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A STRATEGY FOR DEVELOPING STATIONARY BIODIESEL GENERATION

KARL R. RÁBAGO*

I. OVERVIEW

The electricity system in the United States, and indeed throughout most of the developed world, has remained essentially unchanged for nearly 100 years. It is a large, central station-dominated, one-way electron delivery system with relatively little intelligence, little or no cybernetic function, concentrated market power, retail monopolies, and very little choice or control by ultimate customers. With the advancement of clean distributed generation technologies and the systems to interconnect them with the grid, the stage has been set for a fundamental restructuring of the architecture of electricity systems. Biodiesel-fueled stationary electric generation has the potential to be a leader in the advancement of this transformation. Dispatchable, renewable, clean-burning, non-explosive, environmentally degradable, and now supported by federal incentives, biodiesel has the potential to fuel tens of thousands of megawatts of standby generators already in place in cities across the country.[1]

The staying power of the basic architecture of the electric grid mirrors the scale of capital investment that built it. Thus, despite attempts at electric utility deregulation on a retail scale, the introduction of wholesale competition, and fairly significant advances in electric technologies, the electric grid's basic structure has not changed much over the past several decades. Essentially, modern electric systems are one-way electron delivery systems characterized by large central station generating plants and a network of transmission and distribution infrastructure dividing into smaller and smaller subsystems for the ultimate delivery of useful energy. And notwithstanding the advent of "distributed energy resources" thinking and advocacy, most system planners and operators today still

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[1] For an overview of the electricity system, see AMORY LOVINS ET AL., SMALL IS PROFITABLE (2002).

assume a system characterized overwhelmingly by economies of plant scale and commodity markets. All this could change.

This paper discusses the drivers of change in the electricity system and the opportunities presented for biodiesel electric generation in this context. This paper also introduces the primary issues facing increased utilization of biodiesel—both those that challenge increased use of the fuel and those that support this use. Finally, the paper presents key elements of a strategy for realizing the potential of an electric generation infrastructure that incorporates more distributed biodiesel generation in the near term and even more distributed energy resources over the longer term.

II. THE DRIVERS

The broad direction of the electricity industry is dictated by a number of factors. Traditional factors include the overall rate of growth in the economy, cost of capital, regulatory climate, fuel prices, and technology. Over the life of the industry, particular constellations of drivers have created the opportunity for major system shifts. Three of these drivers in particular suggest the potential for a period of rapid development and deployment of clean distributed generation. First, the general shift toward smaller distributed energy systems embedded close to demand should accelerate as competitive market forces and technology innovations increasingly reveal the higher value of these solutions. Second, the growing imperative of environmental performance in energy generation will favor efficiency and renewable fuels. Finally, factors such as the need for resilience and robustness in the face of natural disaster, the threat of terrorism, increasing preference for domestically produced fuels, and requirements for extremely high availability are creating an "Energy Security" driver.

A. Distributed Generation

The electricity industry has always faced pressure to perform at the lowest cost. Widely regarded as an essential or necessary service, electricity was comprehensively regulated by state regulatory commissions who fixated on maximizing both public and private returns through an agenda of capturing economies of plant scale in generation. During periods of declining incremental or marginal cost, regulators and utilities could reduce average rates fairly easily; all they needed do was build more generation capacity. Unfortunately for the industry, costs did not always fall. The excessive cost overruns of the nuclear construction era triggered a transition event in which true least cost planning seeded the ultimate deregu-

lation movement and the emergence of "alternative" energy supply and services options, including renewables and efficiency. In more recent years, the declining cost trends in natural gas generation that accompanied the commercialization of aero-derivative turbines have reversed as persistently rising prices have complemented traditional natural gas price volatility. Dramatic overbuilding of capacity followed by shake-outs and a wave of plant retirements in competitive wholesale markets have resulted in tighter supply markets, today characterized by very high prices.

