# MICROPOWER AT THE CROSSROADS

## Public Health and the Future of Distributed Generation

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# TABLE OF CONTENTS

# EXECUTIVE SUMMARY

The debate over Massachusetts' energy future has focused increased attention on micropower, the generation of electrical energy by homeowners and businesses near the place it is used as an alternative or supplement to the statewide power grid.

Micropower, also known as distributed generation (DG), is a growing sector of the energy market that holds great promise for locally controlled power generation.[1] Having facilities widely dispersed increases reliability, and some of these technologies are among the most environmentally friendly electricity generating technologies ever invented. But continued reliance on other types of micropower, technologies that are highly polluting, poses a threat to public health.

Currently, micropower is not subject to the same air pollution controls as central power plants, and the most prevalent form of micropower currently in operation is also the most polluting form – diesel engines. These generators have been installed outside many public buildings and advertised for home use as a solution to the "energy crisis."

As micropower has grown, policy makers have come to realize that limits on emissions from micropower facilities are needed to avoid the cumulative effects of many small but very dirty generators. And states increasingly recognize that they can increase energy generation flexibility and realize major environmental improvements by encouraging the cleanest forms of micropower.

The Massachusetts Department of Environmental Protection (DEP) is planning to set air pollution standards for micropower technologies. They are seeking to establish a technology-neutral standard for all applications that works to reduce environmental emissions and protect public health.

The DEP should set strict standards that fully protect human health and the environment, and should phase them in over time to allow manufacturers to prepare for change. New standards should encourage clean technologies such as solar and wind, allow developing technologies such as fuel cells and microturbines to gradually decrease emissions, and prohibit or dramatically reduce use of the most polluting technologies. Due to severe environmental and public health impacts from the growing use of diesel generators, emissions standards must be set at levels that limit diesel applications to emergency situations and only when generators are operated in conjunction with emission-control measures.

Micropower is at a crossroads. New standards should promote clean technologies, not allow dirty technologies to proliferate and pollute the air. And standards need to establish uniform treatment of the various micropower technologies and applications.

We have produced this report to point the way to a clear future direction. As we work to promote the highest possible level of efficiency in our use of energy, we must simultaneously support sustainable, reliable, versatile technologies that can bring efficient energy generation right to the source of use while reducing harmful air pollution.

## Policy Recommendations

### Principles

To ensure that public health is protected and new technologies that reduce pollution are encouraged, distributed generation policy should be based on the following principles:

- Micropower must be as clean as or cleaner than the cleanest central power plant technology currently in widespread use.

- o State rules and incentives must promote the cleanest energy industry for the future of Massachusetts.
- o Regulations should be as simple as possible so manufacturers can anticipate changes and comply with new technology requirements.

### Primary Recommendations

State agencies can help move micropower in the right direction. To protect the health of the people of Massachusetts and the air quality of the state while helping to assure reliable local power generation, we recommend the following immediate policy actions:

- o Set stringent emissions standards for all micropower units operated in Massachusetts. Use output-based standards to encourage greater efficiency of performance.
- o Conduct a comprehensive inventory of existing micropower and other on-site generation.
- o Streamline the permitting process for clean units that meet or beat new, stringent standards.
- o Ensure aggressive enforcement of standards and establish significant penalties for violation.

### Additional Recommendations

In addition, many other specific policies could advance clean micropower while curbing the use of dirty micro-power. We recommend that state agencies:

*Establish standards and rules for micropower operation:*

- Require that all micropower units operated in Massachusetts receive certification or permits as a condition for being connected to the electric grid.
- Require that transmission grid operators draw on clean, efficient micropower before similarly priced dirty generation facilities.
- Require emissions control measures for diesel generators used for emergency back-up power supply.
- Require that all new residential and commercial construction be "solar-ready" with the basic infrastructure to ease future installation of photovoltaic panels.

*Provide funding for clean micropower*:

- Require formal consideration of clean micropower as a potential least cost alternative to transmission and distribution upgrades and a means of avoiding the cost of future environmental regulation.
- Expand funding for clean micropower technology advancement.
- Expand the availability of financial incentives, including financing assistance, buy-down programs, tax credits, and grants, for the installation of clean micropower.
- Provide incentives for developers to include clean micropower at new residential or commercial construction projects.
- Provide incentives for the trade-in and upgrade of polluting micropower installations.

*Clear hurdles to the implementation of clean micropower*:

- Streamline the permitting and utility interconnection process for clean micropower installations.
- Develop incentive tariffs and reduced standby and exit fees for clean micropower installations.

The adoption of these recommendations will promote a vital distributed generation system that reduces the negative public health impacts associated with diesel and other dirty micropower technologies.

# What Is Micropower?

For more than a century the standard formula for generating and distributing electricity has been simple. Build a huge power plant and run power lines to population centers where industry and people need the electricity. Connect the individual home or business to the electrical grid and power up.

Primarily using fossil fuels, these facilities have grown in scale and quantity as our demand for electrical power has increased. Many of these giant power plants have been major polluters as they have worked to provide a cheap, reliable electricity source for consumers. Despite advances in technology, these large central power plants continue to dominate our energy system in size, environmental consequences, and convenience.

The dominance of this model has facilitated the proliferation of electrically powered devices to the point where most of us never think about how power is generated. We just plug our computer into the wall outlet and get to work.

In some cases it has been advantageous to develop localized power generating capacity. Geographically isolated facilities and some large factories have been using local power generation for years, frequently deploying many of the technologies that cause environmental harm. But it was a rare occurrence when an individual would need or want independent local power generation for a home or small business.

Deregulation of the electric power production industry and the recent turmoil in energy markets has started to change all that. With growing concerns about the reliability of traditional power sources due to increases in power plant down time, more and more consumers are questioning the conventional model of central power plants. They are looking for more reliable energy sources, searching for greater control over power costs, and seeking alternatives to power sources that degrade the environment and undermine public health.

The combination of advancing technology and widespread concerns about large central power plants has made localized power generation an idea whose time has come. Instead of concentrating power sources at large plants, micropower systems locate power sources closer to the consumer – in an office building, a neighborhood, a factory, or a home.[2]

For many, small power generation units located near the point of use have been a safety and reliability measure to supply back-up power during blackouts. Others have suggested that in light of escalating energy costs during peak demand periods, micropower can be used as a cheaper alternative power source or a source of profit by selling the distributed power into the grid.

In grid-congested areas where transmission line upgrades would otherwise be needed, micropower has the potential to significantly reduce costs for power. Transmission and distribution costs can reach $1.50 for every $1.00 spent on electricity generation.[3] In addition, society can benefit through enhanced reliability and decreased need for infrastructure. Estimates of the monetary value of these benefits range as high as 2.8 ¢/kWh. This

**Table 1: The Economic Benefits of Decentralized Power (¢/kWh)[4]**

| Benefit | Savings |
|---|---|
| Substation deferral | 0.16-0.6 |
| Transmission system losses | 0.2-0.3 |
| Transmission wheeling | 0.28-0.71 |
| Distribution benefits | 0.067-0.17 |
| Enhanced reliability | 1.0 |
| **Total** | **1.7-2.8** |

is a substantial savings from current generating and distribution costs, which are now typically 4-9 ¢/kWh.

Growing interest in local control of electrical power generation is both an opportunity for and a threat to Massachusetts residents. The central power plant system has evolved some cleaner technologies, but older, dirtier micropower technologies are still predominant. We cannot allow the proliferation of localized power generation to undermine pollution standards.

The affordability of meeting stricter emissions standards was documented in a 2002 study by Energy Nexus Group analyzing the economic feasibility of complying with proposed new standards for micropower in California. The study found that with the amount of technology advancement expected under normal market forces, nearly all of the cleanest technologies will meet the standards in 2003, most of the new technologies will meet the standards in 2007, and all but the dirtiest technologies will meet the standards in 2012. The study determined the cost of adding emissions control equipment to fossil fuel-based micropower to be only about 1 ¢/kWh.[5]

As public agencies consider regulations addressing micropower technologies, we have the opportunity to promote cost-effective renewable energy sources that are significantly less harmful to our health. But if the growing demand for micropower results in the proliferation of polluting technologies, we face the prospect of higher levels of localized emissions that place our respiratory health at significant risk.

