political environment, therefore, should be characterized by environmentally aware leaders and high levels of civic engagement. Effective polices, laws, and regulations should go beyond making rules to empowering citizens to make environmentally beneficial choices. Overall, institutions implementing environmental policy should be capable of advocating for reform and educating both residents and community leaders.

Of special concern will be decisions related to siting renewable energy generation facilities and equipment (i.e., solar arrays, wind farms, power lines). Whether emerging technologies will require physical separation from residences as do power plants and refineries depends on scale (Lovins, 2011) and the extent to which each technology results in spillovers like noise, dust, fumes, or heavy transport (Andrews, 2008, p. 243).

Wind farms do not pollute, but they do permanently affect residents' views, even from miles away, given their height and (typically) prominent hilltop siting in rural landscapes that help maximize wind capture. Energy generation from wind, therefore, is only possible where neighboring landowners and local permitting agencies value the development's economic benefits over an unobstructed horizon. Rooftop solar panels also involve unique challenges that can only be overcome with effective planning. For instance, local zoning codes that govern building height and setback requirements can be used to guarantee direct access to sunlight in the face of shading by nearby structures and trees (Andrews, 2008, p. 243).

Education, leadership, and capacity building

Environmental education, rural leadership, and capacity building programs can help to achieve optimal results by shaping policy, explaining it, and making it work. Indeed, by taking a more participatory approach to policy formation, these programs have the potential to bring stakeholders into the process in meaningful and effective ways (Scriabine and Day, 2000, p. 85). Authentically participatory processes help build ownership, buy-in, and distributed responsibility (LaChappelle, 2009). Cultural, economic, and political factors have led to what one observer of the public sector calls a "dramatic shift in emphasis away from the management and leadership *of* public organizations to management and leadership across organizations", i.e. a shift from a focus on hierarchy to a focus on networks and inter-organizational partnerships (Morse 2008, p. 80). Educational programming focused on rural leadership development and natural resource, energy, and land use planning has similarly increasingly focused on skill building related to collaboration, conflict resolution, public issues education, and participatory planning (Addor et al., 2006; Kay, 2009; Singletary et al., 2008; Sirianni, 2009).

Since the 1970s, efforts made to increase citizen awareness of and concern for the natural environment and its problems have been considered forms of environmental education. Successful environmental education programs go beyond the presentation of information to help students wrestle with values and gain the skills needed to solve problems. This is generally done by helping people develop research and analytical skills, but has also been used to train professionals to consider the environment in the work they do (Monroe, Day, and Grieser, 2000, p. 5-6). Environmental education is also distinct from other efforts in that it teaches students *how to think*, not *what to think*. In other words, specific behavioral change is not the only target of much environmental education programming. Rather, program

participants build the capacity to collect and analyze information in order to make sound judgments on their own.

UNESCO—or the United Nations Educational, Scientific, and Cultural Organization—in a report to the Intergovernmental Conference on Environmental Education in 1978, identified five objectives of environmental education programs that still hold merit today:[54]

- **Awareness**: to acquire an awareness and sensitivity to the total environment and its allied problems.
- **Knowledge**: to gain a variety of experiences in, and acquire a basic understanding of, the environment and its associated problems.
- **Attitudes**: to acquire a set of values and feelings of concern for the environment and motivation for actively participating in environmental improvement and protection.
- **Skills**: to acquire the skills for identifying and solving environmental problems.
- **Participation**: to encourage citizens to be actively involved at all levels in working toward resolution of environmental problems.

Summary & outstanding issues

The premise of this paper is that the transition to renewable energy is inevitable and that there is a distinctive set of possibilities for rural America as this transition unfolds. The paper has provided some basic background on the production and consumption of energy, especially renewable energy, and relevant energy policies (or the lack thereof). It has also considered some of the forces, trajectories and geographies that are likely to be involved in the transition to renewable energy. Most significantly, it has tried to point out the implications and issues for rural places in this transition.

At this point, as in the Lab's paper on Local and Regional Food Systems (Jensen 2011), it is time to "draw out key themes for the Lab's future consideration." Some of the themes echo those found in the food systems paper, in part because of RUPRI's consistent interest in the well-being of rural communities. Energy, like food, is fundamental to human existence and development.

Energy, like food, has also primarily been produced in rural places and sold in commodity markets for consumption in other places and energy, like food, has a long history serving as the economic anchor of many rural communities. And in a more than trivial sense, energy and food are also strongly codependent. Energy is a major input into modern agriculture, and especially as corn ethanol has increasingly fueled the automobile fleet, the term "energy feedstock" has taken on new meaning. Among the questions that remain unanswered is one raised in Jensen's paper: What are the compatibilities and incompatibilities between food system and energy system policy goals?

Building sustainable wealth: Some unanswered questions

As noted, both food and energy have been and probably will be primarily produced for domestic if not international export. This opens the door to wealth creation in rural communities, but far from guarantees that the wealth will not simply exit from whence it came. What financial, regulatory, and regional economic development mechanisms can most effectively help rural communities attract investment and keep a fair share of the wealth "down on the farm" and field? Are rural financial and

[54] List of objectives adopted from AED 2000, p.5.

economic development institutions, governments, and utilities preparing for the transition? What potential exists for existing and evolving rural energy institutions like municipal utilities and rural electric cooperatives to lead and support rural community and economic development during the transition to renewable energy? How much investment in renewable technology will be regionally or even domestically controlled?

Different forms of renewable energy have significantly different wealth and job creation profiles—though all use natural resources found in rural places, many are highly capital intensive. Only biomass requires a significant amount of local enterprise to provide the fuel that powers renewable systems. How significant then is the potential for the manufacture in rural places (or in the U.S. as a whole for that matter) of the energy capital that will be deployed in rural places? Even if this potential is low, what is the potential for low (relatively if not absolutely) cost locally generated renewable energy to be a spur for rural economic development? Will rural areas have privileged access to the energy they produce? To what extent can rural enterprises use the energy they produce to add value to locally produced products, and market the value added products rather than raw energy?