Wholesale competition in electric generation, now present in most of the country, has meant a number of things in the industry. First, there has been a discernable trend toward smaller size in unit generating capacity. Over are the days of 1,000 megawatt (and larger) nuclear plants that tied up billions of dollars in capital construction costs for decades before yielding a return through sales of electricity. Competitive capital seeks quicker returns on investment and reduced risk. Smaller units deliver those benefits. Small scale natural gas units (less than 100 megawatts) and even smaller wind turbines (averaging 1.5 megawatts per unit) epitomize the rapid-build power plant model that reduces all manner of construction and investment risk. Embedding smaller units close to the point of electricity demand enables significant savings in line losses and costs of transmission and distribution infrastructure. When matched against marginal distribution capacity costs, for example, even small scale generators with higher nominal per-kilowatt costs can compete effectively against traditional solutions. Literally hundreds of other distinct financial, economic, operational, and other benefits result from making generation investments that are the "right size." As carefully set forth in Rocky Mountain Institute's *Small Is Profitable*,[2] these benefits, although site and technology specific, often offer cumulative benefits as much as ten times greater than the installed cost per kilowatt of capacity. For market players with a bottom line to watch, this means a reversal of the economies of plant scale benefits of large generation.

B. Environment

A second major set of drivers relates to the environment, particularly air quality. As populations continue to crowd large urban centers, pollution problems associated with the burning of fossil fuels threaten continued economic development. The more acute problems of smog, acid precipitation, particulates, and air toxins

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[2] LOVINS, *supra* note 1.

are increasingly accompanied by a strong concern over carbon dioxide emissions. This is especially so given the increasing occurrence of violent hurricanes, ever warmer years, and the application of heightened pressure from other countries on the United States as the leading source of anthropogenic global warming pollution. In many major cities, it is practically impossible to install combustion-based generation in a cost-effective manner. The search for reliable electricity, ironically, is most acute inside heavily developed cities and suburbs. In these locations the demand for electricity continues to grow, but the traditional system of generation with remote large generation stations and lengthy transmission and distribution infrastructure becomes increasingly less capable of handling the demand. The search for environmentally friendly (that is, permit-able) generation that can be sited at or near the source of demand is accelerating. Advanced efficiency concepts like combined heat and power and small scale renewables—that can reduce emissions profiles while meeting demand—have an increasing advantage.

C. Energy Security

Energy security means having energy services when they are needed, under acceptable terms and conditions, and without fear of unexpected interruption. In recent years, events such as terrorist attacks, regional blackouts, severe climate events, and wars to secure fuel supplies have led to a renewed focus on the security of energy services in many major cities. The capital costs associated with hardening the current large central station system and its large transmission lines against this range of threats challenges the ability to form adequate, reasonably priced investment. The traditional hardening and redundancy approach is, by definition, capital intensive.

Absent policy directives or extremely strong incentives, competitive markets will not build redundant excess capacity in a commodity system. Clean, embedded distributed energy resources, including distributed generation as well as energy efficiency technologies, offer a more cost-effective and competitive approach. Distributed energy resources can be connected not only with distribution systems, but also with intelligence systems. Distributed resources can be islanded—set to operate independently of the grid if necessary. Therefore, they can offer uninterruptability, rapid restart, critical load support, and dispatchability, especially when interconnected with two-way intelligent communications systems. The "smart grid" offers performance and cost benefits even in the absence of security events. For example, empowering cus-

tomers with dispatchable generation or curtailable load to respond to the differences between peak and off-peak system prices will not only create an opportunity to improve system-wide economic efficiency, but also allow those customers to harvest benefits that can offset price premiums associated with smaller systems.

III. THE BIODIESEL OPPORTUNITY

As the distributed generation, environmental, and energy security drivers more powerfully influence the development of the electricity system, market opportunities will emerge for certain technologies. The technologies that succeed in this new market environment will be characterized by most, if not all, of the following criteria:

- Diffusible—Successful new technologies can be integrated into the grid virtually anywhere.
- Robust—Such technologies will offer benefits and perform to standards under a wide range of system conditions and in situations of abrupt change.
- Empowering—Successful new technologies should strengthen customer control over energy use patterns and choice of services.
- Complementary—Increased use will offer multiple benefits and support accomplishment of other objectives.
- Transplantable—Underlying concepts as well as approaches developed through experience are applicable across a wide range of regimes.
- Marketable—Viable new technologies must be competitively sound and profitable in established or emerging market segments.

Biodiesel-fueled stationary generation meets these criteria and therefore should be positioned for significant growth. The benefits of biodiesel electric generation fit into three general categories: benefits associated with feedstocks, benefits associated with generation equipment, and benefits associated with the product—dispatchable green power.

