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BLENDING WIND AND SOLAR INTO THE DIESEL GENERATOR MARKET

*by Virinder Singh**

Diesel generators are a major source of air pollution in the United States. And they are growing in capacity every year. Now is an ideal time for regulators and industry to pursue strategies to advance wind and solar as clean, economic alternatives to dirty diesel.

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A Message from the Staff of the Renewable Energy Policy Project

The following report is one of several REPP has released recently on renewable energy and the environment. Earlier this year, Adam Serchuk outlined ìthe environmental imperativeî for renewable energy by catalogingthe air, water and land impacts of different electricity sources. And in *A Guide to the Clean Air Act for the Renewable Energy Community*, David Wooley discussed the small role that renewables play in current air pollution policy, and the potential for renewables and our air to win through better integration between air regulation and renewables.

The earlier reports focus primarily on pollution from the large, fossil fuel power plants that our nation depends upon today. This report looks at distributed generation—small-scale power sources that are increasingly seen as a vehicle to take us down a cleaner energy path. Yet while small, cleaner energy sources such as photovoltaics, fuel cells, and microturbines grab most of the attention, in reality we rely on a less savory form of distributed generation today—diesel generators dot our cities, our farms, and even our remote villages, providing energy but at a great environmental cost.

This is an important time for diesel generators and the environment. California has passed legislation on more stringent air regulations for diesel generators. Texas is contemplating the same. It appears that the (justified) fear of more diesel generators is translating into action. Further, the focus on "dirty diesel" by more mature campaigns targeting diesel buses and trucks may now be spilling into other diesel markets.

We hope that these trends will lead to cleaner distributed generation. However, we worry that the cleanest distributed energy technologies—such as solar, wind, and even geothermal—will get lost in the scramble to cut pollutants one-by-one at the lowest short-term cost. Renewable energy sources cost more than other options such as natural gas engines. Yet their higher cost is compensated by a sharp reduction of ALL pollutants.

But multi-pollutant strategies have not taken hold yet in the air regulation arena. The air regulator judges pollution controls according to their ability to cut individual pollutants—multi-pollutant issues fall between the cracks dividing different regulatory jurisdictions. The "individual pollutant approach" blunts the ability of air regulators to contribute to a change in capital stock to the cleanest energy technologies—an opportunity that comes again only 10, 20, even 30 years in the future.

As *A Guide to the Clean Air Act* demonstrates, renewables have a lot to gain from the Clean Air Act, but only if changes are made in the way government officials change their approach. A similar scenario exists with distributed generation. While cleaner energy technologies such as natural gas engines may move forward in the market, even cleaner, commercially-ready technologies such has renewables stand a good chance of being completely left behind under new air regulations.

But do environmental regulators have a responsibility in advancing the cleanest options? We think they do. What this report offers is, beyond much needed regulations, recommendations for programs to advance renewable energy in markets dominated by diesel. Environmental agencies play a role in these efforts, and they have plenty of experience running market-based programs such as the federal Energy Star program. And the emergence of $1.5-billion-worth of state clean energy funds means that environmental agencies have willing partners to ensure that distributed renewables can go where the environment needs them the most. We do not give up hope that environmental regulations can contribute to a clean energy transformation. But we want to make sure environmental agencies play their rightful role in advancing renewables as a key pollution control strategy.

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BLENDING WIND AND SOLAR INTO THE DIESEL GENERATOR MARKET

by Virinder Singh

EXECUTIVE SUMMARY

The Case for Wind and Solar as Pollution Control Strategies

Diesel generators are a major source of pollution in the U.S. In 1996, they released 293,000 tons of nitrogen oxides (NOx), 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 NOx 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 NOx 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.

In spite of these estimates, diesel generators face weak environmental regulations though recent news may indicate a change in approach. In California, uniform emissions standards for small, "distributed generation" are to launch in 2003, with the potential for stringent limits on emissions. This decision goes against past tradition. Diesel generators, particularly stationary generators and those employed for back-up power needs, tend to fall beneath federal and state thresholds that trigger regulation. And, as policy stands, even if most stationary diesel generators ran all year, they would not emit enough pollutants to trigger federal regulations.

As regulators appear to be moving on diesel generators, now is the time to determine the best pollution control approach. Traditionally, regulators have addressed different pollutants such as NOx and carbon monoxide separately, with clear opportunities for multiple-pollutant approaches judged feasible if they demonstrate cost-effectiveness on a single-pollutant basis (e.g., cost per ton of NOx controlled).

Traditional controls for diesel engines, such as fuel switching and add-on controls, can reduce some types of emissions yet worsen others and even cut generator efficiency. If regulators want to look beyond traditional controls to address the skyrocketing population of generators, then zero-emission, no-fuel technologies such as wind and solar offer a key control strategy for local air quality, global warming, water quality, and occupational health.

One way to bring wind and solar to the fore in the regulation arena is for federal and state agencies to adopt air standards that treat multiple environmental problems as holistically as is feasible. Another way is for environmental agencies, other government partners, and the wind and solar industry to craft a variety of measures the address diverse market barriers. Programs to advance wind and solar would fit well with federal programs such as Energy Star that bring energy efficiency technologies to the marketplace due to their many economic and environmental benefits. Crafting effective approaches to advance wind and solar within the existing diesel generator market require an intimate knowledge of the diesel and renewable energy industries.

This analysis examines how the diesel industry and the renewable energy industry function in two consumer markets, specifically:

- The Alaskan remote village power market, where diesel generators serve as "baseload" generation within small village power grids and where wind-diesel hybrid systems show strong promise.
- The back-up power market, where diesel generators run infrequently and where solar photovoltaic (PV) systems offer emission free, secure power for smaller customers in case of blackouts or brownouts.

For both of the above markets, the analysis examines the diesel industry based on Michael Porter's five key sources of competition. The analysis demonstrates whether or not diesel industry firms can benefit from incorporating renewable energy technolo-

gies in their offerings, and what the renewable energy industry faces if it is to succeed in these markets. The analysis then examines the renewable energy industries to determine if they are poised to compete in specific markets, and if not, what they may need to compete.

ALASKA VILLAGE POWER

Market Setting

Wind-diesel hybrids are a feasible, proven power source for Alaska's 175 remote villages. These villages are often low-income communities that are exposed to diesel fuel price volatility, frequent fuel spills, and high operations and maintenance costs for transporting diesel fuel and maintaining diesel bulk storage tanks. Most villages require some form of state or federal subsidy, usually in the form of low-to-zero interest loans. Wind power offers a way to reduce such costs and harness a plentiful Alaskan energy resource.

The diesel industry has an extensive business network in Alaska, since diesel generators were the original power technology of choice to light up the state's remote villages. The industry includes distributors and servicers located in all major Alaskan cities, who can reach a remote village in need in one or two plane flights. Some distributors and servicers are owned by large diesel generator manufacturers, some are not.

Overall, the industry is stable but highly competitive for village bids. Additionally, diesel *generator* manufacturers who are not also diesel *engine* manufacturers hold little bargaining power with engine suppliers. (Diesel engines are one component of diesel generators.) Alternatives beyond wind are not yet available, but wind power is now a technology with field experience in Alaska, and may become an attractive product for those diesel *generator* manufacturers and distributors who wish to offer more diverse and attractive products to villages, and who want to reduce reliance on diesel *engine* firms.

In contrast, the wind-diesel industry is relatively immature, with very little in-state presence, a high reliance on custom products, and no favorable subsidy treatment from state and federal agencies. Like the diesel generators of the 1970s, the first wind-diesel hybrids in Alaska were made possible through strong government involvement in project formulation, design and funding, though primarily for demonstration purposes.

Recommendations

- Diesel equipment firms should diversify by retrofitting diesel generators with wind power.
- Governments should tailor financing to wind power rather than diesel power.
- Governments and the wind industry should train local citizens to install and maintain wind-diesel systems.

BACK-UP POWER

Market Setting

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.

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.

The diesel generator industry is mature and even conservative. The same handful of firms, including Cummins, Caterpillar, and Detroit Diesel, have dominated the manufacturing sector for years. Dealer networks include those owned by manufacturers. They also include rental companies that specialize in serving end-users such as construction firms, with diesel generators one product among many for these end-user groups. While the nature of the industry makes it unlikely that most firms within it will adopt solar photovoltaics, there are a number of technologies such as microturbines and fuel cells that promise to shake up the industry. The diesel industry should respond either by adopting these products, or engaging in price wars to maintain its dominance. Either scenario may offer an opportunity for PV to attract attention among competing firms, but this is not the case today.

Yet PV, especially PV uninterruptible supply systems (UPS) with batteries, offers unique values that will attract customers looking for back-up power and more. While not amenable to easy installation and rentals, PV with batteries are now a bundled product that meets universally recognized safety and performance standards. Since PV UPS products can also connect into the grid, they can benefit from new net metering policies in 30 states, which substantially cut into their price. Finally, net metering, in which PV power is sold to the utility, means that PV's energy value to the user moves beyond its ability to provide power during occasional outages—it can be an integral power source year-round that can protect a customer from high price periods, including those in the summer and in deregulated electricity markets.