How significant, in particular, might the role of distributed renewable energy systems be? Will they play a major part in a rural transition to renewables, or will they exist only in tiny niche contexts as counterpoints to a dominant, centralized renewable utility system that mirrors the existing fossil fuel powered utility system? What forces will determine this? Will farm, food, and climate policy at the federal and state levels take shape in ways that promote or conflict with distributed energy systems (or more likely both simultaneously)?

What about job creation in the renewable industry itself? Will rural workers be qualified for the jobs, or will they go primarily to immigrants? Will the people who take the jobs, regardless of their origin, be long term or short term residents of rural communities? How many of the jobs provided will be quality jobs providing a livable wage and job security?

Finally, as in the food sector, questions about entrepreneurship and innovation are pressing. How can policymakers and communities encourage entrepreneurship within local and regional energy systems in rural regions, paying particular attention to the potential for distributed energy and district energy systems? How will innovations in renewable energy technology, not to mention nonrenewable energy technology, contribute to the potential for renewable energy development in rural areas? Can rural entrepreneurs benefit from participating in and promoting climate change mitigation and ecosystem services through diversity and new technologies on their land?

Social equity: Who will benefit and who will lose?

The transition to renewable energy will have multiple equity aspects involving different groups. One aspect involves the distribution of change impacts among people already living in rural places, for example farmers obtaining payments for energy land leases and others in the community who will lease no land. Another aspect involves those who will likely move both to and away from rural places because of energy transition effects. The pace and scale of change may well be dramatic, and will tent to benefit the adaptable and prepared while challenging those with less flexibility and fewer resources. As we have discussed, the transition has rural implications nationally that will be related to the uneven distribution of both renewable and nonrenewable energy resources in different regions of the country. The transition also focuses attention on minority, Native American, and low-income rural populations—with vastly different access to rural land and energy resources—posing the question of how they can more fully participate in and benefit from renewable energy development.

The transition also involves questions about the way the relationship between rural and urban places in the U.S. will change. And because food and energy systems have been increasingly internationalized for commodities produced in rural places, it also involves international equity issues, just as farm policy does. The old question of who owns, and will in the future, own and control rural land is relevant. Both economic theory and history suggest that owners of land suitable for renewable energy production are likely to be the first-ring beneficiaries of the transition. What will landowners who gain windfalls do with their gains? Will they spend them quickly on consumer goods or invest? Will they use the land as before, or change the use of land? Will they keep their money in the region or spend nearly all of it elsewhere? Will they continue to live locally or move elsewhere?

Finally, at a time when there is much attention being given internationally to "land grabs" by countries and companies interested in acquiring food and fuel sources as a hedge against future price increases, it is worthwhile thinking about the relevance of this issue to rural America as well. How significant is it that 1.7% of privately held agricultural land was in foreign ownership as of 2009, or that between 2006 and 2009 foreign holdings increased by 6.3 million acres (Blevins et al., 2009)?

Regional collaboration and urban-rural interdependence

Rural and urban energy systems are and will remain interdependent, though in a renewably fueled society not in the same way and to the same degree. Many of the questions Jensen highlights in her paper also pertain to energy: What do regional energy systems look like today in terms of their economic reach, social inclusion, and environmental impacts? For example, how do regional energy systems contribute to or detract from economic development and environmental quality in rural America, and quality of life and public health outcomes in urban places? Do local and regional energy systems increasingly focused on renewables help protect good agricultural farmland from development? Are there thresholds of concentration on renewable energy production that cannot be passed without negative consequences for rural regions?

Moreover, how will rural places currently supported by the tourism sector be affected, and how will urban people relate to a countryside that is reverting from an amenity landscape back to a production landscape? Will renewable energy policies that supply the urban population with power affect agriculture in a size neutral way; will they provide primarily further incentives for farm consolidation, or will the open new doors for medium and small scale agriculture? How does energy driven relocalization interact with the long progressive push in the land use planning community for more energy efficient and compact development patterns, which has tended to focus on making pre-existing urban communities more densely settled while protecting farm and open space?

How can rural communities prepare for the changes that will affect them?

Most people live where they do because they have chosen to do so. Although some change is often welcome, dramatic change is normally not. During the transition to renewable energy, there will be dramatic, even transformational change in many rural communities as landscapes are converted from their current uses. Much of this change will in effect be part of a deal rural places make with urban places to exchange money and jobs for energy.

Even if the rural majority favors more wind and solar and more intensive use of crop and forestland, others will not. Moreover, fossil fuels like natural gas and oil will also be more intensively mined in rural places. Even communities that do not have intensive energy industry in them are likely to be affected as the need to dramatically expand the electricity grid and make it "smarter" becomes more pressing.

These changes will not simply pass over parts of rural America that have increasingly been valued for their beauty and amenity value and the tourism economy. Not everyone thinks a windmill is a grand addition to the skyline. Even the wealth and prosperity that may come to many communities will likely bring change, division, and newcomers. Conflict is inevitable. But, as this paper has tried to convey, communities with the proper governance infrastructure, consensus building skills, land use planning capacity, and financial and capital planning tools to deal with change will be the best prepared for the future opportunities this transition will bring.

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Appendix A: Understanding energy systems

Definitions

An energy system can be thought of as a constellation of dispersed energy resources of different types that are connected to end users through transmission and distribution networks. The process by which raw forms of energy are transformed and then consumed by end users involves six phases: exploration, extraction, processing, distribution, storage, and end use (Smil, 2010).[55] The most notable environmental impacts for rural places occur at the exploration, extraction, and processing phases, as they typically involve great effort and expenditure to locate the resource, retrieve it from the earth, and distill or mechanically transform it into a usable energy commodity (Chiras, 2010, p.279). Transmission and distribution impacts can also be significant as ecosystems and communities are transected by pipelines, powerlines and ancillary development.