What follows is an overview of the pollution and public health impacts of many of the technologies currently available to those interested in the deployment of micropower. We have grouped the various technologies into three categories based on their current environmental performance. New regulations should be performance-based, so that emerging technologies have equal opportunity to meet emissions standards in the future.

**Clean Micropower –** The cleanest distributed generation technologies, primarily using renewable fuel sources. These include solar, wind, and fuel cells. These forms of power generation have minimal negative public health impacts. In addition,

**Figure 1: Emissions from Micropower Technologies[6]**

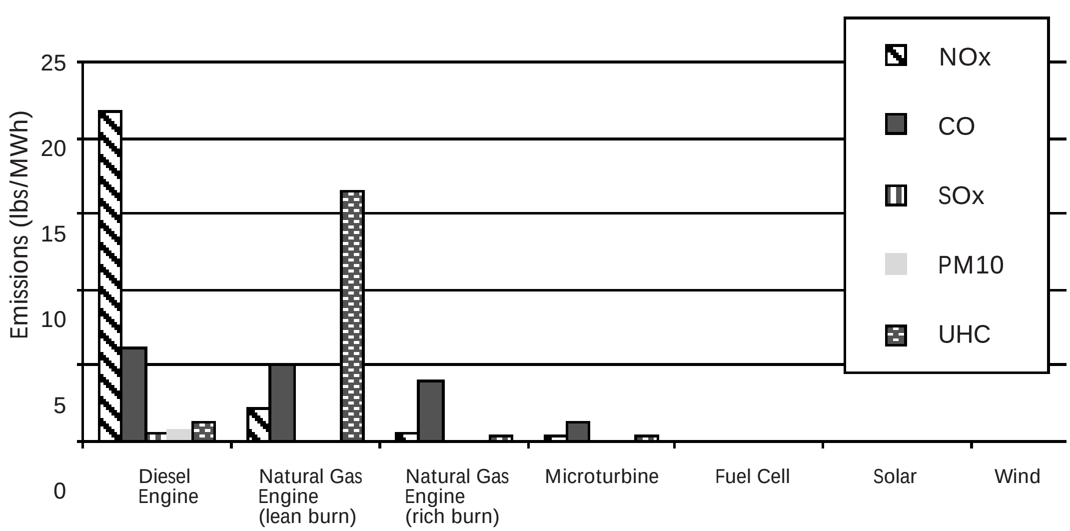
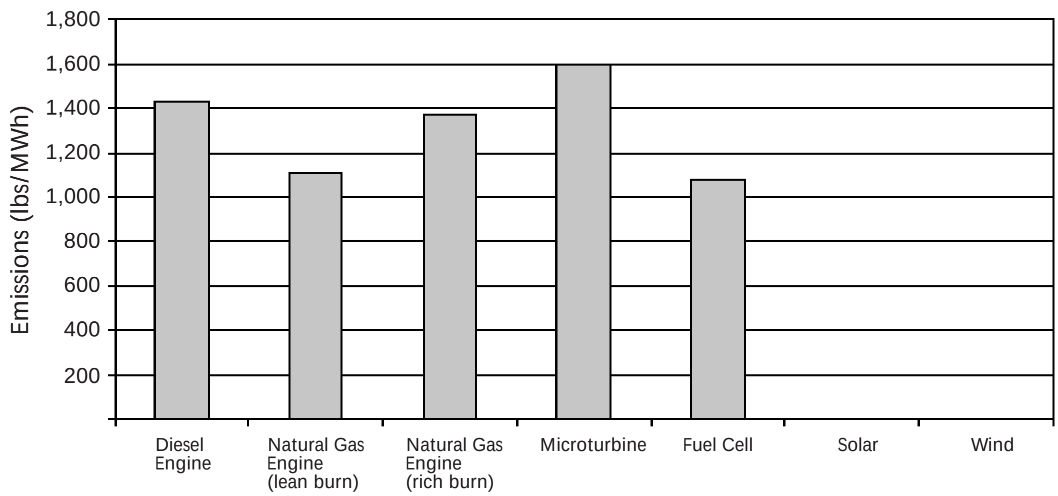


**Figure 2: Carbon Dioxide Emissions from Micropower Technologies**[7]




high-efficiency combined heat and power systems can significantly reduce negative impacts.

**Dirty Micropower** – The dirtiest and best-known technologies, using fossil fuel sources. Diesel generation is the most prevalent technology, but there are also gasoline and natural gas engines that are excessively polluting. These forms of power generation undermine public health and cause disease.

**New Micropower** – Emerging technologies have the potential to deliver cleaner power. Options such as alternative fuels and micro-turbines hold promise for the future. The health impacts of these forms of power generation vary.

On-site power generation in itself is no panacea for the problems plaguing the energy market. If the rush to micropower is a rush to the most available and least expensive technology, then some of the problems – including increased pollution, inefficient energy production, costs tied to non-renewable fuels, and growing public health problems – will be perpetuated.

The technology is available to avoid those pitfalls and to promote efficient and increasingly cost-effective micropower that can benefit the environment, the reliability of the electricity system, and public health. Some of the potential advantages of clean micropower include:

- Power doesn't have to travel long distances over the grid, reducing energy loss and the need to build new power lines.
- Wind and solar technologies are fueled by renewable energy sources.
- Generation at point of use allows for the utilization of waste heat for other energy needs.
- Local generation can enhance the reliability of the electricity system by reducing the burden on the grid.
- Fewer large, central-station power plants will be needed as micropower increases.
- The potential for large-scale blackouts is reduced.
- Local control of energy sources allows increased responsiveness to local concerns.
- Power sources can be built to appropriate scale for local consumption.

The vast majority of micropower units currently operating in Massachusetts are diesel generators. Diesel generators release as much as 363 times more smog-forming pollutants than the most efficient natural gas power plant technologies.[8] These pollutants have been shown to increase the risk of serious health problems ranging from headaches and nausea to asthma complications and lung cancer.[9]

The opportunity to end this threat to public health is at hand if we use emission standards and policy incentives for distributed generation to push newer technologies to the forefront.

# The Cleanest Micropower Technologies

Solar and wind technologies have been proven effective for local power generation throughout the country. With free fuel, advanced technology, and incentives provided by the state, these technologies are becoming more cost effective and cost competitive.[10]

Recently the power industry has made substantial advances in fuel cell technologies and in using combined heat and power systems to increase energy efficiency. Public agencies, small and large businesses, and individual homeowners are taking advantage of these advancements to install localized and independent power generation capacity.

These clean technologies are not without their environmental impact, but they substantially reduce the environmental impacts of electricity generation.

## Solar Photovoltaics

Many people mistakenly believe that solar power can only be harnessed effectively in the Southern and Southwestern states, but solar PV is a valuable resource for Massachusetts as well. The state's solar potential is excellent, and solar power generation peaks at the same time that energy demand peaks – in the heat of summer afternoons.

Photovoltaic technology converts sunlight directly into electricity without using any moving parts. The basic building block is the photovoltaic cell, which is made of semiconductor materials. Cells can be connected together to form modules, and modules can be connected to form arrays. A few PV cells will power a hand-held calculator, while interconnected arrays can provide electricity for a remote village or serve as a power plant for a city. PV is a truly unique technology with many advantages. According to the U.S. Department of Energy, "it is easy to foresee PV's 21st century preeminence."[11]

Although PV panels only generate electricity when the sun is shining, connection with the grid makes it possible to depend on PV, both from the consumer and the state planning perspectives. On hot days, when electricity consumption is at its peak, PV panels feed excess electricity into the grid. In the evening when the sun is down and electricity demand is lower, customers draw electricity from the grid. Recent improvements in "net metering" – in which the electricity meter runs backward when power is being fed into the grid – have made this much more practical for consumers.