The PV industry has matured substantially, with a number of large, experienced manufacturers (some of whom have sales, distribution, and servicing operations), improved geographical reach in its distribution and servicing networks, and integrated products that reduce consumer hassle. Nevertheless, these gains still fall short of the diesel generator industry. In particular, PV suffers from inadequate consumer education, limited distribution and servicing networks that include seasoned technicians and stable firms, inadequate financing packages, and lack of rental products.

Recommendations

- State environmental agencies should jump-start replacement efforts with a multi-year incentive program.
- The PV industry should align itself more closely with the energy services industry, and vice versa.
- PV should be better integrated into the federal Energy Star program.
- Government and industry should publicize existing financing options and integrate easy-to-understand information into marketing efforts.
- The PV industry should develop a resale market.
- The PV industry should make portable systems a priority.
- State energy funds should share costs with environmental agencies and the PV industry to catalyze diesel generator replacements and PV product development.

GENERAL RECOMMENDATION: THE OVERSEAS MARKET

Finally, the diesel generator industry should incorporate renewable energy technologies into their product offerings for the export market. Diesel generators serve basic, baseload power needs for industrial, commercial, high-income residential, and off-grid markets in developing nations. The inherent problem with diesel generators in developing nations is their fuel needs. Fuel costs in many developing nations are heavily subsidized and vulnerable to price spikes. In villages, the basic question is whether the fuel will be shipped in regularly to meet power needs.

Beyond operations, diesel generators will merely intensify local air pollution and global warming, the latter issue being of special interest to the U.S. government. Consequently, both diesel generator manufacturers and distributors as well as the U.S. government should promote hybrid products. The U.S. government should also promote hybrid products melding renewable energy and microturbines and fuel cells, which suffer from similar fuel drawbacks as diesel generators, but have much lower emissions.

BLENDING WIND AND SOLAR INTO THE DIESEL GENERATOR MARKET

by Virinder Singh

The United States has a lot of diesel generators – in 1996, there were 626,000 installed units with a total capacity of 102,000 megawatts (MW). (See Table 1.) And more will follow. For remote villages, utilities, industries, commercial customers, and residents, diesel generators are the on-site and remote power sources of choice. But the environmental consequences of diesel generators' prolonged dominance are now apparent, and require advancing cleaner alternatives into the mass market.

This paper examines how wind power and solar photovoltaics can enter two markets dominated by diesel generators—the Alaska village power market (for wind) and the back-up power market (for photovoltaics). The paper reaches several general conclusions.

- Diesel generators are significant sources of air and water pollution.
- Renewable energy, while traditionally not well integrated into environmental policy, represents a key pollution-control technology to reduce the wide range of impacts of diesel generators.
- Government and industry can undertake several strategic measures to transform wind and solar into competitive products within the Alaskan village and back-up power markets. New strategies can clean the environment, meet energy needs, and build a self-sustaining industry whose success can reduce the need for environmental regulations.

There is one important note worth mentioning up front—the international market for diesel generators continues to expand dramatically. In 1994, 361,000 new generators were installed at 32,000 MW of capacity. This was equal to a third of new installations of fossil, nuclear, and hydro facilities that same year. Sales from 1994 generated $5.5 billion in revenues. Developing nations such as India and China consumed 40 percent of all generators.[2] Developing nations in particular need diesel generators for both back-up and baseload power to guard against frequent power outages and to serve off-grid markets. Japan and Denmark have demonstrated that vigorous domestic demand for solar and wind alternatives and incentives to help industry meet that demand also help nations compete in global markets. Similarly, measures to make diesel generators for baseload and back-up markets environmentally cleaner in the United States could pay off handsomely in the export market for U.S. firms.

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.

Environmental Impact of Diesel Generators

Americans should be concerned about the prevalence of diesel generators, which are significant sources of pollution.

- **In 1996, diesel generators produced more than 292,917 tons of nitrogen oxide (NOx) emissions—slightly less than the current NOx emissions of all power plants in Pennsylvania, New York and New Jersey combined. NOx is a prime precursor to ground-level ozone, or smog, which forms in many U.S. cities and regions in the summertime.[3] It also contributes to acid rain, and affects the human respiratory system.**
- **They also produced 13.2 million tons of carbon dioxide (CO_2) emissions – 40% more than the emissions from all power plants in New Jersey.[4] These 1996 totals could grow by over 25 percent during the next decade assuming an annual growth rate of 1.7% (Table 2).[5]**

A disturbing trend is customers installing even more diesel generators due to concerns about electricity reliability. Customers include not only industrial, commercial and residential customers, but also electric utilities that plan to use generators to support the distribution grid. A comparison of 1996 and 1998 data shows that generator installations grew by 6%, at an annual

Table 2. NOx and CO_2 Emissions from Diesel Generators in the United States, 1996 and 2010 (in tons)[6]

Year	NOx Emissions	CO_2 Emissions
1996	292,917	13.2 million
2010	370,885	16.7 million

growth rate of approximately 2.65%. At that annual growth rate, 2010 emissions could be 44% higher than those in 1996.

Most disturbing, diesel generators run more frequently in the summer, when customers need back-up power due to the heightened threat of blackouts and brownouts in the electricity grid and when construction sites, which receive power from mobile generators, are most active.

Diesel generators also emit small particulate matter, another important contributor to smog. Of the total particulate matter released by a typical diesel engine, 94 percent is under 2.5 microns in diameter. The leading association of state and local air pollution officials has found that diesel particulates are responsible for 125,000 cancer cases in the United States, with 96 percent of cases occurring in metropolitan areas.[7]

Diesel generators also pollute water. Though comprehensive data are not available, anecdotal data show that diesel fuel frequently spills into waterways. For example, diesel fuel spills are a common event in Alaska—a review of a randomly selected, three-month period reveals monthly spills ranging from 100 gallons to 3,000 gallons due to human errors or undocumented reasons. Apart from ecological costs, the cost of cleaning a single diesel fuel spill can reach $100,000.[8]

Finally, diesel generators harm workers. The Occupational Safety and Health Administration (OSHA) finds that one million workers are exposed to diesel exhaust, which is associated with risks for lung cancer, bladder cancer, dizziness, drowsiness, headaches, and nausea.[9] OSHA concludes that diesel engines are a "very serious hazard…and such exposure is increasing due to the expanding use of diesel equipment."[10]

Environmental Regulations Controlling Diesel

Environmental regulations for diesel generators traditionally have not been up to the challenge posed by greater demand for diesel generators and its associated environmental impact. Overall, diesel engine (of which generators are a subset) regulations target mobile applications rather than stationary applications. However, in 1996, 51% of generators were stationary.[11] Under U.S. Environmental Protection Agency (EPA) "Tier I" standards, owners of stationary diesel engines must obtain a permit only if the engine releases more than 100 tons of a criteria pollutant (e.g., NOx, particulate matter 10 microns, sulfur dioxide) in one year. The vast majority of generators would not meet that threshold even if they ran all year.

Stationary diesel generators tend to face more stringent regulations if they are located in states or air quality districts that are in "nonattainment" with EPA air quality standards. Typically, regulations require owners of existing generators to install pollution control retrofits; for states and districts with the poorest air quality, the regulations require purchasers of new generators to buy state-approved engines. Unfortunately, the regulations such as those in air quality districts in California frequently exempt back-up generators that run less than 100 to 200 hours per year, rendering the regulations ineffective in controlling pollutants from most back-up diesel generators.[12]

In California, the regulatory loophole for diesel generators may soon be closed. In September 2000, Governor Gray Davis approved legislation that requires the state Air Resources Board (CARB) to adopt a certification program and uniform emissions standards for distributed generation by the beginning of 2003. The legislation requires that certification reflect emissions standards comparable to emissions from "best available control technology" for "permitted central station powerplants in California." Depending upon how CARB defines that last item, the emissions limits for certification may severely restrict new diesel generator installations if the best available control technology is defined as combined-cycle natural gas plants, which feature lower NOx emissions.[13]

Box 1. What are Diesel Generators?

Diesel generators discussed in this paper are run by internal combustion engines that operate by the injection of fine diesel fuel droplets into a combustion chamber heated by compression ("compression-ignited", or CI). The air heats the fuel and causes it to evaporate and mix with the available oxygen. The fuel ignites and spreads through the chamber. Power output is managed by controlling the amount of fuel injected into the combustion chamber. CI engines are different from "spark-ignited" (SI) engines such as gasoline engines, which initiate combustion with a spark of electricity.

Box 2. Other Alternatives to Diesel Fuels and Generators

Solar and wind are two among several alternatives to diesel generators. Most alternatives rely on natural gas with the added ability to consume diesel fuel. Both natural gas generators and microturbines are ready for the mass market today, while biodiesel and fuel cells have entered more limited markets.