Energy exists in primary and secondary forms, and can be renewable or nonrenewable. The division of energy into primary and secondary categories is based on how they are produced. *Primary energy* is contained in raw fuels that are initial inputs to an energy system. Primary sources of energy can be harvested (e.g., wood or crops), extracted from the earth's crust (e.g., fossil fuels), or captured by conversion devices like solar panels, hydroelectric dams or wind turbines (Smil, 2010, p.5).

[55] Though the "exploration, extraction, processing" terminology is most suited to a description of fossil fuel and mineral energy sources, most renewable energy sources must be analogously located, captured, and transformed into a useable form.

Once combusted, these sources become *secondary energy* in the form of heat, light, or electricity. The conversion from primary to secondary sources of energy generally involves a chemical transformation.

Nonrenewable energy sources include natural gas, petroleum, coal, and nuclear energy (Chiras, 2010, p.277). These energy sources are extracted from areas of the earth, as primary sources, in which they have been formed or have accumulated in relatively high concentrations. Most sources of energy used in the U.S. and other developed countries fall under the category of nonrenewables. In fact, approximately 85% of all energy produced and consumed domestically comes from either fossil fuels or nuclear energy (Chiras, 2010, p.275).

How is energy measured and compared?

Different types of energy are measured using a variety of physical units, including:

- barrels (bbl.) or gallons of petroleum
- cubic feet of natural gas
- tons of coal
- kilowatts (kW) of electricity

The British Thermal Unit (Btu) is the most commonly used unit in the U.S. for comparing amounts of energy content in different sources. Some common conversions include:

- 1 bbl. (42 gallons) of crude oil = 5.8 million Btu
- 1 gallon of gasoline = 124,238 Btu
- 1 cubic foot of natural gas = 1,027 Btu
- 1 kW of electricity = 3,412 Btu

(http://www.eia.doe.gov/energyexplained/)

As easy-to-recover fossil fuels have been increasingly depleted, their production, environmental, and geopolitical costs have increased. In general, easy, low-cost nonrenewable resources are exploited first, and even with technological improvements, these resources over time become increasingly difficult and expensive to find, extract, and process. At some point they become too costly to exploit, and can eventually require more energy to develop than the amount they supply for end use.

Hubbert (1956) first predicted that fossil fuel production would exponentially increase and at some point reach a peak output and then decline exponentially. In the continental U.S., peak oil was reached, as Hubbert predicted, in the early 1970s. There is currently much debate about the timing of peak oil worldwide, and whether it has already passed by or still lies ahead (de Almeida and Silva 2009).

Current energy consumption

Total energy consumed by Americans has grown steadily since the 1950s, a result of both population growth and a growing number of appliances and electric devices (Holechek et al., 2003, p.606). In fact, primary energy consumption in the U.S. nearly tripled from 1949 to 2009 (EIA, 2009).

Over a third of the energy consumed in the U.S. is derived from petroleum, while natural gas and coal account for 25% and 21% of energy consumption, respectively. Nuclear power and renewable energy each account for less than 10% of the total consumed, but their shares are growing. Renewable energy consumption rose by 5% from 2008-2009 and 15% from 2007-2009. While there was a small decline in nuclear electric power consumption from 2008-2009, its share of total primary energy consumed increased (EIA, 2009).

Imported oil is important for political and economic reasons. Though the U.S. is the world's third largest crude oil producer, nearly half of U.S. oil consumption is imported. Imports surpassed domestic production in 1995. Canada is the largest single foreign supplier, providing a quarter of U.S. oil. Saudi Arabia supplies less than half that amount, at 12%. The Persian Gulf states combined supply about a fifth of U.S. needs. In a positive trend, U.S. dependence on imported oil peaked in 2005. The EIA attributes the decline in oil consumption to a) the economic downturn after the financial crisis of 2008, b) improvements in efficiency, c) changes in consumer behavior and patterns of economic growth, all contributed to the decline in petroleum consumption. On the supply side, EIA point to a) the increased

use of domestic biofuels (ethanol and biodiesel) and b) increased domestic production of crude oil and natural gas plant liquids which reduced the need for imports.[56]

Energy use in the U.S. can be categorized among four sectors: industrial, commercial, residential, and transportation. The industrial sector encompasses manufacturing, mining, agricultural, and construction operations, while the transportation sector includes vehicles that transport people or goods, whether by air, land, or water. Houses and apartments comprise the residential sector, and the commercial sector includes any non-residential buildings (e.g., offices, schools, hospitals, restaurants, etc.).

While the industrial sector used substantially more energy than any other sector during the middle of the 20th century, industry took drastic energy conservation measures following rising energy prices during the 1970s. Energy consumption in the other three major sectors has generally continued to increase despite the oil, gasoline, and natural gas price escalations that typified the mid-1970s through the early 1980s and more recently the 2000s. Currently, the industrial and transportation sectors account for approximately 30% of energy consumed, while the commercial and residential sectors have somewhat smaller shares (19% and 22%, respectively).

Transportation and energy

Unlike other end-use sectors, transportation relies almost exclusively on petroleum, thus exposing an essential sector to unanticipated fuel price increases and market volatility. While energy use in the residential, commercial, and industrial sectors has become more diverse in terms of energy type, transportation's mixture has remained virtually unchanged.[57] Moreover, by the turn of the 21st Century, more than 4 out of every 10 barrels of petroleum consumed in the U.S. were in the form of motor gasoline, and the transportation sector alone accounted for two-thirds of all petroleum used.[58] As Greene (2004 , p. 276) points out, "petroleum use has become increasingly concentrated in the economic sector that has shown the least ability to find acceptable alternative sources of energy: transportation."