A. Feedstock Benefits

Biodiesel is a relatively easy fuel to manufacture at relatively high conversion efficiencies. It is made from renewable feedstocks such as vegetable oils and therefore displaces (to a large extent) reliance on imported fuels. As a result, increased reliance on biodiesel electric generation complements energy security objectives. Although it will be necessary to think strategically about feedstock

supply at a level sufficient to displace most or all petroleum diesel fuel used in the United States today, feedstock supplies are more than adequate to support the successful launch of a commercial stationary biodiesel electric generation segment. In addition, biodiesel feedstocks are widely available and easily transported to manufacturing facilities. Once processed, the fuel needs no special infrastructure for delivery and handling. As a result, biodiesel electric generation is diffusible and transplantable. The wide variety of feedstocks that can be cost-effectively transformed into biodiesel fuel adds robustness and further enhances geographic diffusibility.

Burning biodiesel fuels offers significant environmental benefits in terms of emissions reductions as well. Biodiesel emissions have been comprehensively evaluated and, with the exception of nitrogen oxides emissions, improve with the concentration of biodiesel used in any blends.

Emission Changes with Biodiesel versus Diesel

Emission Type	B100	B20
Sulfates	-100%	-20%
Nitrated polycyclic aromatic hydrocarbons (nPAH)	-90%	-50%
Polycyclic aromatic hydrocarbons (PAH)	-80%	-13%
Total unburned hydrocarbons	-67%	-20%
Ozone potential of speciated HC	-50%	-10%
Carbon monoxide	-48%	-12%
Particulate matter	-47%	-12%
Nitrogen oxides	+10%	+2%

[3]

Emissions of nitrogen oxides (NO_x) are a significant, but not unsolvable, problem. Many major cities are in a non-attainment status for smog-related emissions, and biodiesel-related increases in emissions of NO_x would not be tolerable. However, not all studies show increases in NO_x. Also, most evaluations have been conducted with a view toward use of biodiesel in the transportation sector, where evaluation and certification protocols are complex and relatively inflexible. With stationary electric generation, there are more options, and there is much more work to be done. Some of the options and issues are discussed in the National Renewable Energy Laboratory publication *2004 Biodiesel Use and Handling Guidelines*:

[3] BARRETT CONSULTING ASSOCS., ASSESSING BIODIESEL IN STANDBY GENERATORS FOR THE OLYMPIC PENINSULA 20 (July 2004), *available at* http://www.transmission.bpa.gov/PlanProj/Non-Wires_Round_Table/NonWireDocs/BiodieselOlympicPeninsula%20_7_04.pdf (last visited Mar. 29, 2006). This is a report for Bonneville Power Administration's Non-Wires Solution Roundtable forum.

> The composition of the biodiesel will affect how much NO_x a biodiesel will produce from a CI engine. . . . Some kinds of B100, such as those high in polyunsaturated fatty acids, produce more NO_x than B100 high in saturated fatty acids. Of course, highly saturated biodiesel starts to freeze at a higher temperature.
>
> Beginning in 2007, new diesel engine and after-treatment technologies that use fuel with less than 15 ppm sulfur content will be required in an effort to *reduce NO_x emissions by over 90%* compared to today's level. Biodiesel has not been thoroughly tested in these new types of engines, so we don't know how much benefit these new technologies may provide. The NREL and NBB web sites will provide updated test data as it becomes available.
>
> While new diesel technology appears to be the long-term solution for reducing NO_x with biodiesel, further study is occurring to find ways to reduce NO_x with B100, and to further understand the biodiesel NO_x phenomenon with existing engines. A slight engine timing retard (1 to 5 degrees) can bring B100 NO_x to diesel baselines or provide NO_x reductions. Retarding engine timing with EPA certified diesel engines, however, without recertification with EPA is considered tampering and re-timing modern diesel engines is generally not a user serviceable item. It is best to check with your engine manufacturer about this option for their equipment, but most manufacturers have not looked into this option for B100 due to the low volumes used in the United States.
>
> Additive manufacturers are working on additives that can improve NO_x, but testing done by NREL with B100 has shown that they provide little benefit while adding significant costs. Most commercial additive tests to date have not been validated with EPA heavy-duty transit emission testing that shows a direct comparison between the B100 fuel with and without the additive and a No. 2 diesel baseline. If you are shopping for an additive, you should ask for data from comparative testing of all three fuels. If you only have steady state mode data, make sure NO_x reductions occur at the high load, high RPM ranges. NO_x emissions are generally not a problem at low load, low RPM ranges. Make sure that the data show emissions of B100 with and without the additive and a diesel No. 2 baseline.[4]

[4] U.S. DEP'T OF ENERGY, 2004 BIODIESEL USE AND HANDLING GUIDELINES 28-30 (K. Shaine Tyson ed., 2004), *available at* http://www.nrel.gov/docs/fy06osti/39451.pdf (last visited Apr. 3, 2006).