### Advantages of Photovoltaic Technologies

- Simplicity – With no moving parts, operation and maintenance costs are minimal.
- Versatility – PV can connect to the existing infrastructure of the utility grid and serve as an alternative power source during peak periods of power demand or it can operate remotely (off the utility power-line grid). Many PV systems are easily transported. PV can also be scaled according to the amount of power needed.
- Reliability – First developed for U.S. man-made satellites in the 1950s – where low maintenance was an absolute necessity – and now with over 40 years of technical advancements improving performance, PV has very high online availability.[12]

- Peak Output – PV power output peaks when demand peaks.
- Quiet – PV systems make no noise.
- Sustainability – PV shares the two advantages common to all renewable energy sources: it has a low environmental impact (it is nonpolluting) and the fuel is free.

Solar PV has zero operating emissions. Therefore, solar PV is exempt from all air quality permitting requirements.

## Wind

Wind turbines are an excellent local power generation option for many Massachusetts residents and businesses. A wind turbine consists of a rotor, an electrical generator, a speed control system, and a tower. When the wind blows and spins the propellers of the turbine, which are akin to airplane propeller blades, the kinetic energy of the wind is converted to mechanical power, which in turn drives the electrical generator and produces an electrical current.

### PV in Cambridge

Gravestar, a Cambridge real estate developer that owns and operates shopping centers, installed a 20 kW photovoltaic array in 1999 as part of a $13 million redevelopment project at the Porter Square Shopping Center in Cambridge.

The Porter Square project included the renovation of an existing strip mall with an addition that houses a pharmacy and health-fitness center. The 20 kW photovoltaic array, consisting of 80 ASE 300 DGF/50 modules, was installed on top of the existing structure.

The annual energy production of 22,000 kWh of energy is applied to site lighting and common areas. This leads to annual savings of approximately $2,200. The system also offsets approximately 31,000 pounds of $CO_2$, 160 pounds of $SO_2$, and 50 pounds of $NO_x$ each year.[13]

The panel location, along the south front with a 35 degree tilt, makes the system more visible from the street and parking areas in order to increase its educational value.

The shopping center also has an educational kiosk in the common area. Using a touch screen, visitors can find valuable information about how the system works, how much energy is produced, and other photovoltaic facts.[14]

Photo by Gravestar

Most people are familiar with these turbines when they are grouped together in a wind farm and operate like a conventional power plant, feeding electricity to the utility grid. But small turbines can be installed and operated individually to satisfy the electrical needs of a home or business, just as they were on farms for hundreds of years.

Individual turbines vary in size, ranging from about 30 feet high with propellers between 8 and 25 feet in length to 40 stories high with propellers over 300 feet in length.[15]

Single home-sized wind turbines in the 10-50 kW range are becoming more popular in many places. Since they don't need as much wind as the larger turbines, they can be effective in more areas.

## Advantages of Wind Technologies

- Simplicity – Operation and maintenance costs are minimal. Modern wind turbines require maintenance checks only once every six months.[16]
- Versatility – Wind turbines can connect to the existing infrastructure of the utility grid or can operate remotely (off the utility power line grid).
- Reliability – Wind power is the fastest growing energy source worldwide and its proven reliability has much to do with its success.[17] Small wind systems are designed to operate for at least 30 years.[18]
- Sustainability – Wind-generated power shares the two advantages common to all renewable energy sources: it has a low environmental impact (it is nonpolluting) and the fuel is free.
- Quiet – Modern wind turbines are much quieter than combustion turbines.

### Wind Power in Hull

The town of Hull recently turned to wind power, embracing its past while moving forward into a clean future. The town, 20 miles southeast of Boston on a peninsula between the Atlantic Ocean and Boston Harbor, installed a 660 kW Vestas V-47 wind turbine in 2001 on a site that was home to a windmill long ago. The 150-foot white tower, with 90-foot blades, is now the largest wind turbine on the East Coast.[19]

The turbine supplies enough energy to power the town's 1,000 streetlights and 14 traffic lights. This alone saves the local taxpayers $60,000 a year.[20]

The turbine produces approximately 1.5 million kWh per year, the equivalent of supplying power to 200-250 homes.[21]

The town is one of 18 recipients of the U.S. EPA's Environmental Merit Award in 2002. Hull was selected from a pool of 90 nominations that year. This award, which has been given out since 1970, honors specific individuals or communities that demonstrate a strong commitment to preserving the local environment.

Photo by Hull Wind Project

Wind technologies have many of the same advantages as solar photovoltaic technologies. Like solar PV, wind has zero operating emissions. Wind turbines are therefore exempt from all air quality permitting requirements.

## Fuel Cells

Where solar photovoltaics or wind turbines are not feasible, fuel cell technologies are a good local power generation option, especially when operated in combined heat and power applications. (See below for more about combined heat and power.) Although they now use fossil fuels to create hydrogen, fuel cells emit far less pollutants than diesel and most other fossil fuel generators. Emissions from current cells are primarily CO2 and water. With further development they will be able to utilize renewable energy to produce their hydrogen fuel.

Through the chemical reaction of combining hydrogen and oxygen to make water, fuel cells convert chemical energy into electricity and heat without combustion. They operate similarly to batteries. Both batteries and fuel cells utilize an electrolyte separated by an anode and a cathode to generate a direct electrical current, and both can be combined into groups to increase power output.

Batteries store their fuel, then periodically run down and require recharging. Fuel cells, on the other hand, are fed a continuous supply of fuel. The varying types of fuel cells all rely on hydrogen as their fuel, but they can get it from a variety of sources.

Four different types of fuel cells – the Phosphoric Acid Fuel Cell (PAFC), the Molten Carbonate Fuel Cell (MCFC), the Proton Exchange Membrane (PEM), and the Solid Oxide Fuel Cell (SOFC) – have been or are operating in 16 countries, and several more types are being developed and tested.

Fuel cells are being developed for use in both vehicles and stationary applications. These applications include power for individual facilities such as hospitals, office buildings, and schools; primary power sources for remote villages and campgrounds; utility power plants; and power sources for temporary needs such as construction sites. As distributed electrical generation becomes more widespread, fuel cells could serve as primary power and thermal energy sources for virtually anything.

Most fuel cells are named for their electrolyte, and they each have different properties, capabilities, fuel requirements, and emissions. For example, the PAFC that is commercially available today is offered in the 200 kW size, though it is technically able to operate in the range of 50 kW to 11 MW. The PAFCs in operation today use either natural gas or propane, but could also be fueled by methane, alcohols, landfill gas, or anaerobic digester gases.

Because of the low emissions of fuel cells, Massachusetts has granted an exemption to PAFCs using natural gas from all air quality permitting requirements in the state.

In the future, renewable energy sources may be widely used to generate the hydrogen needed to power fuel cells. Sunline Transit has a new hydrogen generation facility powered by wind and solar energy.[22]

### Advantages of Fuel Cell Technologies

- Low emissions – Fuel cells emit fewer pollutants than any other fossil fuel-based micropower technology.
- Quiet – Fuel cells are quiet.
- Versatility – Fuel cells are modular in design; so they can be stacked to increase power output.
- Simplicity – With few moving parts, fuel cells are low-maintenance.

### CAPE COD FUEL CELL

Cape Cod will soon be home to a fuel cell of the latest commercial technology at the Coast Guard Air Station in Bourne. The 250 kW Direct Fuel Cell is expected to be installed by Fall 2002.[23]

The fuel cell will operate on natural gas. The energy produced will be used to heat water for station personnel both in the barracks and the galley. Facility managers hope that excess heat from the fuel cell will be used to heat the building in the future. The initial reduction in utility bills is projected to be $50,000 per year.[24]

The fuel cell is projected to be 70% efficient, generating 230 kW for the first two years. In two years the plant's stack is scheduled for replacement in order to take advantage of newer technology. After that upgrade the plant is expected to generate 300 kW or more.