Total petroleum consumption has risen annually for decades (save for two years of slowed consumption following to the OPEC embargo), paralleling the trend in vehicle miles traveled and counteracting significant improvements in vehicle fuel efficiency since the 1970s. Petroleum usage in the transportation sector—and consequent greenhouse gas emissions—can be reduced by increasing fuel efficiency, developing alternatively fueled vehicle technologies, or reducing vehicle miles traveled. Still, while advancements have been made in alternative fuel technology, the transportation sector consumed only 922 trillion BTU (3.4% of total consumption) of renewable energy (in the form of biomass) and 687 trillion BTU (2.5%) of natural gas, compared to 25,342 trillion BTU (94%) of petroleum.[59] The biggest challenge to the widespread development of alternatively fueled vehicles is the incomparable utility of oil as an energy source. Petroleum fuels have the highest fuel density both by weight and volume compared to the most promising alternatives; this property is key as a vehicle's ability to transport people and goods decreases as the weight and/or volume of fuel that must be carried increases (Greene, 2004).

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[56] See http://www.eia.gov/energy_in_brief/foreign_oil_dependence.cfm.

[57] U.S. Energy Information Administration (EIA), 2010, "Annual Energy Review 2009," accessed July 26, 2011, http://www.eia.gov/emeu/aer/pdf/aer.pdf, 38.

[58] United States Energy History," Annual Energy Review (AER), U.S. Energy Information Administration (EIA), accessed July 26, 2011, http://www.eia.gov/emeu/aer/eh/eh.html

[59] See http://www.eia.gov/emeu/aer/eh/eh.html, accessed July 26, 2011,

While advances are being made in hybrid electric (HEV), plug-in, and fuel cell (FCV) vehicle technologies,[60] policies that increase vehicle fuel efficiency (through regulations or market-based approaches such as rebates and subsidies) and decrease vehicle miles traveled may hold the most promise for reducing the transportation sector's reliance on both domestic and foreign sources of petroleum. Werber et al. (2009) highlight a number of advantages of electric (battery) cars over internal combustion engine vehicles, including superior life cycle efficiencies, carbon-free transportation (but only if electricity is generated renewably[61]), significantly less maintenance and repair due to a single moving part in the electric motor, ability to refuel at home, and a number of use scenarios that are favorable for these vehicles (for short trips when gasoline costs are high). Negatives are higher capital cost that grows linearly with the size of the battery pack, which determines the car's range. In rural areas, the range issue seems to point towards hybrid more than fully electric vehicles.

Smart growth planning (concentrating well designed mixed use development in locations near pre-existing infrastructure) has the potential to decrease vehicle miles traveled through a combination of denser development and mixed land uses (residential, shopping, job sites) that reduce the need to travel long distances. Smart growth densitites also enable economically viable investments in transit, and supporting policies can promote less single-occupancy vehicle travel (i.e. ridesharing, car sharing). However, though village and small town revitalization or densification include many elements of smart growth, smart growth is intended to reduce development pressure on rural, less developed regions of the U.S. For those who continue to live outside villages in rural communities, driving less may not be an option. Furthermore, future alternative fuel technologies needing extensive charging or fueling infrastructure may be slow to expand to rural areas. These realities further highlight the need explore local, decentralized solutions to pressing energy challenges as America transitions to more renewable sources.

Electricity usage[62]

Electricity, a secondary energy source, supports much of what many Americans take for granted living twenty-first century lifestyles. U.S. electricity use in 2009 was about 13 times greater than electricity use in 1950. At 38% of overall electricity consumption, the residential sector is the major consuming sector. The residential sector is closely followed by commercial sector consumption (37% of the total), and then the industrial sector (25% excluding industrial direct use of electricity). Little electricity is used in the transportation sector, mostly for trains and plug-in electric cars. (Some scenarios for the future involve the electrification of the automobile—something that would undeniably result in large increases in electricity demand.)

Total electricity consumption has consistently increased over the long run. However, the rate of increase has slowed since 1950, from 9% per year in the 1950s to less than 2.5% per year in the 1990s. Growth in demand is projected by the EIA to continue at about 1% per year through 2035.

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[60] National Renewable Energy Laboratory (NREL), "Hybrid Electric & Fuel Cell Vehicles," accessed July 26, 2011, http://www.nrel.gov/vehiclesandfuels/hev/

[61] Campanari et al. (2009) show that when various typical fossil fuel mixes are used for electricity generation, battery electric vehicles perform much less well. In this case, fuel cell electric vehicles (especially liquid hydrogen generated from natural gas or renewable sources) become "much more favourable both by the point of view of efficiency and CO2 emissions, especially if the driving range requirement becomes significant (e.g. several hundred km) due to the progressive increase in the battery weight."

[62] See http://www.eia.doe.gov/energyexplained/index.cfm?page=electricity_use.

Electricity is overwhelmingly produced by three major primary fuels: coal, natural gas, and nuclear power. The environmental and economic problems or limitations of each of these fuels has become increasingly evident as concerns about high costs, greenhouse gas emissions, and other environmentally hazardous byproducts plague each fuel to a greater or lesser extent. These costs, especially as they become fully internalized, provide the best impetus for the increased use of renewable energy.

Energy conservation and efficiency

It is important to realize that at every stage of an energy system—from exploration to end use—work must be done and energy expended. During the energy conversion process, some of the energy content of a raw energy source is unavoidably (but also some avoidably) consumed or lost as waste heat or light (Chiras, 2010, p.278). As graphically displayed in a chart produced by the Lawrence Livermore National Lab,[63] only about two-fifths of the energy that is converted from primary sources in the U.S. is actually put to use providing useful energy services. Nearly all the energy that is not put to work is from oil consumed in cars and from heat that is lost in the process of generating electricity.

This highlights the critical importance for the future of targeted conservation and efficiency measures in the production of energy. For example, in conventional electricity generating plants (fueled mostly by coal and distantly followed by nuclear and natural gas), about two-thirds of the energy in the primary fuel is lost—vented as heat—right at the power plant.[64] Alternative systems (e.g., combined cycle and combined heat and power or CHP) reuse some of their waste heat for additional electricity production and are often able to capture some of the heat for process or space heating applications in nearby facilities. Conservation and efficiency measures are critical to consider in the development of future technology, regardless of the fuel used.