As a whole, biodiesel offers significant benefits in emissions reductions provided the NO_x issue is successfully addressed over the coming years.

One major concern often voiced about biofuel feedstocks is the adequacy of feedstocks and the economics of supplying adequate fuel supply to generation facilities. These are potentially significant issues under a high market penetration scenario.[5] Several factors mitigate these concerns. First, the biodiesel option can benefit from the infrastructure already in place for petroleum diesel. This will significantly reduce the potential cost of developing fuel supply infrastructure. Second, diesel generators are generally very small in size compared to traditional utility generation plants. As a result, the fuel supply for these facilities will be manageable. Third, there are a wide variety of raw feedstocks with excellent potential as sources of raw vegetable oils, which will add flexibility to feedstock supply systems. Finally, the market is still very small and feedstock supply systems can grow organically to meet growth in the biodiesel electric generation market.

B. Generation equipment

There is an estimated 80,500 megawatts of standby electric generation in the United States. This represents some 10% of the total electric capacity. While many of these generators are large in scale (larger than twenty megawatts), more than a third are in the size range of two to twenty megawatts. The total installed base of diesel generators, which includes standby generators and operating units serving electric utility customers, is in excess of 100,000 megawatts. The adjacent chart, from the 2001 *Renewable Energy Policy Project Research Report*, characterizes the national stock of diesel generators.[6] These generators

TABLE 1. TOTAL INSTALLED DIESEL GENERATOR CAPACITY IN THE UNITED STATES, 1996[1]

Size	*Installed Units*	*Average Kilowatts*	*Installed Capacity*
2.2 – 4.5 kW	6,235	4.2	26.4
4.5 kW – 8.2 kW	34,543	6.2	212.9
8.2 kW – 11.9 kW	40,262	10.4	417.5
11.9 – 29.8 kW	104,448	19.3	1,898.2
29.8 – 74.6 kW	153,705	53.6	8,104.9
74.6 – 130.6 kW	108,415	100.7	10,918.5
130.6 – 223.8 kW	72,434	183.5	13,292.8
223.8 – 447.6 kW	49,690	320	15,902.5
447.6 – 746 kW	38,318	560.2	21,467.4
Over 746 kW	24,674	1,208.5	29,819.5
Total	626,489	166 kW	102,061 MW

Note: Totals do not match due to rounding.

[5] For a treatment of oil feedstock, see J. ALAN WEBER & L. VAN DYNE, COST IMPLICATIONS OF FEEDSTOCK COMBINATIONS FOR COMMUNITY SIZED BIODIESEL PRODUCTION (1998), http://www.biodiesel.org/resources/reportsdatabase/reports/gen/19981201_gen-064.pdf.

[6] Virinder Singh, *Blending Wind and Solar into the Diesel Generator Market,* RENEWABLE ENERGY POL'Y PROJECT RES. REP., Winter 2001, at 1, 6, *available at* http://www.crest.org/repp_pubs/pdf/diesel.pdf.

have significant environmental problems.

> Diesel generators are a major source of pollution in the [United States]. In 1996, they released 293,000 tons of nitrogen oxides (NO_x), a major cause of urban smog and a contributor to respiratory ailments and acid rain. The total makes diesel generators almost on par with all NO_x emissions from electric power plants in New York, New Jersey[,] and Pennsylvania. Diesel generators also released 40% more carbon dioxide (CO_2) than all power plants in New Jersey combined.
>
> The above statistics are especially troubling since diesel generators are poised to grow in capacity. In 1996, there were 102,000 MW of diesel generators. With a 1.7% annual growth rate, they may reach 127,500 MW in 2010, releasing 371,000 tons of NO_x emissions and 16.7 million tons of CO_2 emissions. Recent experience shows that they may grow at an even higher rate (2.65% per year) with dire consequences to air quality. Right now, "distributed generation" equals "diesel generators."
>
> Compounding emissions trends is the tendency for generators to run more often in the summer, when urban smog is most likely to form. Other environmental dangers from diesel include fine particulates, water pollution from diesel fuel spills, and occupational hazards.[7]