Since the mission of the air station is search and rescue, it is particularly important to have power during heavy storms. The Coast Guard determined that the fuel cell would be the most dependable power source for that purpose. It will help support four H60 Jayhawk helicopters and four H25 Falcon jets.[25]

The most significant feature of the Bourne facility is the use of a molten carbonate fuel cell. Molten carbonate fuel cells are a cutting edge fuel cell technology because they have been developed to capitalize on energy efficiency and essentially operate without generating pollution. The Bourne plant is among the first few of these cells to be installed in the United States.[26]

This project is made possible by the joint effort and financial backing of both government and private business. The U.S. Department of Energy Technology Lab, the Massachusetts Renewable Energy Trust, and Keyspan Inc., a natural gas supplier, made it possible for PPL Spectrum and Fuel Cell Energy to create this plant.

Photo by Fuel Cell Energy

- Flexibility – Fuel cells can use different fuel sources since they only need hydrogen and oxygen.
- Reliability – Fuel cells are online a greater percentage of the time than large power plants.

### CHP AT MALDEN MILLS

Malden Mills, in Lawrence, is no stranger to the media spotlight. The mill first received attention in 1995 when a fire destroyed three of its buildings. CEO Aaron Feuerstein gained national acclaim when he decided to rebuild the company while keeping his employees on the payroll.

Now Malden Mills, manufacturer of Polartec fabric, is back in the news. The company was presented with a 2000 Energy Star Combined Heat & Power Certificate, sponsored by the U.S. EPA and the U.S. Department of Energy. The award is given to leaders who increase electric generation efficiency with the use of combined heat and power programs.

Photo by Malden Mills

When Malden Mills began operating its new CHP facility in 1999, then-Secretary of Energy Bill Richardson was on hand to dedicate the facility, along with other dignitaries. Richardson said, "The cogeneration power system we dedicated today will produce energy for the factory while virtually eliminating sulfur dioxide emissions, reducing nitrous oxide emissions by 75 percent, and cutting carbon dioxide emissions by 25 percent. This will make Malden Mills a model of energy efficiency and environmental responsibility."[28]

Malden Mills installed two 4.3 MW turbines, manufactured by Solar Turbines, which use fiber ceramic combustion liners. The liners were specifically developed to decrease NOx emissions by at least another 40%. The two turbines combine to produce enough energy to supply 4,000 homes with power.[29]

The facility at Malden Mills provides electricity for the plant. The mill maintains its connection to the Massachusetts Gas & Electric grid as a back-up energy source in case of turbine failure.

The cogeneration system was developed in partnership with the Department of Energy.

## Combined Heat and Power

Combined heat and power (CHP) is not a specific generating technology but rather an application of technologies to meet end-user needs for heating or cooling as well as mechanical and electrical power.

Recent technology developments – particularly in turbines and microturbines – have made small-scale CHP systems more cost-effective and reliable. When properly designed, fossil fuel-based generators can dramatically increase their efficiency through modification into CHP systems.

In CHP systems, the heat that is normally released as waste heat is instead recovered and used to heat water, rooms and buildings and/or drive motors for air conditioning or refrigeration. CHP systems can also use waste heat to provide steam to generate more electricity, like "cogeneration" at large power plants. Combined heat and power systems can be employed in many commercial and industrial facilities where there is a relatively constant thermal need.

Recovering and reusing waste heat in this manner can make generators more than 80% efficient, more than double the 33% average efficiency of conventional electricity generating systems.[27] The increased efficiency saves the extra fuel that otherwise would be necessary to operate heating systems – often replacing old, inefficient and dirty boilers.

Increased fuel efficiency translates directly into reduced emissions of greenhouse gases and other pollutants. NOx, which forms smog, and CO2, the principal global warming pollutant, are significantly reduced. Combined heat and power systems also reduce SO2 emissions, precursors to acid rain, and particulate matter, a cause of chronic lung disease.

Because it is still based on burning fossil fuels, CHP is not sustainable energy production on the level of wind and solar. But as long as fossil fuels are used to drive generators, CHP should be widely encouraged as a very good improvement over less efficient technologies.

## Advantages of CHP Systems

- Efficiency – Increases efficiency of fuel use by capturing waste heat for heating, cooling and other on-site energy requirements.
- Flexibility – Can be designed to deliver multiple energy services.
- Reliability – Advanced technology and local control enhance service delivery.
- Improved Environmental Performance – Produces lower emissions than conventional separate systems.

## *Key Recommendations for Clean Micropower*

Electricity generation has always had serious negative impacts on air quality. We now have the opportunity, however, to generate our power with minimal environmental consequences. State agencies must do all they can to encourage the widescale implementation of clean technologies, as they simultaneously encourage energy users to consume energy as efficiently as practical. Recommended policy actions include the following.

- Require formal consideration of clean micropower as a potential least cost alternative to transmission and distribution upgrades and a means of avoiding the cost of future environmental regulation.
- Incorporate efficiency in emissions standards to credit the efficiency advantages of combined heat and power.
- Expand the availability of financial incentives, including buy-down programs, tax credits, and grants, for the installation of clean forms of micropower.
- Develop incentive tariffs and reduced standby and exit fees for clean micropower installations.
- Streamline the permitting and utility interconnection process for clean micropower installations.
- Expand funding for clean micropower technology advancement.
- Provide incentives for developers to include clean micropower at new residential or commercial construction projects.
- Establish requirements that all new residential and commercial construction be "solar-ready" with the basic infrastructure to ease future installation of photovoltaic panels.

# The Dirtiest Micropower Technologies

The internal combustion engine (ICE), the traditional technology used in vehicles, is also the predominant technology for portable and stationary generators. Also called reciprocating engines, ICEs can use a variety of fuels, including diesel, gasoline, natural gas, and propane. Diesel is the most common fuel for ICEs used as micropower.

## Diesel Generators

Although there are now many competitive technologies available for micropower, diesel generators have historically dominated the micropower market. This form of micropower has also been the most cost effective for consumers, largely because the public health and environmental costs of burning diesel fuel are not accounted for in the cost of generation.

The diesel generator is also the most polluting form of micropower. Many people are familiar with the black plumes of smoke released by diesel trucks and buses. Diesel generators are no different. The harmful health effects of diesel exhaust have been studied and well documented for decades. Because many diesel generators are located in dense urban settings, this technology significantly increases the public's exposure to cancer-causing pollutants.

### Quantifying the Problem

Diesel generators are widely used throughout Massachusetts, providing power for everything from businesses to agricultural equipment to homes. Diesel generators are found in the basements of office buildings or powering lights used during freeway construction. However, no accurate inventories of diesel generators have been made.

The DEP maintains a database that includes electric generators called the Stationary Source Emission Inventory System (SSEIS). Facilities that burn more than 10 million Btu/hr of energy must register with this system, covering only the largest distributed resources.

The SSEIS database contains records of 760 fossil fuel-based micropower units in Massachusetts. 77% of these are powered by diesel. (See Table 2.)

Estimates based on data from other states indicate that this is likely to vastly understate the prevalence of diesel generators in Massachusetts. The California Air Resources Board (CARB) has made the best attempt among state air quality agencies to quantify diesel generator ownership. CARB estimates that there

**Table 2: Fossil Fuel-Based Micropower Units Registered in Massachusetts[30]**

| Fuel | Number of Generators | Emissions (tons/yr) | | | | |
|---|---|---|---|---|---|---|
| | | $NO_X$ | $SO_2$ | PM 10 | CO | VOC |
| Diesel/Oil | 583 | 407 | 53 | 24 | 175 | 208 |
| Natural Gas | 159 | 621 | 12 | 45 | 322 | 125 |
| Kerosene/Jet Fuel | 4 | <1 | <1 | <1 | <1 | <1 |
| Propane | 9 | <1 | <1 | <1 | 1 | <1 |
| Gasoline | 5 | 1 | <1 | <1 | 28 | 1 |
| **Total** | **760** | **1,030** | **65** | **69** | **526** | **334** |

are a total of 65,382 diesel generators in California. Assuming an equal number of diesel generators per capita in Massachusetts, this equates to 5,638 diesel generators in the state. (See Table 3.)