Natural Gas. Natural gas can replace diesel in two ways. First, cleaner, "spark-ignited" natural gas engines can replace diesel engines. Or, natural gas can replace diesel fuel in existing "compression-ignited" diesel engines, as long as a small amount of diesel fuel is injected. According to U.S. EPA, replacing diesel fuel with duel fuel composed of 95 percent natural gas cuts NOx emissions by 25 percent and CO_2 emissions by a third. However, it leads to a 33 percent increase in carbon monoxide emissions and a seven-fold increase in methane emissions. [14]

Microturbines. Microturbines can burn natural gas, as well as kerosene, diesel, propane, biomass-based fuels, and other fuels. Microturbines, which are based on jet engine technology, range from 25 to 500 kW. They typically emit clean exhaust gas with low NOx concentrations. When used for cogeneration, in which the excess heat is used for heating and/or cooling, their efficiencies reach 60%, thereby lowering greenhouse impacts.[15]

Biodiesel. Biodiesel fuels, or biomass-derived fuels appropriate for diesel engines, are made from methyl esters derived from soybeans. Biodiesel can improve combustion and starting performance. Biodiesel relies on a completely different production process than petroleum-based diesel. Comparing air emissions over their life-cycles (i.e., from production to combustion), biodiesel can cut CO emissions in half, particulate matter by 30 percent, and sulfur dioxide almost entirely. However, it does lead to a 13 percent increase in NOx emissions.[16]

Fuel Cells. A fuel cell combines hydrogen-bearing fuel with air-borne oxygen in the presence of a catalyst and an electrolyte to produce electricity, water and heat. The term encompasses several technologies at different stages of maturity. Because fuel cells do not burn anything, they release no toxic emissions. Separation of hydrogen fuel from hydrocarbon feedstock does produce carbon dioxide, the principal man-made greenhouse gas. But if a fuel cell is also tapped for cogeneration, it will have a lighter greenhouse impact than large, fossil fuel-burning powerplants.[17]

The Case for Wind and Solar as Pollution Control Strategies

The prevalence and continued growth of diesel generators requires concerted action to ensure that "distributed generation" (DG) does not equal "diesel generators." Action should not offer small emissions reductions per generator, since population growth will outstrip such cuts. A host of cleaner energy technologies such solar and wind are available that represent a tremendous environmental improvement over diesel generators. However, a variety of market factors will hinder many of these cleaner technologies, or keep them as marginal players in a vast DG market, as a large and mature diesel generator industry maintains the advantage of incumbency.

Current environmental regulations for diesel equipment do little to challenge the diesel industry's incumbency and spur a technological transformation to zero-emission energy sources. For regulations that target "offroad" diesel engines apart from generators, the chief economic benefit of the regulations is that they do not significantly affect the design of the generator itself, thereby protecting the diesel industry's current practices. For example, current regulatory approaches may encourage diesel engine owners to use new fuels, such as natural gas. However, this can pose significant tradeoffs among different pollutants. (See Box 2.) Reformulated fuels can cut NOx and particulate emissions, but they also tend to cut engine efficiency, raise operating costs, and lower power output. [18]

Solar and wind represent zero-emission technologies that also do not use fuel, thereby solving the water pollution threat posed by diesel. By offering multi-pollutant benefits, and even multi-media benefits, they are the ultimate environmental "control technologies." However, because of the way environmental regulations are made and judged, multi-pollutant and multi-media benefits go under-recognized by regulators who have jurisdiction over more limited pollution issues. Since wind and solar cost more on an individual pollutant basis than many conventional control technologies and reformulated fuels, environmental regulators do not even consider them when approving control strategies on diesel generators.

If environmental regulations persist in judging the cost of a pollution reduction measure by individual pollutant, then environmental agencies should institute programs in parallel with single-pollutant regulations. Through programs, environmental agencies can work with the wind and solar industries, consumers, other government agencies, and private firms to transform the diesel generator market in a way that allows wind and solar (and even fuel cells and microturbines) to capture greater distributed generation market share in a profitable manner.

Examining the Markets

For renewable energy to replace diesel generators in a variety of markets, the renewable energy industry must compete against a mature diesel industry that effectively promotes, finances, installs, and services its products to a wide customer base. Those interested in advancing renewable energy must identify what the renewable energy industry needs in order to compete with or partner with the diesel industry. (See Box 3 for a discussion of what factors affect the cost of using renewables instead of diesel).

The following analysis examines the diesel generator industry and competing wind and solar industries. Specifically, it will look at two markets:

- The Alaskan remote village power market, where diesel generators serve as "baseload" generation within small village power grids and where wind-diesel hybrid systems show strong promise.
- The back-up power market, where diesel generators run infrequently and where solar photovoltaic systems offer secure power for smaller customers in case of blackouts or brownouts.

For the diesel industry, the analysis employs business analyst Michael Porter's five key sources of competition within an industry to see if renewables can actually enter the diesel industry as a new product that offers diesel generator firms competitive advantage among their customers.[19] The five sources are: the entry of new competitors, the threat of substitutes, the bargaining power of buyers, the bargaining power of suppliers, and the rivalry among existing competitors. The purpose of the diesel industry analysis is to (1) determine if they can benefit from incorporating renewable energy sources and technologies in their products and (2) examine what the renewable energy industry is competing against in the remote village and back-up power markets (Tables 3 and 5).

For the wind-diesel and PV industries, the analysis examines seven industry characteristics adapted from Lucid Inc.'s analysis of New England PV markets.[20] The seven characteristics reveal how the industries are poised to compete in specific markets. The characteristics are: existence of a complete value-chain, existence of a standard product, technical challenges, ease of implementation, size of market, the size of environmental benefits, and how well it fits with the existing diesel industry (Tables 4 and 6).

Remote Village Power in Alaska

Alaska has approximately 175 villages far from major electricity interties. For Alaskan towns located far from the electricity grid, diesel generators have been the "modular" power technology of choice since the state began to issue grants in the late 1970s, until every village with more than 60 people was electrified by the mid-1980s. A village has to choose a generator that is the right size to power its own mini-grid. It also needs a generator that is easy to transport to the village by train, barge, or plane. Few of these remote villages can be reached by road from major cities, even in summer.

In 1988, total installed diesel capacity in Alaska was 259 MW, with electricity consumption growing 10 percent annually in villages eligible for state energy support; most machines generate between 151 and 300 (kW).[21] Oil-fired plants in Alaska, for which diesel is the primary fuel, are on average seventeen years old—a promising opportunity for capital turnover and the introduction of new technology such as wind power.

Villages (not including cities such as Fairbanks and Anchorage) have electric cooperatives and municipal utilities to run their grids. These village utilities sold 1.13 billion kWh and collected $162 million in revenues in 1997. The capabilities of these utilities vary. Utilities serving "hub communities" with schools, banks, and other regional services may have several staff members, including dedicated maintenance staff. Conversely, small villages may employ just one person to refuel and perform basic maintenance. One cooperative, the Alaska Village Electric Cooperative (AVEC), serves as a technical clearinghouse for fifty remote villages. About a hundred Alaskan villages require outside technical assistance for their electricity services.[22]

Existing Programs Supporting Villages

Alaskan villages depend on several programs to keep their diesel generators running:

- The Alaska Energy Authority (AEA) supplies technical assistance in resource assessment, procurement, shipping, and installation. However, to create jobs, AEA frequently hires local residents to assist with relatively "low-tech" activities such as refueling.
- Villages receive financial assistance from both the AEA and the U.S. Department of Agriculture (USDA) Rural Utility Service loan program to extend electric service.

Box 3. Relative Costs of Diesel, Wind-Diesel, and PV Systems

What does it cost to go renewable instead of diesel? Unfortunately, a straightforward answer that typifies the national market is hard to quantify. The following discussion should give an indication of what the relative costs will look like and, just as importantly, what factors affect relative costs.

Remote Village Power

The U.S. Navy introduced three 225-kW wind turbines on San Clemente Island, far off of the California coast in the Pacific. While the size of the turbines exceeds those most suited for Alaskan villages, the role they play in the island's power system is similar and serves as a fair indication of wind power's benefits to remote diesel-powered grids. A study of the benefits of introducing two such wind turbines into the island's diesel-power grid reveals the following cost and benefit results for the turbines alone.[24] The important item to note is the payback period for the wind component, or the amount of time it takes for the wind to pay for itself as a result of diesel-fuel savings and reduced running time for the diesel generator.

Cost of Introducing Two 225-kW Wind Turbines to San Clemente Island, California According to Wind Speed

Wind Speed (in meters/second)	Diesel Fuel Savings (in 1,000 liters)	Cost of Wind Energy (in $/kWh)	Payback Period (in years)	Internal Rate of Return[25] (in %)
5	149	0.473	10.6	7
6.1	242	0.461	6.5	14.4
7.2	336	0.449	4.7	21

Because every remote grid is different and because there is not a standardized service and product in the wind-diesel market, costs will fluctuate from site to site. The San Clemente Island example differs from the Alaska village market in several respects: the peak capacity of the turbines is greater; diesel fuel is typically shipped in via boat rather than rail or plane (as is common in Alaska); there is no particular need for turbines that can withstand prolonged cold weather spells; and wind speeds are lower than those for many Alaskan villages. (Kotzebue, Alaska, for example, experiences average wind speeds of 13.5 meters per second.) Overall, the capital and operating cost of the wind equipment, the diesel fuel costs, and the diesel system operations and replacement costs will significantly affect project economics.