Diesel generators occupy an important role in the electricity system. Many of these are deployed at critical facilities as back-up power generators.[8] Standby generators are commonly found in large commercial and industrial facilities, such as institutional buildings and complexes, health care facilities, communications facilities, manufacturing and processing plants, military installations, utility facilities, and other locations where continuous power is a fundamental requirement of operations. A significant portion of these units are suited for participation in demand response programs. This means that the equipment can be operated to respond to operational signals from a local utility operator. These generators are a well-understood option for ensuring operational security.

> Commercial and residential customers, as well as electric utilities, are seeking new sources of back-up power located either on the premises of the end-user, or nearby on the local distribution grid. Greater concern about the reliability of grid power is a key driver for customer demand. Diesel generators are a major source of back-up power nationwide, and continued reliability concerns assure that diesel generators will enjoy continued success in the back-up power market.

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[7] *Id.* at 3.

[8] *Id.* at 7.

> There are many reasons for the success of diesel generators. First, they are easy to transport, install and uninstall quickly, so that customers can rent them for several months in the summer and then return them. Apart from the performance characteristics of generators, the diesel generator industry has an extensive network of distributors and suppliers. They also offer standard finance packages for users, as well as rental and sales options that suit diverse customers, from homeowners to utilities.[9]

The diesel generator industry sector is mature and well capitalized.[10] With established market leader manufacturers distributing products through a network of dealerships, diesel refueling equipment and infrastructure has become ubiquitously available in both urban and rural settings. The technology is relatively simple to maintain and repair; thus, original equipment manufacturers (OEMs) and independent repair shops and technicians are available nearly everywhere. In all, the industry is ideally suited for a "drop-in" change in fuel from petroleum diesel to biodiesel.[11]

C. Dispatchable Green Power

Biodiesel-generated electricity is potentially dispatchable. Dispatchable energy, that is, the ability to start generating energy exactly at the time it is needed, is the most valuable resource in the electric grid. Diesel generators are quick-starting and have well-known operating characteristics; thus, they are a resource that electric system operators can understand and use fairly easily.

The major challenges facing more extensive use of diesel generators as dispatchable units is their size and capital cost under relatively low rates of usage. The dominant electricity model, as described in the introduction, has favored use of extremely large units (hundreds or even thousands of megawatts in scale) for baseload power requirements. Even "smaller" units dispatched for peak power requirements are typically fifty megawatts or larger. The communications and control systems of traditional utilities favor the management of relatively few units in the day-to-day operation and balancing of supply to demand on the grid.

Energy security and reliability concerns, financial imperatives of more competitive electricity markets, and other factors have combined to create an opportunity for the deployment of more intelligence into the grid system. As one commentator noted:

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[9] *Id.* at 4.
[10] *Id.* at 14.
[11] *Id.*

> By 2050, North America will need somewhere between 15 and 20 Terawatt hours/year of electric power (DOE/EIA estimate). The storage, transmission, and distribution technologies of the smart grid of the future—a web-enabled, digitally controlled, intelligent delivery system—must be able to deliver that amount of power to all corners of the continent efficiently. Millions of generation and storage points, both remote and locally distributed, from many different energy sources will be needed to supply that amount of electricity. A continental-scale grid will be needed to interconnect remote gas, coal and nuclear generation with wind, solar, geothermal and other renewables, in both centralized (deserts, offshore) and distributed (house, block, community, business, town) facilities.
>
> Such sources cannot be simply added to the existing grid—it is not smart enough. The management of the grid will require digital control, automated analysis of problems, and automatic switching capabilities more familiar to the Internet (like the routers sold by Cisco that break messages into packets and send them over several different routes to relieve congestion, only to reassemble them at the destination into your next e-mail).[12]

Improving the interoperability and information content of the grid—making it "smarter"—seems inevitable. Therefore, these changes will create an opportunity for the already embedded and interconnected stock of diesel generators if those units can be run in compliance with environmental requirements.