If all generators in the state emit pollutants at the same average rate as the actual average emissions of the generators in the SSEIS database, 5,000 diesel generators in Massachusetts would emit 3,500 tons of NOx, 460 tons of SO2, 200 tons of PM10, 1,500 tons of CO, and 1,800 tons of VOCs. While this is a rough estimate of statewide emissions based on an incomplete database, these numbers are large enough to indicate that diesel generators are a significant source of pollution that demand regulatory attention.

Diesel generators are used in a variety of ways, with three general categories of use:

**Emergency standby generators** – Often referred to as "back-up generators" or BUGs, these are generators that operate on a temporary basis as back-up power supplies in the event of power outages.

**Prime generators** – Generators used on a regular basis to supplement energy from the power grid.

**Portable generators** – Generators that are moved from location to location to provide power (motor vehicles and engines used to propel equipment directly are not considered portable generators).

The more hours a diesel engine operates, the more pollutants it releases into the air we breathe. For example, emergency back-up generators in normal operation are generally used only 25-50 hours a year while prime engines operate anywhere from 100 to several thousand hours per year. Hence, although there are far more emergency generators in Massachusetts, prime engines are a larger source of diesel pollution in the state due to their longer hours of operation.

Currently, diesel generators are regulated differently depending on how they are used. The result has been confusing and inconsistent standards for not only diesel generators but for all micropower. This needs to be improved by developing standards that are based on environmental and public health impacts.

**Table 3: Estimated Diesel Generators in Massachusetts[31]**

| Diesel Generators by Type of Use | Number in Massachusetts |
|---|---|
| Emergency Stand-by Generators | 2,126 |
| Prime Generators | 331 |
| Portable Generators | 3,180 |
| **TOTAL** | **5,638** |

## Emissions

Diesel generators are a significant source of air pollution in the state of Massachusetts and nationwide.[32] As diesel fuel burns, over forty identified toxic air contaminants are released into the air we breathe. The primary pollutant is nitrogen oxides, which can cause lung function deterioration and other serious human health effects. Additional pollutants include carbon monoxide, carbon dioxide, sulfur oxides, and volatile organic compounds. See Table 5 for a description of the health and environmental effects of these pollutants.

Emissions from diesel generators can have a large impact on ambient air quality at times of heavy use. This can be a

**Table 4. Estimated NOx Emissions from Diesel Generators in Metro Boston During Peak Use[34]**

| Estimated Number of Diesel Generators | Estimated Capacity of Diesel Generators (MW) | NOx Emission Rate (lbs/MWh) | NOx Emissions (tons/day) |
|---|---|---|---|
| 1,237 | 408 | 21.8 | 2.7 |

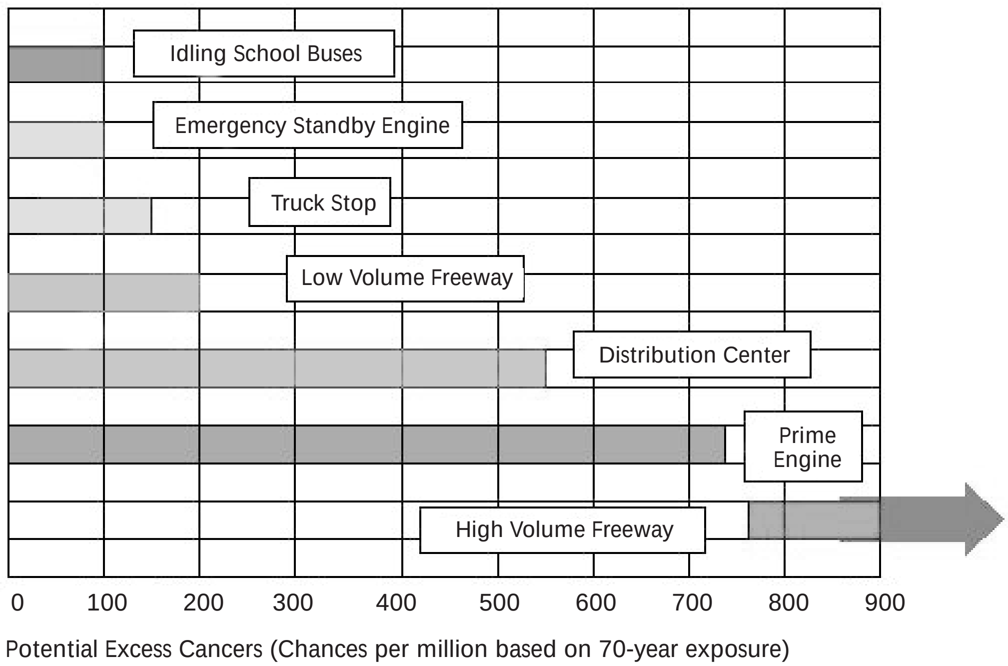
**Table 5: Description of Emissions**

| Name of Pollutant | Abbreviation | Source and Environmental Impacts | Health Impacts |
|---|---|---|---|
| Carbon Monoxide | CO | CO is produced by burning organic matter such as fossil fuels, wood and charcoal. Motor vehicles produce 67% of the man-made CO that is released into the atmosphere. | Fatigue, angina, reduced visual perception and dexterity, death in closed space. |
| Carbon Dioxide | $CO_2$ | $CO_2$ is produced by burning organic matter such as fossil fuels, wood and charcoal. $CO_2$ is a greenhouse gas. | Major contributor to global warming, which has been linked to an increase in the spread of disease. |
| Nitrogen Oxides | NOx | Oxides of nitrogen are the chemicals responsible for giving smog its brown appearance. NOx contributes to the formation of ozone, production of particulate matter pollution, and acid rain. | Irritates lung tissue, causes bronchitis and pneumonia, has been linked to a decrease in lung function growth. |
| Particulate Matter | PM | Particulate matter consists of soot and dust particles that are smaller than the diameter of a human hair. Electricity generation, transportation and industry generate roughly equivalent proportions of PM. | Penetrates deep into the lungs and is associated with numerous respiratory and cardiac problems and cancer. |
| Sulfur Oxides | SOx | Oxides of sulfur are produced by the burning of fossil fuels. Large emitters of SOx include motor vehicles, refineries and power plants. SOx contributes significantly to acid rain. | Reduces respiratory volume, increases breathing and nasal airway resistance. |
| Volatile Organic Compounds | VOC/UHC | VOCs are a class of reactive organic gases that contribute to the formation of ozone and smog. Motor vehicles, refineries and power plants are the primary source of VOCs. Levels of VOCs are often determined by measuring unburned hydrocarbons (UHC). | Coughing, fatigue and nausea; contributes to the inflammation of lung tissue and reduced lung capacity. |
| Air Toxics | | Air toxics like benzene, toluene, and formaldehyde are formed from fossil fuel processing and combustion. The U.S. EPA has identified 188 chemicals as hazardous air pollutants. | Cancer, reproductive disorders, developmental disorders. |

major factor influencing attainment with air quality standards. Hot summer days, when air problems are at their worst, are the most likely time that micropower will be in operation to boost an electricity load that is heightened by the heavy use of airconditioning. In other words, diesel generators put out their highest levels of pollution exactly when air quality is the most sensitive to increases in pollution.

Since there has not been any requirement for registering most diesel generators or any statewide inventory of diesel generators, it is not possible to measure this impact with precision. However, estimates can give us a good picture of how big a problem this is likely to be. Assuming the same number of diesel generators per capita in Massachusetts as have been counted in California, and

**Figure 3: Potential Cancer Risk from Activities Using Diesel Fueled Engines**




assuming that the average size of these generators is 330 kW,[33] 20% of these generators operating for three hours on a day of tight electricity supplies in Boston would emit 2.7 tons of NOx. (See Table 4.) This amount of pollution could push the city into non-compliance with clean air standards.

## Health Impacts

The extended use of diesel generators can result in serious human health implications, especially since most non-agricultural diesel generators are located in densely populated urban areas. Where large numbers of people are, so too are these under-regulated, high-emitting engines that spew smog-forming chemicals, fine particles, and known cancer-causing agents.