Note that the third column—the energy cost of the wind component—does not tell the total cost story alone. Diesel fuel savings translate into substantial savings for small villages, both in avoided fuel purchases and in the avoided cost of diesel fuel storage-tank replacement and maintenance. Since the Kotzebue Electric Association uses 1.4 millions gallons of diesel fuel per year and spends 94 cents per gallon, which in turn fuels 14 kWh of electricity production, one kWh from a wind turbine can save 6.7 cents/kWh in fuel costs, not including the high cost of the fuel tank and of environmental impacts. The Kotzebue Electric Association estimates that its storage-tank capital costs are approximately $8 per gallon of capacity, not including tank maintenance to comply with increasingly stringent state environmental standards.

Back-Up Power

The cost of running a diesel generator that provides back-up power around-the-clock is about 19 cents/kWh, although this depends upon the increasingly volatile cost of diesel fuel. It also depends upon the average running time of the generator—the less often it runs, the higher the cost per kWh will be, although less fuel is consumed, less maintenance is required, and the generator will last longer.

The cost of electricity from a photovoltaic system (including the battery, circuits, inverter, and mounting) will fluctuate depending on solar insolation patterns, the ease of connecting the system to the grid, the availability of net metering, the rate at which the local utility will buy back excess power, financing terms, system configuration (grid-tied versus off-grid, tilted versus flat, fixed position versus tracking), and the size of the system. The Electric Power Research Institute and the U.S. Department of Energy estimates current capital cost to be between $5 to $10 per installed Watt. The per-kWh cost is more variable due to the factors listed above. A range of 15 cents/kWh to 50/kWh more accurately captures price ranges in the U.S. If affordable financing, reasonable incentives, net metering, easy interconnection, warranties, easy access to servicing, and above average solar insolation are available, then costs will be at the lower end of the cost range.

- The AEA provides subsidies to villages making bulk diesel fuel purchases, providing zero- or low-interest loans for up to 90 percent of the wholesale cost of diesel fuel. Villages must repay the loan in one year. AEA also provides loans for expanding bulk fuel storage, for performing emergency repairs on bulk storage tanks, or for procuring emergency supplies of diesel fuel in case fuel vendors threaten to halt delivery.[23]

- Finally, villages receive subsidies for fuel purchases from the state Power Cost Equalization Program (PCE). Based on a permanent endowment, the program offers $15 million per year; the funds are available only for residential meters and only for the first 500 kWh per month per meter.

Status of the Diesel Industry in Alaska

The diesel industry has developed an extensive business network to handle the village power market. Diesel generator manufacturers—such as Caterpillar, Cummins, Detroit Diesel, and Alaska Diesel Electric—have a long history in Alaska, ever since they won contracts from the Alaskan government in the 1970s to electrify Alaskan villages.

Manufacturers team up with generator distributors and service providers, some of whom are owned by the manufacturers while others are independent but approved by the manufacturers. Distributors and service representatives are located in all major cities in Alaska (such as Anchorage and Fairbanks) and in towns on the southern and central coast. When a village inland or on the northern coast experiences a problem with its diesel generator, service representatives can reach the village in one or two plane flights.

Diesel generator manufacturers and distributors also sell other popular products that incorporate diesel engines, such as marine generators and propulsion engines. This provides them with greater staying power in the event of downturns in specific markets. Table 3 summarizes the diesel industry in Alaska according to the five Porter criteria.

Wind-Diesel Technology

Wind-diesel hybrids are a viable option for Alaskan villages. Alaska has three hybrids as a result of pilot projects in Kotzebue, Wales, and St. Paul Island. The best hybrid system for villages is the parallel system, in which a diesel generator and alternator are installed beside a free-standing wind turbine providing AC power directly into the village grid. The diesel generators and the wind turbines are independently attached to the grid, and a control system manages the two connections to meet electricity needs without disturbing the power frequency of the grid.

Since most villages are already electrified, wind-diesel hybrids are usually retrofits of existing diesel-only systems. The operator installs the wind turbines and connects them directly to the grid alongside the diesel generator.

Wind power's share of power produced by a hybrid system can range from one third in areas of moderate wind ("low penetration") to over two-thirds in areas with very high winds ("high penetration"). In both cases, the hybrid system involves smaller diesel generators compared to stand-alone diesel, efficient operation of the diesel generator at all times, lower fuel consumption and emissions, and better economics. In areas that have to fly in diesel fuel over long distances, even low penetration hybrids offer substantial savings.

Fortunately, wind speeds in Alaska are often constant on an hourly basis, offering good reliability for wind power and reducing the required size of the diesel generator. Wind speeds range from moderate (Class 3) to high (Class 6 and 7) on and near the coast, and from low (Class 1) to moderate (Class 3) in interior regions.[26]

The most appropriate wind turbines for Alaskan villages are small, not the type normally associated with large-scale wind farms in the contiguous forty-eight states. Small wind turbines range from 300 watts to 10 kW for individual homes, and up to 225 kW for small industrial and village loads. Portability is the key—the turbine components must fit on a plane for shipment.

The Wind-Diesel Industry

The small-wind industry is still nascent and fairly undeveloped—there is not an extensive network of distributors, nor is there an elongated supplier value chain with highly specialized links. In general, small wind-turbine manufacturers also assemble and install wind systems. Table 4 summarizes the status of the wind-diesel industry.

Recommendations

The Alaskan village power market is unusually dominated by government programs—including grants, loans, and technical assistance to utilities that are too small to rely solely on market forces. Consequently, many recommendations for commercializing wind-diesel hybrids include a government role, although nongovernmental players are also needed.

Diesel equipment firms should diversify into retrofitting diesel generators with wind power. Although diesel generators are typically reliable, they have high operating costs and low efficiencies and require substantial maintenance. The fuel-saving qualities of wind-diesel hybrids, combined with their apparent success in demonstration projects in Alaska, point to

the technology's economic and reliability benefits to remote villages. These systems require diesel generators, so the diesel industry's move into hybrid technology would not represent a drastic move away from their core business. Instead, by offering retrofit services, the industry would move into a new service area, thereby strengthening revenues even during periods of low diesel-equipment sales. They would also lessen their dependence on diesel engine suppliers and improve their bargaining position. (See Table 3.)

By selling hybrids, firms would also hedge against the risk of continued diesel-fuel price volatility, as well as future risk of changing government energy programs. Finally, firms may strengthen their presence in Canadian and overseas markets, where off-grid power and the risk of fuel price increases make wind-diesel hybrids an attractive power source.

Governments should tailor financing to wind power rather than diesel power. The Alaska Energy Authority and the USDA Rural Utility Service (RUS) should shift a significant portion of their financial resources from diesel generators and annual fuel purchases to one-time, low-interest or zero-interest finance packages for wind power. RUS offers a Generation and Transmission Loan Program with a 100 percent loan guarantee and interest rates based on 20- to 30-year Treasury bonds. RUS also offers direct loans based on municipal bond rates, as well as loans and grants for rural economic development. USDA also offers loans and grants under the Rural Housing Service (which also cover community facilities) and the Rural Business-Cooperative Service (available to corporations as well as nonprofits, utilities, tribes, and others).[27]

While annual fuel purchases constitute a major cost for diesel generators, wind turbines have higher up-front capital costs but no fuel costs. By adopting wind turbines to back-up diesel generators, villages would be able to take out fewer AEA loans in the future. For example, in the Alaska Village Electric Cooperative service area, wind power that cut diesel consumption in half would save the equivalent of two entire years of electric service costs over a thirteen-year period.[28]

Governments and the wind industry should train local citizens to install and maintain wind-diesel systems. The prospects for wind power in remote Alaskan villages are dim if there is not an adequate infrastructure to install and service equipment. With unemployment a major problem in rural Alaska, training local citizens to install and maintain wind-diesel systems offers multiple local benefits. Kotzebue Electric Association is creating a regional training center for professional service representatives.

Table 3. Diesel Industry Assessment for Alaskan Village Power

Criteria Affecting Competitive Advantage of Industry	Status
Entry of New Competitors	Stable. Four major firms have established distribution and servicing networks, as well as good relationships with government agencies.
Threat of Substitutes	Fuel cells and microturbines are under development, but require gas hook-ups and may take ten years to penetrate. Other renewables, such as small hydro, have no installations but are under development. Wind turbines are the best alternative to diesel—especially when diesel fuel prices are volatile.
Buyer Bargaining Power	Villages have little choice beyond established diesel firms in Alaska that can serve remote communities that need guaranteed power.
Suppliers Bargaining Power	Due to few suppliers of quality diesel engines (which are the key component of diesel generators), those *generator* manufacturers who are not also *engine* manufacturers need to build relationships with suppliers and hold little bargaining power.
Rivalry Among Existing Firms	There is substantial competition for bids based not only on price, but also on services that guarantee reliable power supply.