One remaining issue of dispatchability relates to underlying economics. Again, the existing stock of generation should have an advantage. Although diesel generators are a mature technology, they are not seen as good providers of commodity energy due to their relatively small scale and fuel requirements. As a result, utilities have not typically invested in diesel generators in their primary energy supply portfolio. As discussed above, however, diesel generators have value as stand-by or backup units that far exceed their value as commodity electricity providers. Moreover, even though average electricity prices are relatively low, the hour-to-hour cost varies dramatically. Firm, dispatchable peak-hours electricity can be worth twenty-five times the cost of electricity in off-peak hours.

The financial opportunity for diesel generators, then, is summarized as the ability to operate generator stock, which is already in place and already paid for as a result of energy security needs, as

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[12] Roger N. Anderson, *The Distributed Storage-Generation "Smart" Electric Grid of the Future*, http://www.pewclimate.org/docUploads/10%2D50%5FAnderson%5F120604%5F120713%2Epdf (from workshop proceedings, "The 10-50 Solution: Technologies and Policies for a Low-Carbon Future," The Pew Center on Global Climate Change and The National Commission on Energy Policy).

dispatchable peak power selling premium-priced electricity. Again, the key is environmental operability.

Biodiesel-generated electricity is "green power," meaning that it is electricity generated from renewable resources. In blended products, of course, this trait is limited to the portion of the fuel derived from renewable resources. Depending on the legal or certification regime, green power "credit" may be granted either on a pro rata basis or specifically for blends that meet minimum percentage requirements. According to the widely accepted "Green-e" certification standard for biodiesel blends:

> Biodiesel blended with petroleum diesel is permitted if the following conditions are met:
>
> • The biodiesel is separately metered from the petroleum diesel, and
>
> • Contracts are in place to allow [the Congressional Research Service (CRS)] to verify that the biodiesel was converted to electricity.
>
> Only the amount of energy generated from the biodiesel may count towards the 50% renewable criteria.[13]

Green power is sold in voluntary, utility-sponsored or competitive market programs in which customers pay premiums for renewable energy. Approximately 20% of utilities offer green power. Altogether, some 600 utilities offer 125 distinct programs across the country. The total market value of green power provided by regulated utilities is only about $35 million, but price premiums, lackluster marketing, and a fairly steep learning curve for traditional utility operators define this value. As such, the most compelling aspect of biodiesel electric generation is that it may provide a more valuable and dispatchable electric generation option to utilities than wind and solar generation, which are often too remote and intermittent to become economically viable.

Biodiesel electric generation can also become a factor in emerging, renewable-energy credit or certificate (REC) markets. Such a marriage could be worth nearly $1 billion by the end of the decade. RECs are highly liquid, tradable certificates that represent electricity generated from renewable resources. They are the mechanism by which at least fifteen states execute their renewable electricity or "portfolio" standards. These standards are mandates that require a percentage of electricity to come from renewable resources. In addition, RECs are a highly liquid mechanism for

[13] Green-e.org, Green-e Standard for Electricity Products, http://www.green-e.org/ipp/electricity_standard.html (last visited Apr. 3, 2006).

extracting premium value from the "renewableness" of qualifying generation. This provides the opportunity for stationary biodiesel electric generation to derive a significant additional revenue market by selling RECs from generation projects to create revenues above and beyond the value of the electricity itself.

IV. REGULATORY AND POLICY ISSUES

A number of regulatory and policy issues arise from the significant expansion of the use of stationary diesel generation. Although a detailed treatment of each of these issues is beyond the scope of this paper, they are briefly summarized here.

A. Interconnection and Stand-by Tariffs/Charges

Interconnection and stand-by tariffs/charges arise from the terms and conditions imposed on the generator by the utility for the privilege of being connected to the grid. The utility could not possibly maintain overall safety, grid stability, and power quality if it did not ensure that small generators meet certain requirements in the design and electrical interconnection, as well as in the operation of their generation equipment. In addition, the "generation" customer represents a different revenue and cost profile than an ordinary "all requirements" customer. In some cases, a customer may meet substantially all of its electricity needs through its generator. Such an entity may be governed by "stand-by" tariff provisions. In the author's experience, it seems that all-requirements electric service is generally under-priced, while stand-by service is generally overpriced. In some cases, stand-by tariffs can be so severe as to effectively foreclose any realistic opportunity for self-generation. Such severity obviously benefits the utility in the near- to mid-term, but may not represent the most economically efficient course in the long term. Furthermore, all of these issues are magnified under a scenario of high penetration of distributed generation into the grid.[14]

The situation facing a potential operator varies greatly from jurisdiction to jurisdiction.[15] In the portion of Texas covered by the Electric Reliability Council of Texas (ERCOT), for example, gen-

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[14] For an excellent model rule relating to interconnection of small generators, see INTERSTATE RENEWABLE ENERGY COUNCIL, TECHNICAL INTERCONNECTION STANDARDS AND PROCEDURES FOR SMALL GENERATOR FACILITIES (Oct. 2005), http://www.irecusa.org/connect/model_interconnection_rule.pdf.