Individuals living in the U.S. also have enormous opportunities to reduce their energy consumption and make more efficient use of existing energy systems. It is instructive to consider that Europe's significantly lower per capita energy use can be attributed roughly evenly between energy efficiency and other factors, such as lifestyle (IEA, 2004). Energy conservation, in and of itself, has the potential to mitigate climate change and reduce America's dependence on foreign energy sources. Lester Brown, in his popular book titled, *Plan B 3.0* (2008, p.215), suggests that simply replacing inefficient incandescent light bulbs may be the "quickest, easiest, and most profitable way to reduce electricity use worldwide." Significant energy savings can also be achieved through the use of energy-efficient technologies, more efficient building design, and more sustainable transport. Transportation options include such strategies as the use of more energy efficient automobiles, combining more destinations in a single trip, ride sharing, and mode shifts from automobiles to public transit, bicycling, and walking.

One overarching way to evaluate energy efficiency is to consider the energy inputs required to run the economy. Lester Lave (2009) has estimated continued GDP growth through 2030 would, without enhanced efficiency measures, require more than a doubling of oil imports and vast increases in natural gas production to fuel the associated 69% increase in national energy demand. A National Academy panel has provided estimates of the overall potential for the contributions of energy conservation in

[63] See https://flowcharts.llnl.gov/.
[64] See, for example, http://www.eia.doe.gov/cneaf/electricity/chg_stru_update/chapter3.html#N_3_.

2020 and 2030 (2010a).[65] They concluded that by 2030, 30.5 quadrillion BTUs of energy might be saved conservatively (35.8 optimistically). They also found that energy efficiency in buildings offered the greatest possibility for U.S. energy savings.

Finally, there are several indirect benefits of conservation that should be emphasized. Savings in electricity production and use can forestall the need to build difficult to site and costly new power plants.[66] In general, less environmental (air, land, and water) pollution is caused, and high economic, social, and health costs are reduced when less energy is consumed to get the same benefits. One related issue that is often raised in relation to conservation is the so-called economic "rebound effect", or the paradoxical notion that conservation can actually stimulate increased energy consumption. This economic effect is logically possible if conservation reduces demand for energy so much that the price of energy falls, because a price reduction would indeed stimulate some rebound in consumption. However, while most empirical studies note that there is indeed some detectable rebound, it tends to be very low to moderate in size (Greening et al., 2000).

Energy transmission, distribution, and management

Energy sytems require extensive infrastructure networks throughout each stage of production and consumption. The closer the source of production to the point of consumption, the lower the investment needed in transmission and distribution. Thus, there is generally a value premium for energy that is produced close to market. However, because most energy supplies are remote from urban consumers, and because large scale generation facilities are mostly incompatible with residential urban development, an enormous infrastructure investment has been made in transmission and distribution systems to connect generators with consumers. Though electricity can be economically moved long distances through the electric grid, it is not efficient to move heat for more than short distances. Thus, usable heat is generated (or captured/converted in the cases, for example, of solar and geothermal heating systems, or lakewater cooling systems) at or near the point of use, more or less regardless of the fuel source.

In the case of electricity in particular, extensive networks of transmission and distribution lines are required before most electricity can be used, in addition to a host of converters (i.e., lights, appliances, electric motors) ready to use the delivered energy (Smil, 2010). Historically, the costs derived from installing, operating, and maintaining the transmission and distribution system comprised about two thirds of the total costs of producing and delivering electricity to residential-commercial customers, and over one third of the total costs of supplying electricity to large industrial customers (Baughman and Bottaro, 1976).

[65] The estimates are assessments of the potential energy savings achievable with the use of energy efficiency technologies, assuming a rapid rate of deployment, but one nevertheless consistent with past deployment rates. See http://books.nap.edu/openbook.php?record_id=12621&page=3.

[66] Forestalling new fossil fuel power plants through conservation has in some ways gotten easier. Over the past 30 years there has been a dramatic decrease in the optimal size of electric power plants as natural gas-fired turbines in the range 50–100 MW became economically competitive with older and larger coal-fired plants. Renewable energy installations tend to be even smaller (Sharaboff et al., 2009). Chupka et al. (2008) estimate that "aggressive energy efficiency and demand reduction programs" could significantly reduce a projected large need for new generation capacity. According to their models, such measures drop the forecasted need for new capacity from 214 GW to an estimated 133 GW, a 38% reduction.

Appendix B: Energy prices

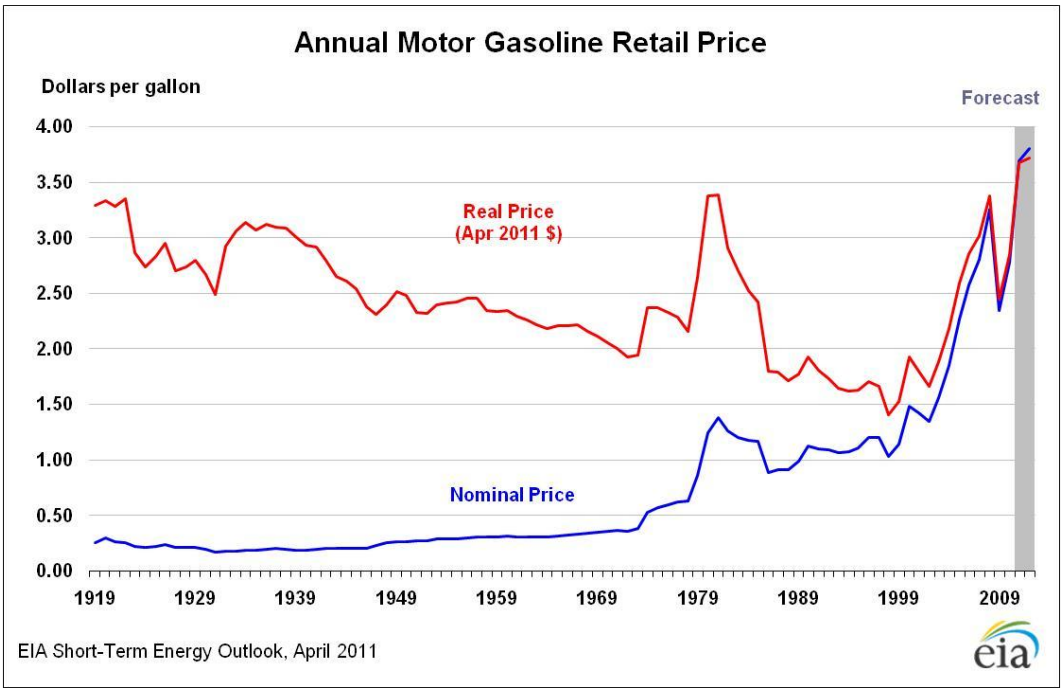
The real price of gasoline and heating oil trended downward through most of the twentieth century, spurring consumption until shocks associated with the OPEC embargo in 1973 and Iranian hostage crisis in 1979. Subsequently, prices re-stabilized during the 1990s but then experienced upward pressure during the 2000s due to tightening supplies, political instability in producing regions, and strong economic growth in populous countries like China and India.