U.S. EPA, the Alaska Energy Authority, and other agencies, in partnership with wind power companies and rural electric utilities, can support such efforts through grants for environmental protection, renewable energy adoption, and community economic development. Local training can ensure that disruptions to the village grid can be handled quickly, without relying on repair shops a plane flight or more away.

While this may seem in conflict with attracting diesel generator distributors to wind systems, such firms can still profit from transporting wind equipment and providing technical assistance with the continued operation of the diesel generator, or a new generator installation to complement the wind system.

Back-Up Power

Back-up generation is useful for a wide range of applications, encompassing industrial, commercial, and residential customers. This analysis focuses on the residential and commercial markets, where solar photovoltaics (PV) have made some progress and where their typical size and cost are more appropriate. These markets are increasingly important, especially as concerns about unreliability in the electricity grid grows amid restructuring.

Table 4. Wind-Diesel Industry Assessment for Alaskan Village Power

Criteria Affecting Competitive Advantage of Industry	Status
Existence of Value-Chain	***Manufacturing.*** Several firms manufacture turbines that can be integrated with diesel. These manufacturers also serve as distributors. ***Distribution and maintenance.*** Due to small market, there is no distribution and maintenance presence in Alaska. ***Financing.*** No special financing products apart from targeted government grants. Financing available to utilities from the Rural Utility Service program of the Department of Agriculture can fill some of this need. Other programs and approaches, such as tailoring AEA programs to wind economics, are needed.
Existence of Standard Product	No.
Technical Challenges	Some. Need to improve power controls to minimize power fluctuations. Wind turbines are not yet modular or easy to transport.
Ease of Implementation	Wind-diesel installations require outside sources of financing, primarily government sources. Still *perceived* as a risky technology, though utility experience is rapidly growing.
Size of Market	Up to 130 MW, assuming wind can replace half of total diesel capacity. Should be substantial given existing domestic markets for wind-diesel hybrids and small wind turbines. Markets in nearby Canada offer more revenues, with at least 500 MW of installed diesel capacity in 300 communities.[29]
Size of Environmental Benefits	Less diesel fuel use translates into avoided fuel spills, which occur frequently statewide and threaten land and water resources. Lower air emissions may benefit local and occupational health.
Fits with Diesel Industry's Existing Business	Technology requires different installation and maintenance skills. The diesel industry could use the technology to hedge against fuel price volatility, address villages' concerns about secure power supply, and improve environmental quality.

Restructuring has introduced concerns about the adequacy of current and future transmission and distribution lines and about the commitment of utilities to maintenance and safety in a competitive environment.

According to one survey, small businesses experienced three power outages per year, costing $7,500 each. Half the companies blamed at least one of their outages on the local utility.[30] A U.S. Energy Information Administration survey showed that 78 percent of buildings with on-site electricity generation use it for emergency back-up. The study found that larger buildings are more likely to have on-site generation.[31]

Particularly important for suppliers to the back-up power market is the value consumers place on avoiding a brownout or a blackout. The value of the foregone electricity is not measured simply by the prevailing rate for those kilowatt-hours, but by the foregone activities during the power interruption—lost business, lost data on computers, lost items spoiled by lack of refrigeration, and severe inconveniences to families. With power supply constraints a major concern in the summer due to air-conditioning demands, customers who enter into bilateral contracts for electricity services that include "interruptible" conditions are finding their supplies cut off more often.

Furthermore, electricity restructuring pushes both suppliers and consumers to recognize more accurate price signals. With the emergence of "real-time" pricing that accurately reflects supply and demand, there should be a compelling price-based interest in on-site power that not only backs up the grid but can replace it and feed into it.

Size of Market

The size of diesel generator installations for back-up power is uncertain, but most likely a majority of the 626,000 diesel generators are in service nationwide are for back-up power. Of these, 320,000 are stationary, most of them back-up generators. In 1998, annual sales for all generators exceeded 58,000 units. The majority of all installed generators are below 500 hp (131 kW). (See Table 1).

Ownership models for diesel generators vary. *End-users* own generators. *Rental companies* own generators and rent to end-users. *Energy service companies* own generators to offer as a rental to customers. And *utilities* own generators to support distribution grids.[32] The diversity of ownership models is a key strength of the diesel generator industry and is indicative of two qualities that characterize generators—they are easy to use and easy to transport and install for short periods of time.

The Diesel Industry

The diesel industry has a mature value chain that makes it easy for a customer anywhere in the United States to select, finance, install, and service a generator. Cummins is the largest supplier of diesel generators in the United States, has twenty-four-hour operators to provide product information, 175 company distributors nationwide, and many more independent dealers and service providers certified to sell and repair Cummins generators.

Caterpillar, another diesel giant, meets the financing needs of its customers by owning its own $11.6-billion financial subsidiary to provide consumer credit. Caterpillar also offers insurance and warranties, including temporary replacements. Caterpillar boasts "We build it. We finance it. We insure it."[33] Table 5 summarizes the diesel industry in the back-up power market according to the five Porter criteria.

PV Technology

PV for back-up power represents a substantial market opportunity. However, it will not be easy to seize this opportunity without high-quality products and service given the entrenched diesel industry and the emergence of new technologies such as fuel cells and microturbines (which still require fuel, preferably from a nearby natural gas pipeline). But technical advances in PV systems strengthen its market position.

Past criticisms of PV products included lack of standardization, lack of third-party certification, and poor warranty coverage. These three hurdles are eroding. PV systems meet Underwriters Laboratories (UL) testing procedures for safety, as well as the National Electric Code (for fire safety) and Institute of Electrical and Electronic Engineers standards. Many PV modules have twenty-year warranties, although other components have more limited warranties.

A PV Uninterruptible Power Supply (UPS) system features a PV module connected to a battery and, for some systems, to the electricity grid. The battery stores power in case the sun is not shining during an outage. PV UPS systems thus guarantee to offer power when the grid fails. The amount of time they can supply power depends upon the size of the system and the customer's demand for power during an outage. The smallest systems for residential customers usually can supply at least two hours of power even when the sun does not shine, with larger systems offering longer service. Such power significantly augments the limited amount of power offered battery-only UPS systems—often 15 minutes or less.

PV UPS systems can compete directly with diesel generators based upon conventional customer values in the back-up power market (i.e., the need for power during outages). But they also offer

Table 5. Diesel Industry Assessment for Back-Up Power

Criteria Affecting Competitive Advantage of Industry	Status
Entry of New Competitors	The same major firms have dominated the industry for years. Extensive dealer networks and a commodity-like market environment will make it difficult for new firms to enter the diesel generator market, unless they can offer substantially higher value. The main threat comes from overseas firms.
Threat of Substitutes	Increasingly high with availability of natural gas engines, and the development of microturbines and fuel cells. Caterpillar has attempted to anticipate this by offering gas turbines for industrial applications.
Buyer Bargaining Power	Limited but growing. Diesel generators are the traditional technology of choice, but natural gas turbines are becoming competitive.
Suppliers Bargaining Power	Diesel generator suppliers also tend to make diesel engines.
Rivalry Among Existing Firms	May heat up with emergence of new technologies and growing markets in the wake of restructuring. Competition may take the form of price cuts, diversification into new technologies and subsequent dominance of emerging sectors, and improved services. With the last already robust, it is the least likely scenario.

different values than diesel generators, since they can run as long as the sun shines, thereby becoming an integral power source to the customer year-round. In states with "net metering," a grid-connected PV system serves as an unobtrusive power plant that can provide power both to the customer and into the grid. Power fed into the grid allows the customer to receive payment from the local utility, usually at wholesale power rates. If the PV system generates power during high-price spikes, owners can benefit both from avoided grid costs and from high returns from the sale of their own power. (The thirty states that have "net metering" policies typically do not include diesel generators.)

The economics of PV are also increasingly favorable. Lucid Inc.'s market transformation study of uninterruptible power systems (UPS) for computer networks in New England found that augmenting existing computer UPS systems with PV can be an attractive market opportunity for the PV industry, and is an affordable option for businesses that lose productivity from computer network outages. The analysis finds that the PV system could pay for itself in seven years, assuming less than two hours of power outages per year. The bulk of the value comes not from avoided electricity costs, but from avoided productivity losses.[34]

The PV Industry

Despite increasingly favorable technical and economic qualities, the PV industry suffers from "non-technical" factors such as financing, education, regulatory barriers, and a limited business infrastructure. While increased research and development of PV technology is welcome, deployment strategies are in short supply, yet strategies like these are invaluable if PV is to enter the lucrative back-up power market.