This can create significant health risks for entire neighborhoods. People living within 10-20 average city blocks of a diesel generator operating only 100 hours per year experience elevated mortality risks.[35]

## Cancer Risk

In recent years, an increasing number of health organizations, as well as the U.S. EPA and state environmental agencies, have recognized the cancer-causing effects of diesel exhaust exposure.[36] Air pollution control officials now estimate that based on a lifetime risk of seventy years exposure, diesel exhaust may be responsible for over 125,000 cancer cases each year nationwide, including 2,900 in Boston.[37]

The cancer risk from an emergency standby engine is equivalent to that of an idling school bus. The cancer risk from prime engines (including non-agricultural engines and agricultural engines) is more than that of a low-volume freeway or that of a facility that has constant diesel truck traffic. Both current diesel back-up generators and prime engines substantially surpass the acceptable risk level of one in a million cancer cases established by the U.S. EPA.

The California Air Resources Board has estimated that a person's lifetime cancer risk increases by 50% if he or she lives near a single one-megawatt diesel generator that runs for as little as 250 hours annually.[38] Another California study found the cancer risk in five cities to be 70-140 times higher than commonly accepted levels in the most affected neighborhoods.[39]

### Non-Cancer Health Risks

Diesel exhaust is also known to cause numerous non-cancer respiratory problems. Diesel is a major source of particulate matter (PM), or soot, which can lodge deep in the lungs and result in the exacerbation of asthma, respiratory infections, increased susceptibility to allergens, chronic obstructive lung disease, pneumonia, and heart disease. A recent study found that even short-term exposure to PM may increase the chance of heart attacks in at-risk populations.[40]

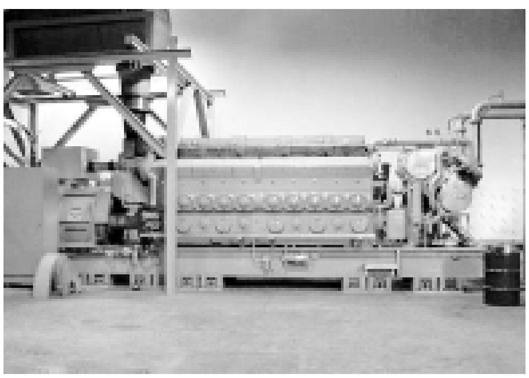


Photo by High Frequency Active Auroral Research

Diesel exhaust also contains nitrogen oxides (NOx). NOx in the presence of sunlight and volatile organic compounds forms smog. Recently, the USC Keck School of Medicine found in a long-term study that both NOx and PM can permanently reduce the lung function of a child living in Southern California by as much as 10%. Diesel exhaust was believed to be a significant contributor.[41]

Many other toxic substances are found in diesel exhaust. More than 40 components of diesel exhaust are listed as hazardous air pollutants by the U.S. EPA.[42]

## Other Fossil Fuel Internal Combustion Engines

### Natural Gas Engines

Internal combustion engines fueled by natural gas are cleaner than diesel generators, but still have high emissions of dangerous air pollutants. Natural gas generators have large reductions in NOx and SOx compared with diesel generators, medium reductions in PM and CO2, and minimal reductions in CO and VOCs.

Natural gas engines are offered with two tuning settings – rich burning (stoichiometric) or lean burning (in which the air/fuel ratio is increased). However, the choice is a trade-off of lowering emissions of one pollutant while increasing those of another. The low emission tuning will reduce NOx and hydrocarbon emissions, but increase CO2 emissions. All other

**Table 6: Emissions of Diesel and Gas Micropower and Large New Power Plants (lbs/MWh)[43]**

| Generator Type | Efficiency | NOx | CO | $SO_2$ | PM10 | UHC | $CO_2$ |
|---|---|---|---|---|---|---|---|
| Diesel Engine | 38% | 21.8 | 6.2 | 0.5 | 0.8 | 1.2 | 1,432 |
| Natural Gas Engine (lean burn) | 36% | 2.2 | 5.0 | 0.01 | 0.03 | 16.5 | 1,108 |
| Natural Gas Engine (rich burn) | 29% | 0.5 | 4.0 | 0.01 | 0.03 | 0.4 | 1,376 |
| Combined Cycle Natural Gas Power Plant | 51% | 0.06 | 0.1 | 0.004 | 0.04 | 0.05 | 776 |

emissions are similar between the two tunings.[44] Natural gas generators still contribute significantly to the same environmental and health impacts described in Table 5.

### Engines Using Other Fossil Fuels

ICEs can also use gasoline, propane, and kerosene as fuel. Though not as common as diesel and natural gas generators, such generators are commercially available.

Emissions levels from gasoline-fueled ICEs fall between those of natural gas and diesel-fueled generators. Gasoline generators are the cheapest generators on the market, but have a reputation of high maintenance requirements as compared to generators using any of the other fossil fuels.

Propane generators emit very similar amounts of pollutants as the natural gas generators.[45]

## Improving Engines for Emergency and Portable Use

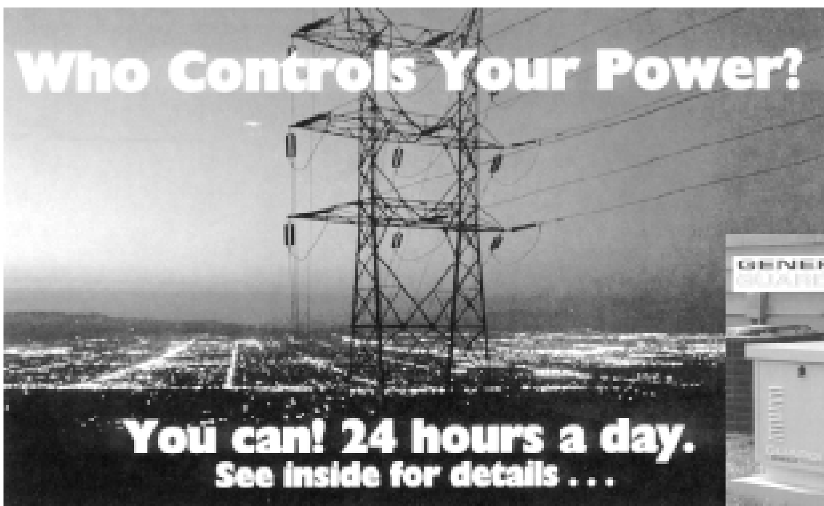
Due to the severe public health and environmental hazards associated with ICE generators, their use should be limited to emergency back-up generation and portable operations, and then only when operated in conjunction with emission-control measures. The pollution-reducing measures that can reduce the harmful impact of diesel generators on nearby communities include fuel advancements, control technologies, improved efficiency, and stringent operations standards.

- Fuel Advancements – The U.S. EPA recently adopted regulations requiring petroleum producers to distribute low-sulfur diesel (15 ppm sulfur content) nationally by 2006 for vehicle use. This rule should also apply to off-road diesel use. Massachusetts should institute this requirement on its own. Because most advanced diesel pollution control devices are sulfur-sensitive, such steps to require low-sulfur diesel are essential to achieve further emissions reductions for diesel engines.
- After-Treatment Technology / Emission Control – Particulate traps physically capture particulate matter in a filter and can reduce PM emissions by 83%.[46] Selective catalytic reduction (SCR) uses ammonia as a catalyst to break down NOx. SCR systems have been shown to reduce NOx by 65% to 99%.[47] Nitrogen oxide adsorbers have the potential to reduce NOx by 90%. This technology involves both a chemical catalyst and burning the filter clean. Even with these improvements, however, diesel and other fossil fuel generators are still dirtier than the good micropower technologies discussed earlier.
- Increased Efficiency – The efficiency of ICE generators can be improved by ensuring proper installation and sizing. Improper installation can account for a 25% loss in efficiency. Another way to improve efficiency is to capture and reuse the generator's heat. The waste heat produced by the generator can be recovered to provide energy for further electricity production or space and water heating. This can reduce emissions by 35 to 50%.
- Hours of Use – Reducing the operating hours of ICE generators will also reduce the amount of pollution that is released into the air we breathe.