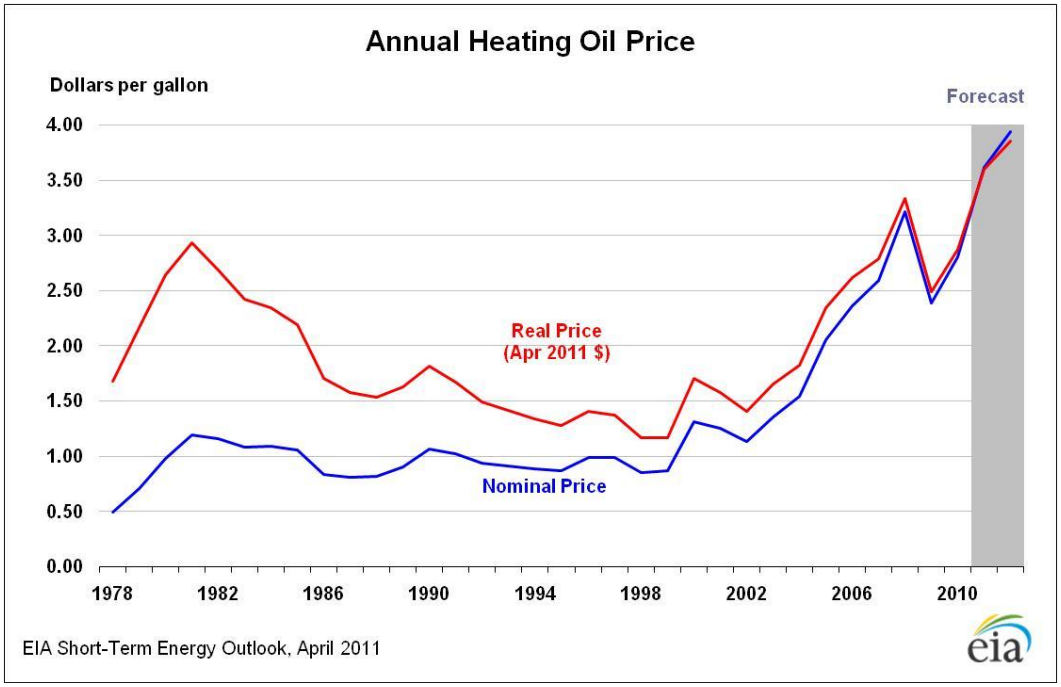
Coal prices in recent years have also increased significantly, though with large reserves, most analysts project "peak coal" to be a ways off, though perhaps not so distant as many suppose.[67] Low cost coal has been the basis for most electricity generation in the U.S., though due to market conditions and environmental concerns, natural gas has been increase its market share, as have renewable sources (wind and biomass in particular) from a small base.

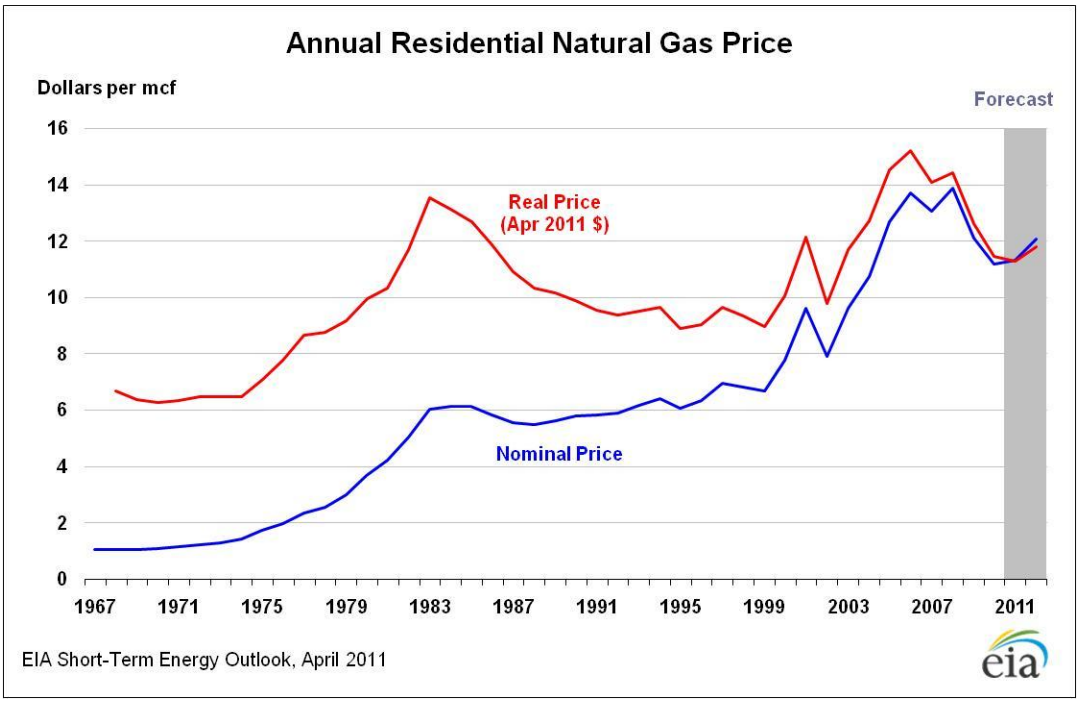
Residential natural gas prices have followed a trajectory somewhat like that of coal prices, though with greater volatility. Recent applications of technology enabling the economic extraction of natural gas from "tight shales" seem likely to decelerate or limit price increases of this fuel.[68] However, the hydraulic fracturing technology for gas extraction is controversial and policy about the conditions of its application is still in flux. Though natural gas markets are not yet as fully globalized and commodified as oil markets (an outcome that depends largely on the future of relatively costly liquefied natural gas, or LNG, which makes international trade in natural gas feasible), because gas bearing shales are widespread around the world, damping effects on price seem likely regardless of the resolution of contested issues about regulation of this form of energy extraction in the United States.