The PV industry for back-up power consists of:

- Several large manufacturers who have moved directly into retail sales, either through their own operations or through acquisitions of firms focused on systems integration and distribution. Firms include BP Solarex and Kyocera.
- Manufacturers who build solar modules that are sold to firms who integrate them into systems. Firms include ASE Americas and Siemens Solar.
- Firms that integrate PV systems (e.g., incorporating batteries, inverters, transformers, and other balance-of-system components into the PV module, and designing the system for custom applications) and distribute them for the back-up power market. Firms include Idaho Power, Evergreen Solar, and Astropower.
- Manufacturers and suppliers of balance-of-system components. Firms include Kyocera and Xantrex/Trace Engineering.

- Consumer financing primarily from governments, including state system benefits funds (e.g., California), state tax credits, state low-interest loans, federal financing programs for which PV is eligible (e.g., Energy Star loans, Department of Housing and Urban Development loans, and Veterans Affairs loans) and private programs (Fannie Mae, General Motors Acceptance Corporation). Utilities also offer rebates to consumers of PV.

The biggest gaps in the PV value-chain include:

- *Marketing.* Few people know about PV options in lieu of diesel generators. Even if a potential customer is aware of PV, few know that it works, and even fewer know where to buy systems. The growth of e-commerce could make this easier.

- *Distribution and servicing.* While numerous firms distribute, install, and service PV systems, their reach does not compare with a diesel industry that has a network that guarantees twenty-four-hour response to inquiries and distributors and service providers in every state who can reach customers quickly either through visits or in-store service.

- *Financing.* While existing state and federal consumer finance programs can make the high up-front cost of PV easier to bear,

Table 6. PV Industry Assessment for Back-Up Power

	Back-Up Power
Existence of Value-Chain	*Manufacturing.* Several firms have expanded manufacturing and have introduced innovative processes (e.g., thin-film production), mainly due to the overseas market. More expansion can drive down the cost of PV, perhaps at a rate of 18 percent for every doubling of production. *Distribution and servicing.* Limited geographic reach compared to the diesel industry. Greater volatility as firms rise and fall, since firms performing these functions and not vertically integrated are exposed to the financial dangers of project failure. *Finance.* Options exist, but most are virtually unknown.
Existence of Standard Product	Emerging, although custom installation and associated high costs are still common. Universally recognized standards (such as National Electric Code and Institute of Electrical and Electronic Engineers) will avoid confusion about product quality and reliability.
Technical Challenges	Amid technology improvements, regulatory barriers to interconnection to the grid (to take advantage of net metering) and obstructive neighborhood covenants persist. These can eat into the profits of system installers and the value of customers who must obtain permits.
Ease of Implementation	Variable, based on the ability of the installer, PV system packaging, and regulatory barriers in a given locale.
Size of Market	Potentially enormous.
Size of Environmental Benefits	Promising. While back-up diesel generators run less than baseload generators, they often run in the summertime when tropospheric ozone is at its worst and nonattainment with the Clean Air Act is most likely.
Fits with Diesel Industry's Existing Business	It is unlikely the diesel industry, absent strict emissions limits and other regulatory incentives, will seriously consider PV except as a way to diversify products amid the arrival of new technologies. However, other industries, such as energy service companies (ESCOs) or even the uninterruptible power supply (UPS) industry supplying businesses that run Local Area Networks, may be more willing to incorporate PV into their products. However, no such efforts are occurring in the mass market.

learning about program details and obtaining application forms requires more time and effort than diesel purchases.

- *Rentals.* The PV industry is focused on equipment sales, not on short-term rentals. Yet customers may appreciate the option of back-up power only in the summer when electricity prices are volatile and power interruptions are more likely. The diesel industry is experienced in renting equipment.

Table 6 summarizes the PV industry's capacity to provide back-up power.

Recommendations

It is unlikely that the conservative diesel industry will be open to including PV in its product mix—industry sales are healthy and the threat of alternatives is not yet palpable. However, the question of how to reach customers should lead the PV industry to other firms, including those offering alternatives to diesel generation and those offering more holistic services that add value above reliability.

State environmental agencies should jump-start replacement efforts with a multi-year incentive program. In recognizing the environmental benefit of replacing diesel generators with PV and other cleaner technologies, state air agencies should consider creating a multi-year grant program that offers funding to owners of stationary diesel engines such as generators for back-up power. The funding can cover all or a portion of the incremental cost of buying the cleaner power source.

The program should publicize the benefits of renewables versus diesel, and show potential customers how renewables can replace diesel to meet customer needs. It should last for several years to minimize market volatility. A single subsidy program that swamps the unsubsidized market can backfire completely if it ends unexpectedly and carries with it the heavy hopes of the industry.

In California, the Air Resources Board has already developed the Carl Moyer incentive program for heavy-duty engines (see Box 4). While the program does not include emerging sources of power such as renewables, fuel cells, and microturbines to replace diesel, it serves as a useful example of an air agency that recognizes the problem of "off-road" diesel and has begun to address it.

The PV industry should align itself more closely with the energy services industry, and vice-versa. This option targets the energy services company (ESCO) industry, including firms that

Box 4. Incentives to Replace Old Diesel: The Carl Moyer Program

The California Air Resources Board (CARB) administers the $48 million Carl Moyer program to fund private companies or public agencies that go beyond what is required to reduce emissions from "heavy-duty" engines, primarily diesel engines. Named after the late air-quality scientist, the program covers the additional capital cost of buying a new engine to replace or retrofit large, heavy-duty engines. (Local air districts must offer a 2-to-1 match for each project.) CARB certifies what technologies can replace or clean the existing engine. Renewable energy technologies or fuel cells do not appear to be certified options.[35] Engines that qualify for replacement include on-road vehicles and off-road equipment such as marine vessels, locomotives, and stationary agricultural equipment.

Replacement technologies, including new diesel engines, alternative fuels, and equipment retrofits, must meet CARB NOx standards for diesel engines (which are more stringent for newer engines), plus cut NOx emissions beyond CARB standards by 25 to 30 percent and emit no more particulate matter than the old engine. CARB set the criteria so that the newly purchased engine cuts emissions beyond what is required for new engines, and does not merely represent a natural capital turnover that would have happened regardless of the program. Projects must result in NOx emissions reductions that cost less than $12,000 per ton. (If the project results in cuts that cost more than $12,000, then private funding must cut the cost to make the project eligible).

So far the response has been strong. Californians submitted applications worth $80 million, and CARB issued $20 million in funds by the end of 1999. Funded projects include new diesel engine installations for water pumps and marine vessels, natural gas trucks, and electric forklifts.[36] As of the end of 1999, the program averted almost 1,500 tons of NOx emissions at a cost of less than $3,000 per ton. With continued funding, CARB believes the program can avert over 7,000 tons in 2005, or 40 percent of the likely annual emissions reductions expected from new standards effective 2004 for every car, pickup, and sport utility vehicle in California.[37] Perhaps just as important, the reductions will happen where they are needed most—in areas with the dirtiest air—thereby highlighting the environmental benefit of catalyzing technological change in an air quality program.

offer both services (such as audits) and equipment to reduce monthly bills and bolster power reliability.

PV firms can enter the energy services sector either by diversifying their own operations or by partnering with ESCOs. The fusion can offer potential energy-efficiency customers the option of purchasing clean, on-site power—an option ESCOs offer their customers today in the form of diesel generators. By partnering with ESCOs, the PV industry can achieve three things:

- offer a product to customers who will save money from energy efficiency, and can therefore finance a PV purchase from new, future revenue streams. Further, since they are combined with measures to improve energy efficiency, PV systems can be smaller than otherwise, thereby reducing the cost of the system;

- tap into energy efficiency's customer base, which is knowledgeable about different energy options and/or environmentally aware; and

- position the PV industry in the services sector, thereby hedging against downturns in the durable goods market.

The final point is crucial to identifying the benefits of the approach. In the United States, an expanding installed base of durable goods and the volatility of the durable goods market has shifted revenues in U.S. industries from manufacturing to services – in this case, energy audits, retrofits, financing, and repairs. For the PV industry, expanding the range of services offered to include energy efficiency puts the industry into an area with higher profit margins and growth potential. It has the additional advantage that the service sector often grows counter-cyclically to growth in the manufacturing and wholesale sectors. [38]

The approach faces one problem. The energy services industry has primarily succeeded in the commercial and industrial market, while PV has appealed particularly to residential customers and off-grid markets. However, a number of retail businesses have begun to show an interest in making purchases based on environmental value. Firms such as Fetzer Vineyards and Interface have installed PV as a visible environmental commitment. Others, such as Kinko's, Toyota, IBM, and others have purchased "green power", or grid-delivered power generated by renewable energy. PV can capitalize on this trend by offering environmental public relations benefits, as well as important power reliability value unique to on-site power sources.