### *Key Recommendations for Dirty Micropower*

The Massachusetts state government has an obligation to protect the state's air quality. Since the move to local power generation has partly involved an increased reliance on the most polluting forms of electricity generation, state agencies should take steps to discourage the use of dirty micropower. This would include the following measures.

- Require that all micropower units operated in Massachusetts receive certification or permits as a condition for being connected to the electric grid.
- Provide incentives for the trade-in and upgrade of polluting micropower installations.
- Require that transmission grid operators draw on clean, efficient micropower before similarly priced dirty installations.
- Require ultra low-sulfur diesel for all diesel engines in Massachusetts, on and off-road.
- Establish a clear and limited definition of "emergency use."





Manufacturers and distributors of diesel generators used the "energy crisis" to encourage consumers to purchase polluting home power systems.

# New Micropower Technologies

New technologies for generating local power are emerging in the marketplace. Although they are not as clean as the renewable energy sources, most of these alternatives are distinct improvements over current diesel generators. By phasing in stringent standards regardless of technology, state officials will push manufacturers to improve these technologies to limit harmful emissions.

Some of these micropower options can be used in combined heat and power applications. They are not as simple to operate and maintain as sustainable options such as wind and solar, but they are often versatile and reliable. Most available technologies utilize carbon-based fuels. While they pollute less than diesel engines, they still emit harmful gases.

## Alternative Fuel Reciprocating Engines

The reciprocating engine, or internal combustion engine, is the traditional engine used in vehicles and diesel generators, as noted above in the "Dirtiest Micropower" section. This system draws air into a cylinder, compresses the air to heat it, then injects fuel, which ignites when mixed with the hot air. The resulting explosion moves the piston. It is an open system, meaning that it does not reuse the air it draws in; instead it releases it into the atmosphere as exhaust heat and gases.

Stationary reciprocating engines, like the diesel generator, are typically 5 MW or less, with the 1-3.5 MW range being the largest growing segment recently.[48]

When fueled by traditional fossil fuels, these engines are the most polluting of the micropower options. When operated with alternative fuels, however, their emissions can be reduced. See Appendix A for information on alternative fuels.

## Turbines

A gas turbine differs from the reciprocating engine in that it uses a continuous combustion process rather than intermittent combustion. Like a reciprocating engine, the basic gas turbine is an open system, but it can be modified to reuse its exhaust heat. Exhaust treatment technologies can reduce NOx emissions significantly, and some manufacturers are now incorporating similar technology into the combustion process itself.[49]

Gas turbines have traditionally been manufactured to generate several hundred megawatts for use as central power plants. Now some manufacturers are scaling down their units to less than 30 MW.[50] Most new turbines are fueled by natural gas. Some can also use other petroleum fuels or a dual-fuel configuration.

## Microturbines

Introduced over the last few years, the microturbine has a rapidly growing market. Based on the same technology as a jet engine, although much reduced in size and improved with advanced components and software, microturbines can provide power in the 25 kW to 500 kW range. The initially available commercial units generate power ranging from 28 kW to 75 kW. These smaller units are about the size of a refrigerator.

The turbine shaft of a microturbine spins as fast as 100,000 rpm. The high-frequency power generated is then converted to 60Hz for common use. This simple design lends itself well to the low-maintenance needs of distributed generation.[51]

Microturbines have the potential to operate on a variety of fuels. Manufacturers, with some support from federal and state agencies, are working to improve microturbine performance, including generation efficiency. Models built to date have lower efficiency, and thus higher CO2 emissions, than traditional engines.

In addition to their small physical size and flexibility regarding fuel sources, microturbines have only one moving part and, therefore, low maintenance costs. They are highly suitable for combined heat and power applications.

Microturbines' advanced fuel combustion technology results in low NOx emissions, without any emission control technology, in comparison with gas-fired central station plants. Early tests indicate that this emissions performance will be maintained over extended operating periods. Capstone Turbine Corporation claims that current units emit NOx at the rate of 0.50 lbs/MWh, and projects that performance improvements will decrease NOx emissions to 0.14 lbs/MWh by 2005 and 0.05 lbs/MWh by 2008.

## Stirling Engines

Stirling engines are powered by the expansion of a gas that results when the gas is heated and the compression of a gas that results when the gas is cooled. In this closed cycle system, a fixed amount of gas is externally heated, usually by combustion, and as it expands and contracts, it moves the pistons.

Theoretically these engines can use any heat source. Currently systems are being developed that use biomass, woodchips and solar heat. Stirling engines are physically smaller than conventional engines and relatively quieter. Engines ranging from 500 watts to 10 kW are either available now or under development.

Emissions associated with Stirling engines vary according to the heat source used. The Stirling engine itself has no emissions, so when it is developed to use solar heat as the heat source, the entire system will be emission-free. When fossil fuels are burned to provide the heat source, there are emissions. Since the combustion takes place externally, it can be monitored to burn fuels completely and limit the temperature, reducing emissions somewhat.

### Potential Advantages of Emerging Technologies

Technical advancements, including improvements in fuel combustion and emissions reduction equipment, have the potential to significantly reduce the environmental impacts of these micropower technologies. Federal, state and manufacturer-funded research and development programs are pursuing such improvements. Clear emissions standards will provide clear signals regarding technology performance targets, and a strong incentives policy can establish attractive market advantages for the cleanest micropower technologies.

### *Key Recommendations for New Micropower*

These technologies already show the promise of being safer for public health than the dirtiest micropower. But to make sure that they move toward the cleanest micropower technologies, we must ensure that pollution standards are applied across the board to all developing technologies, and complement the standards with policies that provide economic and other incentives to the cleanest micropower systems. State agencies should take the following actions.

- Establish priority funding for clean micropower technology advancement.

- Streamline the permitting process for clean units that meet or beat air pollution standards.
- Require that all micropower units operated in Massachusetts receive certification or permits as a condition for being connected to the electric grid.
- Ensure adequate enforcement of emissions standards and establish significant penalties for violation.

# Policy Recommendations

Micropower is here to stay, and is likely to expand rapidly in the coming years. This is both an opportunity and a risk for public health in Massachusetts. Clean micropower options have the potential to greatly reduce dangerous emissions from electricity production, but the most common micropower technology – the diesel generator – is even more polluting than the leading technologies of large central power plants.

### Principles

To ensure that public health is protected and that new technologies that reduce pollution are encouraged, micro-power policy should be based on the following principles:

- o Distributed generation must be as clean as or cleaner than the cleanest central power plant technology currently in widespread use. Regulations should target attainment of equivalent performance as soon as practical.
- o State rules and incentives must promote the cleanest energy industry for the future of Massachusetts.
- o Regulations should be as simple as possible so manufacturers can anticipate changes and comply with new technology requirements.

### Primary Recommendations

State agencies can help move micropower in the right direction. To protect the health of the people of Massachusetts and the air quality of the state while helping to assure reliable local power generation, we recommend the following

- o Set stringent emissions standards for all micropower units operated in Massachusetts.
- o Conduct a comprehensive inventory of existing micropower and other onsite generation.
- o Streamline the permitting process for clean units that meet or beat air pollution standards.
- o Ensure adequate enforcement of standards and establish significant penalties for violation.

### Additional Recommendations

In addition, many other specific policies could ensure that the move to local power generation leads to air quality benefits rather than a digression to polluting technologies. We recommend that state agencies:

*Establish standards and rules for micropower operation:*

- Require that all micropower units operated in Massachusetts receive certification or permits as a condition for being connected to the electric grid. This policy establishes a check against the operation of excessively polluting micropower systems and preferred treatment for the cleanest micropower options.
- Require that transmission grid operators draw on clean, efficient micropower before similarly priced dirty installations. Air pollution emissions should be considered in decisions regarding which generators are used in times of excess power capacity.
- Require emissions control measures for diesel generators used for emergency back-up power supply. Back-up generators will continue to be a major pollution problem if they are left out of the regulatory picture.