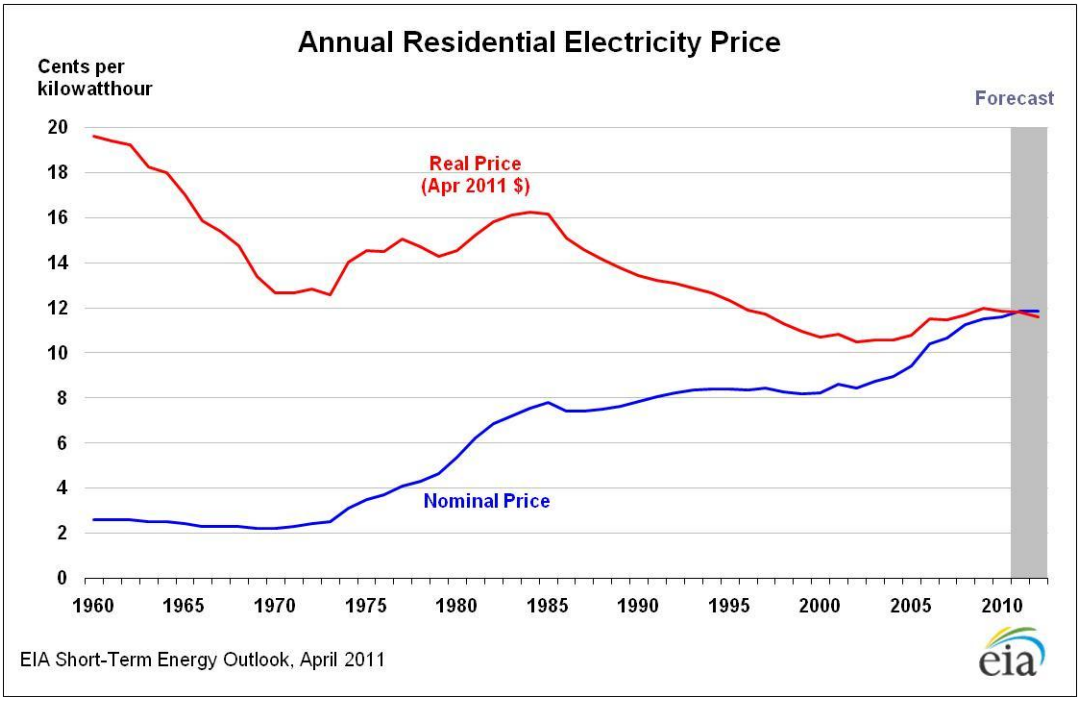
Though nominal prices have increased, real residential electricty prices have declined throughout most modern history. The exceptions of rising real prices were during the period of energy shock adjustment from the 1970s through the mid 1980s and again since the turn of the century. Prices reflect the interaction between production/transmission costs (which vary mostly by type of fuel and power plant technology, the distance between the generator and end user, and regulations) and energy demand. Weather conditions can affect both supply and demand. Electricity demand growth has continued but slowed in each decade since the 1950s. From 2000 to 2009 (including the 2008-2009 economic downturn) demand grew by 0.5% per year. The Energy Information Administration expects electricity demand growth to remain modest as growing demand for electricity services is offset by efficiency gains from new appliance standards and investments in energy-efficient equipment. The average retail price of electricity in the United States in 2009 was 9.2 cents per kilowatt-hour (kWh), with residential, commerical and transportation customers paying slightly higher than average prices and industrial customers paying less.[69]

[67] For example, Mohr and Evans (2009) predict that worldwide production will likely peak between 2010 and 2048 on a mass basis and between 2011 and 2047 on an energy basis.
[68] See EIA projections at http://www.eia.gov/analysis/ and a related summary/presentation at http://www.eia.gov/neic/speeches/newell030210.pdf, accessed June 30, 2011.
[69] See http://www.eia.gov/energyexplained/index.cfm?page=electricity_factors_affecting_prices, accessed June 30, 2011.


Annual Motor Gasoline Retail Price
Dollars per gallon
Forecast
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Real Price
(Apr 2011 $)
Nominal Price
1919
1929
1939
1949
1959
1969
1979
1989
1999
2009
EIA Short-Term Energy Outlook, April 2011
eia