This fits well with a couple of trends in the ESCO industry. First, it faces the threat of lower profit margins in energy efficiency services. Customers are demanding services for more difficult and low-margin tasks. Second, competition in the ESCO industry is heating up with the entry of electric utility affiliates in a deregulated market. Intense competition should lead to a variety of differentiation strategies. PV businesses can be a part of emerging strategies for offering comprehensive efficiency, billing, and energy supply options that appeal to different values, including secure power supply and environmental protection.[39]

Overall, ESCOs appear interested in "co-branding" energy efficiency products and services with green power, so that a single certification and brand identity such as U.S. EPA's and U.S. Department of Energy's Energy Star program, whose well-known label can adorn buildings or products that meet energy efficiency standards, can benefit both products. PV, which is a part of several green power offerings, should be a part of this equation due to its power quality features.

PV should be better integrated into the federal Energy Star program, with a view toward to "Energy Star Plus" label. U.S. EPA and U.S. DOE can play a role in facilitating the marriage of energy services with PV. The federal Energy Star program has become the premier consumer label of energy efficient products and services. Currently, the program is a certification and marketing vehicle for energy efficiency technology. The program currently offers two benefits for PV. First, Energy Star mortgages for homes can cover PV installation to streamline financing. Second, the evaluation of commercial buildings to determine whether they merit the Energy Star rating includes an on-site renewables component.[40] However, PV is not a central feature in the program—the two elements discussed above are barely known by potential PV purchasers.

By more actively incorporating PV, the Energy Star program would benefit the PV industry by:

- Placing an Energy Star label on PV products to build consumer confidence.

- Offering education materials to potential customers explaining the benefits of combining energy efficiency and renewable energy such as PV.

- Making clean, on-site generation a more prominent criterion for certifying a building.

In the future, the federal government can reward efficiency and renewable energy partnerships (including green power supplied through the electricity grid) by fashioning an "Energy Star Plus" label that recognizes the role the customer is playing in crafting a clean energy sector and thus reducing emissions both from the grid and from off-grid pollution sources such as diesel engines. For those customers who are already environmentally aware, the label will be a more powerful symbol of their commitment.

Government and industry should publicize existing financing options and integrate information into marketing efforts. Several federal programs, private programs, and emerging state programs offer financing to purchasers of PV. However, learning about these programs requires determination on the consumer's part. A federal agency, industry association, or non-profit should publicize the availability of federal and state financing programs for PV systems. Information should include a phone number and website to obtain conditions and application forms. Ideally, government and industry should assemble a simple process whereby the consumer can select a PV system, determine its cost based on financing options, apply for financing, and find a qualified contractor with minimal hassle.

The PV industry should enter the resale market. In 1992, the diesel industry earned a quarter of its engine sales revenues from resales.[41] Clearly there is substantial consumer interest in buying used goods at a lower price. There currently is no analog in the PV industry. By tapping into resales, the PV industry can reach out to consumers who cannot afford new PV systems, and to those who would buy a PV system only if there was an option to resell and recoup some of the initial cost.

Financial institutions will also provide better financing terms for PV systems if it could collect and resell the system in case of default from the borrower. This would reduce financing costs since the financier faces lower risk and can liquidate the asset if necessary.

The PV industry should make portable systems a priority. In addition to resales, the PV industry could pursue another lucrative diesel generator market—rentals and portable systems—by creating portable PV systems that a rental company or customer can move easily for itinerant activities such as construction. Portable systems are more amenable to rentals because they are easy to move and connect. They fill the niche created by customers who want back-up power for the summer but do not necessarily want PV year-round.

State energy funds should share costs with environmental agencies and the PV industry to catalyze diesel generator replacements and PV product development. Power reliability and price concerns associated with electricity deregulation coincide nicely with the emergence of state clean energy funds. Most state legislatures created these funds in conjunction with deregulation, so that new money is now available at a time when diesel generator use is expected to rise sharply. There are $1.5 billion in state funds now available.

State funds can play a role in all of the recommendations listed above. For example, state fund managers can share costs with environmental agencies to fund all or some of the incremental costs to replace diesel generators with cleaner energy sources. Further, state funds can provide incentives to ESCOs to integrate renewable energy in their offerings, support education efforts on financing, offer additional financing, and invest in industry efforts to develop portable products.

RECOMMENDATION: THE OVERSEAS MARKET

The diesel industry should incorporate renewable energy technologies into their product offerings for the export market. The world market for diesel generators is immense. Japanese and British firms are competing with U.S. firms for the export market, and domestic firms in emerging markets such as India and China are becoming major market players.[42]

Developing countries typically purchase diesel generators for baseload capacity, although many industrial, commercial, and high-income residential customers may purchase them for back-up needs. Baseload capacity is often needed in villages far from the electricity grid. These villages benefit most when they use power systems with minimal operations and maintenance, and do not rely on erratically imported fuel supplies. Imported diesel fuel costs can also fluctuate due to changing exchange rates. Governments in developing nations often subsidize diesel fuel, so much so the International Monetary Fund has specifically targeted the elimination of such subsidies as a part of economic reform programs. Renewable energy technologies such as solar and wind are ideal options for energy self-sufficiency.

Solar and small wind markets are expanding in developing nations, particularly for off-grid markets. Accordingly, the diesel generator industry should reconsider relying on traditional products to maintain and increase market share. The industry would make a forward-looking step by committing itself to creating standard hybrid products that connect wind and solar systems with diesel generators.

The federal government can encourage diesel-renewable industry partnerships as a part of its effort to ease the way to a climate-friendly development path overseas. Government involvement is especially timely given concern about climate change, and interest in transferring clean energy technologies to developing nations so they can leapfrog over the stage of "dirty economic development" that can entail skyrocketing greenhouse gas emissions. The U.S. government should also promote hybrid products melding renewable energy and microturbines and fuel cells, which suffer from similar drawbacks as diesel generators, but have much lower emissions.

APPENDIX: BACKGROUND ON EMISSIONS ESTIMATES

Diesel generator population estimates. Data represents 1996 population of diesel generators. It is based upon 1996 mobile diesel generator population estimates for generators beneath 600 horsepower (447.6 kW) from the U.S. EPA, obtained from Power Systems Research, Inc., as a part of its Nonroad Vehicle and Engine Emissions Modeling (see http://www.epa.gov/otaq/nonrdmdl.htm for documentation). The U.S. EPA data grouped mobile diesel generators according to size classes in horsepower. REPP converted the figures so that they also included stationary generators. The conversion is based ratios of stationary to mobile generators obtained from Christian E. Lindhjem, *Nonroad Engine Population Estimates*. U.S. EPA, December 9, 1997 revised June 15, 1998. Report No. NR-006A, Table 1.

Data for generators above 600 horsepower (hp) were based upon 1998 population data obtained by REPP from Power Systems Research, Inc. REPP estimated the 1998 ratio of generators between 600 and 1000 hp(746 kW) versus those beneath 600 hp, and generators above 1000 hp versus those beneath 1000 hp. REPP then applied the ratios to the 1996 data for generators beneath 600 hp to reach figures for generators above 600 hp.

Operating hours. Average annual operating hours for mobile generators are assumed to be 600 hours, while operating hours for stationary diesel generators are assumed to be 100 hours. This is based upon personal communication with Power Systems Research, Inc., November 16, 1999.

Emissions factors. Factors are based upon U.S. EPA AP-42 factors. (U.S. EPA, *AP-42*, Volume 1, 5th Edition, Stationary Internal Combustion Sources. October 1996. Available at http://www.epa.gov/ttn/chief/ap42/index.html.) This analysis assumes that engines below 600 hp do not have emissions controls, while those above 600 hp do. U.S. EPA's estimates that diesel engines below 600 hp emit 0.031 pounds of NOx and 1.15 pounds of CO2 per horsepower-hour (hp-hr). Engines above 600 hp with controls emit 0.013 pounds of NOx and 1.16 pounds of CO2 per hp-hr.

Estimates for 2010. Estimates for 2010 are derived from annual industry growth estimates from the Bureau of Economic Analysis, as discussed in U.S. EPA, *Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines*. 1998. EPA420-R-98-016. Annual growth data was then applied to the 1996 emissions data discussed above for each year from 1996 to 2010. BEA estimates the annual growth rate to be 1.7%, though recent market trends show that it may be much higher. From 1996 to 1998 the annual growth rate was 2.7%.

Discussion.

- The U.S. EPA AP-42 emissions factors for generators below 600 hp are higher than those estimated by the California Air Resources Board (CARB), which assumes that uncontrolled NOx emissions from offroad diesel engines built after 1987 are 0.018 pounds per hp-hr. (CARB does not include CO_2 factors for comparison.) Thus, this analysis implicitly assumes the generators in this analysis are older than 13 years. If we assume that half of all installed generators among all size classes are less than 13 years of age, the new total estimate for NOx emissions would be 176,316 tons in 1996.

- However, offsetting this potential overestimate is the exclusion of emissions data based upon engine deterioration. For example, CARB estimates that diesel generators between 25 and 40 hp emit 31% more NOx for a 31% reduction of its useful life. Since REPP does not have precise data on population age classes, the total reached in this report could greatly underestimate total emissions.