[15] An excellent state-by-state compendium of rules and incentives relating to renewable energy is available at http://www.dsireusa.org/index.cfm.

erators under ten megawatts in capacity can interconnect according to a standard set of terms and conditions promulgated by the state utility commission, in conjunction with restructuring. Standardized environmental permits have also been promulgated by the state environmental regulator.

In other places, utilities are openly hostile to independent small generators—a hostility unmitigated by regulatory relief. In these cases, the cost and difficulty of complying with complex interconnection requirements and delays may render a particular project simply uneconomic. If distributed energy resources interoperating in smart grids are indeed the wave of the future, regulators and utility operators in many jurisdictions have much work ahead of them.

B. Deregulation/Restructuring

Electric utility restructuring, also known rather inaccurately as "deregulation," changed the functioning of commodity electricity markets in important ways, even if the basic physical infrastructure remains essentially the same. Federal legislation, including the recently enacted Energy Policy Act of 2005, has resulted in further changes, such as the repeal of the Public Utility Holding Company Act (PUHCA) and, in certain markets, the "must buy" provisions of the Public Utility Regulatory Policies Act (PURPA). A careful assessment of the regulatory context is a prerequisite to any successful biodiesel electricity generation project. Proponents of increased biodiesel use have a definite stake in any further changes in federal and state regulatory regimes, especially those that impact distributed generation markets.

C. Emissions

As described above, the initial experience with increased NO_x emissions associated with the use of biodiesel poses a potential problem for the development of a robust stationary biodiesel electric generation market. Solutions may lie in greater experience with the operation of biodiesel generators, technology development, feedstock development, and regulatory reform. Rising concern over the impacts of particulate pollution on human health and the on-going problem of global warming could help expand markets for stationary biodiesel generation.

D. Islanding

Islanding is the term used to describe small systems of electricity supply and demand operating independently from the broader

grid network. Very small systems, in the range of a few kilowatts of capacity, do not pose major issues for the utility. These can typically be interconnected according to standard terms and conditions and typically have automatic switch equipment to prevent them from islanding—from operating when the grid is down. This prevents accidental electrocution of utility personnel working to restart the grid.

Most standby generators with modern interconnections have equipment that automatically starts generators when the grid goes down and physically disconnects the subsystem from the grid to prevent injury to workers. But this relatively larger equipment must be synchronized with the grid to run when the grid is operational. This adds expense that may make a project uneconomic except in a pure backup configuration. Improvements in the cost and functioning of "gateway" interface equipment that ensures smooth operation of distributed generation within the greater grid will provide important societal benefits and added opportunities for stationary biodiesel generators.

Continued operation in the face of grid outages has significant value to many customers, even without an opportunity to sell electricity into an operating grid. But more opportunities to generate revenues will make biodiesel electric installations more cost-effective. As described above, a highly interactive intelligent grid with widespread embedded generation offers considerable economic and energy security benefits.

E. Valuation of Energy

There is considerable discussion underway across the country about the potential benefits of "demand response" systems in which customers could adjust their load in response to price signals from the utility system operator. A major competitive opportunity lies in the development of such time-of-use pricing regimes because they could also encourage operation of dispatchable generation units targeting the most valuable price segments of the day or year. These opportunities would favor biodiesel stationary generators embedded in the grid because these systems are typically located relatively near distribution grid nodes with high marginal operating costs. In fact, if regulators required utilities to competitively procure energy resources based on marginal distribution capacity

costs, small scale generators of many kinds would enjoy significant market opportunities.[16]

Some smaller distributed generation systems may qualify for "net metering."[17] Net metering means an arrangement where customer-owned generators effectively "spin the meter backwards." The result is that the customer receives full retail credit for generation based on the average price charged by the electricity provider. Net metering rules vary according to the size limits on generators and other requirements, including the rate treatment for generation that exceeds the customer's use. Utility receptiveness to net metering also varies by jurisdiction and frequently by the nature of the utility itself.