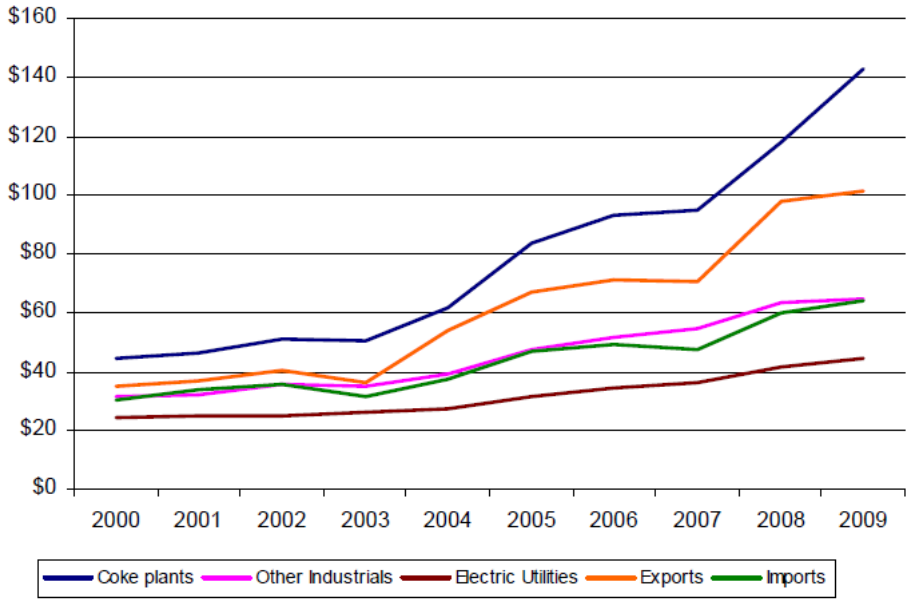

Annual Heating Oil Price
Dollars per gallon
Forecast
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Real Price
(Apr 2011 $)
Nominal Price
1978
1982
1986
1990
1994
1998
2002
2006
2010
EIA Short-Term Energy Outlook, April 2011
eia





Source: http://www.eia.doe.gov/EMEU/steo/realprices/index.cfm.

Figure 7. Delivered Coal Prices, 2000-2009
(Nominal Dollars per Short Ton)



Sources: Energy Information Administration, Quarterly Coal Report, October-December 2009, DOE/EIA-0121(2009/Q4) (Washington, DC April 2010); Coal Industry Annual, DOE/EIA-0584, various issues; and Annual Coal Report, DOE/EIA-0584(2003), various issues; Electric Power Monthly, March 2010, DOE/EIA-0226 (2010/03), (Washington, DC); and U.S. Department of Commerce, Bureau of the Census, "Monthly Report EM 545" and "Monthly Report IM 145."

Source: http://www.eia.gov/FTPROOT/coal/article_dc.pdf.

Appendix C: Comparative Costs of Renewables

Technology	Typical Characteristics	Typical Energy Costs (U.S. cents/kilowatt-hour unless indicated otherwise)
Power Generation		
Large hydro	*Plant size*: 10 megawatts (MW)–18,000 MW	3–5
Small hydro	*Plant size*: 1–10 MW	5–12
On-shore wind	*Turbine size*: 1.5–3.5 MW *Blade diameter*: 60–100 meters	5–9
Off shore wind	*Turbine size*: 1.5–5 MW *Blade diameter*: 70–125 meters	10–14
Biomass power	*Plant size*: 1–20 MW	5–12
Geothermal power	*Plant size*: 1–100 MW; *Types*: binary, single- and double-flash, natural steam	4–7
Solar PV (module)	*Cell type and efficiency*: crystalline 12–18%; thin film 7–10%	----
Rooftop solar PV	*Peak capacity*: 2–5 kilowatts-peak	20–50
Utility-scale solar PV	*Peak capacity*: 200 kW to 100 MW	15–30
Concentrating solar thermal power (CSP)	*Plant size*: 50–500 MW (trough), 10–20 MW (tower); *Types*: trough, tower, dish	14–18 (trough)
Hot Water/Heating/Cooling		
Biomass heat	*Plant size*: 1–20 MW	1–6
Solar hot water/heating	*Size*: 2–5 m^2 (household); 20–200 m^2 (medium/multi-family); 0.5–2 MWth (large/district heating); *Types*: evacuated tube, flat–plate	2–20 (household) 1–15 (medium) 1–8 (large)
Geothermal heating/cooling	*Plant capacity*: 1–10 MW; *Types*: heat pumps, direct use, chillers	0.5–2
Biofuels		
Ethanol	*Feedstocks*: sugar cane, sugar beets, corn, cassava, sorghum, wheat (and cellulose in the future)	30–50 cents/liter (sugar) 60–80 cents/liter (corn) (gasoline equivalent)
Biodiesel	*Feedstocks*: soy, rapeseed, mustard seed, palm, jatropha, and waste vegetable oils	40–80 cents/liter (diesel equivalent)
Rural Energy		
Mini-hydro	*Plant capacity*: 100–1,000 kilowatts (kW)	5–12
Micro-hydro	*Plant capacity*: 1–100 kW	7–30
Pico-hydro	*Plant capacity*: 0.1–1 kW	20–40
Biogas digester	*Digester size*: 6–8 cubic meters	n/a
Biomass gasifier	*Size*: 20–5,000 kW	8–12
Small wind turbine	*Turbine size*: 3–100 kW	15–25
Household wind turbine	*Turbine size*: 0.1–3 kW	15–35
Village-scale mini-grid	*System size*: 10–1,000 kW	25–100
Solar home system	*System size*: 20–100 watts	40–60

Note: Costs are indicative economic costs, levelized, exclusive of subsidies or policy incentives. Typical energy costs are under best conditions, including system design, siting, and resource availability. Optimal conditions can yield lower costs, and less favorable conditions can yield substantially higher costs. Costs of off-grid hybrid power systems employing renewables depend strongly on system size, location, and associated items such as diesel backup and battery storage. Costs for solar PV vary by latitude and amount of solar insolation. *Source*: Data compiled from a variety of sources, including U.S. National Renewable Energy Laboratory, World Bank, International Energy Agency (IEA), and various IEA Implementing Agreements. Many current estimates are unpublished. No single published source provides a comprehensive or authoritative view on all costs. Changes in costs from the equivalent Table 1 in the *Renewables 2007 Global Status Report* reflect a combination of refined estimates, technology changes, and commercial market changes. For further costs reference, see World Bank/ESMAP, *Technical and Economic Assessment: Off Grid, Mini-Grid and Grid Electrification Technologies*, ESMAP Technical Paper 121/07 (Washington, DC: 2007); and IEA, *Deploying Renewables: Principles for Effective Policies* (Paris: OECD, 2008).

See http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf, p.26.