- Finally, CARB has fuel correction factors based on 1992 California diesel fuel regulations for aromatics and sulfur. The factors could bring emissions from a generator down by 12.5%. However, these are not national standards, and have not been included in the analysis. If included, it would reduce the national total for NOx by approximately 1.25%, since California has 10% of all diesel generators in the nation (Personal correspondence with Power Systems Research, September 7, 1999).

END NOTES

1 See Appendix. By comparison, the population of diesel generators in 1998 was 667,626, or a 6.6% increase from 1996.
2 Gerald Parkinson, AMPS, Presentation at 1996 Electrical Generator Supply Association Annual Meeting.
3 See Greg Janssen and Rich Wilcox. *Seasonal and Monthly Activity Allocation Fractions for Nonroad Engine Emissions Modeling*. U.S. EPA. Report No. NR-004. December 9, 1997. Available at <http://www.epa.gov/otaq/models/nonrdmdl/nr-004.pdf>. The study finds that diesel engine use for industrial, agricultural, and construction activities peaks in the summer months, except in warmer regions in the West.
4 State emissions data from U.S. Energy Information Administration. *Electric Power Annual 1999, Volume 2*. Washington, DC: October 2000. DOE/EIA-0348(99)/2. Available at <http://www.eia.doe.gov/cneaf/electricity/page/annual.html>
5 The 1.7% annual growth rate figure is assumed by U.S. EPA in *Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines*. Washington, DC: 1998. EPA420-R-98-016.
6 See Appendix to see how figures were reached.
7 State and Territorial Air Pollution Program Administrators and the Association of Air Pollution Control Officials, *Cancer Risk from Diesel Particulate: National and Metropolitan Area Estimates for the United States*, March 15, 2000. Available at <http://www.4cleanair.org>
8 For example, in one three-month period sampled, three spills occurred. The Igiugig diesel power plant spilled 300 gallons of diesel fuel due to tank overflows in July 1999. The previous month, 100 gallons of diesel fuel spilled into Goodnews Bay for unknown reasons. In May 1999, almost 3,000 gallons of diesel used for heating and electricity generation spilled into biologically sensitive waters at Little Diomede due to a hole in the dispensing filter. Alaska Department of Environmental Conservation, Division of Spill Prevention and Response, Prevention and Emergency Response Program, viewed 9 September 1999 at <http://www.state.ak.us/local/akpages/ENV.CONSERV/dspar/perp.htm>.
9 The Health Effects Institute found that diesel exhaust increases the risk of lung cancer among workers by 20 to 50 percent, although further study may be required to confirm such risk. Kathleen Nause, "Diesel Exhaust: A Critical Analysis of Emissions, Exposure and Health Effects," Health Effects Institute, October 1997 (mimeo).
10 Occupational Safety and Health Administration (OSHA) website, viewed 25 June 1999 at <http://www.osha.gov/ohinfo/priorities/diesel.html>
11 In 1996, 319,986 generators out of 626,489 were stationary.
12 For example, CARB exempts stationary engines which run less than 100 hours per year from "Reasonably Achievable Control Technology" (RACT) or controls for existing generators. California's South Coast Air Quality Management District goes a step further and exempts from RACT stationary diesel engines that operate less than 200 hours per year for emergency stand-by power, as well as engines used for agricultural and livestock operations. Other air quality districts include additional exemptions.
13 California SB 1298 (Bowen). Visit <http://www.senate.ca.gov/> to view the legislation. New U.S. EPA standards for sulfur content in diesel fuel may help the diesel generator industry, since low-sulfur fuel enables a range of NOx-control technologies required under regulations for diesel engines in vehicles.
14 U.S. EPA, op. cit. note 4.
15 Adam Serchuk and Virinder Singh, *Mesa del Sol: The Prize Is Worth Having*. Washington, DC: Renewable Energy Policy Project. Available at <http://www.repp.org>
16 John Sheehan et al., *An Overview of Biodiesel and Petroleum Diesel Life-Cycles*, NREL/TP-580-24772. Golden, CO: National Renewable Energy Laboratory, May 1998.
17 Technologies include the proton exchange membrane (PEM) cell; the phosphoric acid cell; the molten carbonate cell; the solid oxide cell; and others. Serchuk and Singh, op. cit. note 15.
18 For example, see "Lubrizol and Caterpillar to Develop Cleaner Fuel," Reuters Limited. Viewed 10 September 1999, at <http://www.lubrizol.com/performance/purinox.htm.>
19 Michael Porter, *Competitive Strategy: Techniques for Analyzing Industries and Competitors* (New York: Free Press, 1998).
20 Eric Ingersoll and Roman Vysatova, Lucid Inc., "Commercialization Strategies for Photovoltaics in Southeastern New England." prepared for the Rhode Island Renewable Collaborative. April 1998.
21 William R. King and Bertrand L. Johnson III, *Worldwide Wind/Diesel Hybrid Power System Study: Potential Applications and Technical Issues*. Golden, CO: Solar Energy Research Institute, April 1990.
22 For an extensive discussion of the Alaskan electricity sector, see Karl Rábago, Tom Feiler, Floyd Damron, and Deanna Gamble, *Report to the Alaska Public Utilities Commission and the Alaska State Legislature, Study of Electric Utility Restructuring in Alaska*, Final Report. CH2M Hill, June 30, 1999.
23 Alaska Division of Energy website, viewed November 9,1999, at <http://www.dced.state.ak.us/doe/Doe_loan.htm.>
24 E. McKenna and T. Olsen. *Performance and Economics of a Wind-Diesel Hybrid Energy System: Naval Air Landing Field, San Clemente Island, California* (Golden, CO: National Renewable Energy Laboratory, 1999), NREL/SR-500-24663.
25 The internal rate of return is a rate applied to a stream of costs and benefits derived from an activity. The rate should make the present value of the future cost-benefit stream equal to zero. Higher internal rates of return usually indicate more attractive investment opportunities.
26 See <http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-16m.html> for a wind map of Alaska.
27 See Michael Eckhart, *Scoping Paper: Financing Solar Energy in the U.S.* Washington, DC: Renewable Energy Policy Project, August 1, 1999. Available at <http://www.repp.org.>
28 Fuel purchases represented 31% of AVEC's total cost of electric service in 1994. Rábago et al., op. cit note 17.
29 Based on 1988 data from King and Johnson, op. cit. note 20.
30 A. Deering and J.P. Thornton, *Applications of Solar Technology for Catastrophe Response, Claims Management, and Loss Prevention*. Golden, CO, National Renewable Energy Laboratory, April 1999.

31 U.S. Energy Information Administration (EIA), *A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures*. DOE/EIA-0625(95), October 1998.

32 Utilities are an important customer in the diesel generator market. For example, the U.S. Energy Information Administration found that utilities, primarily municipal utilities and cooperatives, added 66 MW of diesel-fueled generation in 1998, with most generators below 5 MW. U.S. Energy Information Administration, *1998 Electric Power Annual, Volume 1*. Washington, DC: April 1999, DOE/EIA-0348(98)/1.

33 Caterpillar, Inc. website. <http://www.caterpillar.com/cgi-bin/frameset.pl?nav=services&content=/services/ cat_insurance/cat_insurance.html> accessed 24 January 2000.

34 Ingersoll and Vysatova, op. cit. note 20. Beyond productivity losses, monetary losses due to lower revenues from services are also substantial. For example, the cost of one hour of downtime for packaging and shipping services is $25,000 to $30,000. For a firm offering network connections for computer users, it can be $10,000 to $15,000. Joergen Madsen. "Continuous UPS Availability: How Important Is It to Your Company?" *Energy User News*, November 2000, pp. 12-14.

35 See <http://www.arb.ca.gov/msprog/moyer/guide.htm> for program guidelines.

36 CARB, *The Carl Moyer Program Status Report*, December 29, 1999. Available at <http://www.arb.ca.gov/msprog/moyer/moyer.htm>

37 Ibid.

38 See Richard Wise and Peter Baumgartner, "Go Downstream: The New Profit Imperative in Manufacturing." *Harvard Business Review*. September-October 1998.

39 See William R. Prindle and Ryan Wiser, *Certification and Brand Identity for Energy Efficiency in Competitive Energy Services Markets*, available from Alliance to Save Energy at <http://www.ase.org/profess/technical/brandid.htm.>

40 For Energy Star financing opportunities, see Eckhart, op. cit. note 28. For Energy Star's methodology for rating buildings, see EPA, *Energy Star Label for Buildings: Technical Description*. Washington, DC: May 27, 1999.

41 U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census, *1992 Census of Manufactures*. MC92-I-35A. Washington, DC: 1995.

42 Parkinson, op. cit. note 2. In 1994, Japanese and British firms represented 54 percent of total exports, while U.S. firms were responsible for 24 percent. In 1994, Indian and Chinese firms combined to make 134,000 generator sets primarily for domestic use.

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