F. RECs and Green Power

As discussed above, stationary biodiesel electricity can qualify as green power. While wind power generally enjoys a cost advantage as a source of green power, biodiesel generation benefits from an opportunity to sell into utility green power programs for several reasons. Distributed generation can be located in the local grid, potentially resulting in a visible demonstration to customers of the difference their premium payments are making. The dispatchability of biodiesel generation offers added value that can support the total project cost and help keep green power prices competitive. The relatively smaller size of biodiesel generation projects allows utilities to make incremental additions to green power programs, reducing investment risk compared to other green power generation plants. As biodiesel generators improve their environmental performance regarding NO_x emissions, regulators can act to encourage utilities to launch and expand green power programs to take advantage of the resource.

Stationary biodiesel generator operators can take advantage of an additional revenue opportunity by selling resulting renewable energy certificates (RECs). About one-third of the states now have renewable energy generation requirements, also known as renewable portfolio standards. Several cities are also adopting this approach. In many cases, states or other government bodies with re-

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[16] *See* JOEL N. SWISHER, CLEANER ENERGY, GREENER PROFITS: FUEL CELLS AS COST-EFFECTIVE DISTRIBUTED ENERGY RESOURCES (2002), *available at* http://www.rmi.org/images/other/Energy/U02-02_CleanerGreener.pdf.

[17] *See* INTERSTATE RENEWABLE ENERGY COUNCIL & N.C. SOLAR CENTER, STATE AND UTILITY NET-METERING RULES (2005), *available at* www.irecusa.org/connect/net_metering.pdf (a component of the "Connecting to the Grid" Project, summarizing net metering provisions in the United States).

newable energy standards use REC systems as the mechanism for implementing the requirement. The benefits of biodiesel generation in a green power portfolio also apply to RECs. In addition, the liquidity of RECs, which can be sold independently of the underlying electrical energy, offers expanded market opportunities. Regulators and market managers have a major role to play in encouraging the formation of voluntary markets for renewable energy products built with RECs.

V. CONCLUSION: ELEMENTS OF THE STRATEGY

This paper has attempted to convey the interesting and potentially lucrative opportunity that is growing for biodiesel-fueled electricity generation. The extent to which the opportunity is realized will be a function of a number of factors, including economics, technological development, regulation, and ultimately whether the distributed energy resource model successfully emerges. In order to accelerate the development of biodiesel stationary electric generation market opportunities, a strategy comprised of five elements is appropriate.

1. Pilot Demonstrations

Much more practical experience is needed in the use of biodiesel in stationary generators for the provision of electricity services. Regulators and other government leaders, utilities, and facility managers with standby generation should aggressively pursue opportunities to conduct pilot demonstrations.

2. Engine Inventories

Assessments of the existing stock of diesel generators in urban markets should be conducted to characterize the fleet comprehensively. In addition, these inventory assessments should be correlated with assessments of the proximate distribution grid in order to understand the opportunity for embedded generation. Such assessments will allow project developers to identify projects with the best economics.

3. Supplemental Technology Development

The application of additional technologies to the basic generating engine can further enhance the value of biodiesel generators. Although federal regulations will lead to new diesel engines with substantially improved environmental performance, the need remains for cost effective emissions reduction technologies that can be used with the massive fleet of existing generators. For example,

exhaust gas recirculation technologies can significantly reduce emissions. Also, because diesel engines are combustion systems, there is a substantial opportunity to further enhance overall system efficiency by taking advantage of the waste heat in the exhaust. Combined heat and power systems can make use of this heat to accomplish other tasks such as cooling and heating.

4. Feedstock Quality and Quantity

As the market expands, publicly and privately funded research and development should address feedstock issues to ensure consistent high fuel quality and sufficient supplies to meet growing demand.

5. Regulatory Reform

The national experience with electric utility restructuring has been mixed at best. A more careful and comprehensive approach to the development of distributed energy resources and systems is now in order. Utility resistance to embedded generation can be overcome as long as adequate protections for grid reliability and stability are ensured. After all, utilities actually have many reasons to support distributed energy generation. Utility regulators and government policymakers should undertake comprehensive regulatory reform to encourage this fundamental change in the electricity system.