- Require that all new residential and commercial construction be "solar-ready" with the basic infrastructure to ease future installation of photovoltaic panels.

*Provide funding for clean micropower:*

- Require formal consideration of clean micropower as a potential least cost alternative to transmission and distribution upgrades and a means of avoiding the cost of future environmental regulation.
- Establish priority funding for clean micropower technology advancement. State research and development programs can target the most promising clean micropower technology options. Public money for the development of these technologies would be a good investment for the long-term health of the state economy.
- Expand the availability of financial incentives, including financing assistance, buy-down programs, tax credits, and grants, for the installation of clean micropower. As long as consumers are expected to shoulder the burden of the investment costs of new technology, the government should provide financial assistance.
- Provide incentives for developers to include clean micropower at new residential or commercial construction projects. Since builders don't pay the ongoing energy costs of the units they build, they are reluctant to include energy saving measures that will increase the initial sale price of their buildings.
- Provide incentives for the trade-in and upgrade of polluting micropower installations. Other states have shown this to be a cost-effective approach to reducing air pollution.

*Clear hurdles to the implementation of clean micropower:*

- Streamline the permitting and utility interconnection process for clean micropower installations. Micropower is currently at a disadvantage compared with traditional power generation due to an unnecessarily complicated interconnection process. Eliminating this disadvantage for clean micropower would promote its expansion.
- Develop incentive tariffs and reduced standby and exit fees for clean micropower installations. This would address financial disincentives in utility relationships with micropower operators.

The adoption of these recommendations will promote a vital micropower system that reduces the negative public health impacts associated with diesel and other dirty micropower technologies.

# APPENDIX A: ALTERNATIVE FUELS

Several non-traditional fuels have been developed that can replace pure fossil fuels in some combustion engines, microturbines, Stirling engines, and fuel cells. While some of these fuels may hold promise for reducing emissions from electricity generation, most of them involve levels of health risk similar to those of traditional fuels.

**Biodiesel** is a fuel that is made from vegetable oils or animal fats. This is the "bio" part, which can be used alone, but is usually mixed with conventional petroleum diesel fuel at a ratio of 20-30% "bio" to 70-80% diesel.[52] The fuel operates in a conventional combustion engine like a diesel generator. Compared to regular diesel, biodiesel has reduced emissions of CO, $SO_2$, and particulate matter, but has increased $NO_x$ and soluble $CO_2$ emissions.

**Propane**, also called Liquefied Petroleum Gas (LPG), is formed as a by-product of processing natural gas and refining crude oil. Propane usage emits no aromatic compounds, benzene or particulates. Engines that are optimized for propane have lower $CO_2$ emissions than diesel generators. Propane can be used as a substitute for diesel fuel in internal combustion engines.

**Ethanol** is made from the fermentation of sugars or starches in grains, agricultural feedstocks and agroforestry products. Ethanol is mixed with gasoline in different percentages to be used as a fuel.

**Methanol** is predominantly made from steam reforming of natural gas. It can also be made from feedstocks of coal or biomass, but currently these are not as economical. Like ethanol, methanol is mixed with gasoline to be used as a fuel. In these gasoline mixtures, both are referred to as gasohol and are designed for vehicle use.

**Biomass** describes many types of technologies to turn agricultural materials and waste into energy. Some are unacceptably harmful to the environment while others provide a net benefit to the environment. The use of biomass in fuel cells, microturbines and Stirling engines is still being researched.

**P Series Fuels** are blends of methyltetrahydrofuran (MTHF), ethanol and hydrocarbons. Currently MTHF is produced from biomass or petroleum feedstocks.

# Appendix B: Glossary

**Back-up generators (BUGs)**
Emergency power generators used to avoid potential power interruptions caused by malfunctioning power plants, natural disasters, or demand overloads on the electric grid.[53]

**British thermal unit (Btu)**
The standard measure of heat energy, equal to the amount of energy needed to raise the temperature of one pound of water by one degree Fahrenheit at sea level. It takes about 2,000 Btus to make a pot of coffee.

**California Air Resources Board (CARB)**
The regulatory agency that ensures California's compliance with the Clean Air Act. CARB has done more than any other state environmental agency to inventory micropower resources and measure their effects.

**Carbon monoxide (CO)**
An air pollutant produced by burning organic matter such as oil, natural gas, fuel, wood and charcoal. Motor vehicles produce 67% of the man-made CO that is released into the atmosphere.

**Carbon dioxide (CO2)**
A greenhouse gas, produced by burning organic matter such as oil, natural gas, fuel, wood and charcoal.

**Combined heat and power (CHP)**
A power generation system that uses waste heat to heat water, rooms and buildings; provide air conditioning or refrigeration; or provide steam to generate more electricity.

**Department of Environmental Protection (DEP)**
Massachusetts' regulatory agency that ensures compliance with the Clean Air Act.

**Distributed generation (DG)**
Energy production that occurs near the place where it is used. This term is used interchangeably with "micropower" throughout this report.

**Emergency standby generators**
Often referred to as "back-up generators" or BUGS, these are generators that operate on a temporary basis as back-up power supplies in the event of power outages.

**Fuel cell**
An energy production technology that creates electricity and heat through the chemical reaction of combining hydrogen and oxygen to make water.

**Kilowatt-hour (kWh)**
The most commonly-used unit of measure telling the amount of electricity consumed over time, equal to one kilowatt of electricity supplied for one hour. A typical household consumes 500 kWh in an average month.

**Megawatt (MW)**
One thousand kilowatts (1,000 kW) or one million watts. One megawatt is enough energy to power 1,000 average Massachusetts homes.

**Megawatt-hour (MWh)**
One thousand kilowatt-hours, or an amount of electricity that would supply the monthly power needs of a typical home having an electric hot water system.

**Microturbine**
A new micropower technology based on the same technology as a jet engine although much reduced in size and improved with advanced components and software.

**Net metering**
A system for metering electricity consumption that subtracts the amount of power fed back into the grid by a micropower unit from the amount that is drawn from the grid.

**Nitrogen oxides (NOx)**
The chemicals responsible for giving smog its brown appearance. NOx contributes to the formation of ozone, production of particulate matter pollution and acid rain.

**Particulate matter (PM)**
An air pollutant made up of soot and dust particles that are smaller than the diameter of a human hair.

**Peak load or peak demand**
The electric load that corresponds to a maximum level of electric demand in a specified time period. Peak periods during the day usually occur in the morning hours from 6 to 9 a.m. and during the afternoons from 4 to about 8 or 9 p.m. The afternoon peak demand periods are usually higher, and they are highest during summer months when air-conditioning use is the highest.

**Photovoltaic (PV) panel**
Also known as a solar panel, PVs convert sunlight directly into electricity using semiconductor technology.

**Prime generators**
Generators used on a regular basis to supplement energy from the power grid.

**Portable generators**
Generators that are moved from location to location to provide power (motor vehicles and engines used to propel equipment are not considered portable generators).

**Sulfur oxide (SOx)**
An air pollutant produced by the burning of fossil fuels. Large emitters of SOx include motor vehicles, refineries and power plants. SOx contributes significantly to acid rain.

**Volatile organic compounds (VOCs)**
A class of reactive organic gases that contribute to the formation of ozone and smog. Motor vehicles, refineries and power plants are the primary source of VOCs.

**Wind turbine**
An energy generation technology in which the kinetic energy of the wind is converted to mechanical power, which in turn drives the electrical generator and produces an electrical current.

# NOTES

1. Throughout this report, the terms "micropower" and "distributed generation" are used synonymously.

2. Micropower should not be confused with the "peaker plants" that are much in the news recently. Although both are small electricity generating plants, peakers are generators operated by utilities and independent power producers that are used only during peak demand times. They are typically 50-100 MW. Micropower units are normally not operated by utilities, and are typically in the 2 kW to 1 MW range, with some as high as 10 MW.

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