

DISTRIBUTED GENERATION



DISTRIBUTED GENERATION — locating electricity generators close to the point of consumption — provides some unique benefits to power companies and customers that are not available from centralized electricity generation. Distributed power technologies are inherently modular, and include natural gas, fuel cell, cogeneration, and renewable energy systems. The term “distributed resources” includes modular power technologies and nongenerating demand-side-management (DSM) measures, such as energy efficiency improvements, that reduce the load at the

distribution level of the transmission and distribution (T&D) grid.

Photovoltaic (PV) technology is well suited to distributed applications and can, especially in concert with other distributed resources, provide a very close match to the customer demand for electricity, at a significantly lower cost than the alternatives. In addition to augmenting power from central-station generating plants, incorporating PV systems enables electric utilities to optimize the utilization of existing T&D assets.

MAINFRAMES VERSUS NETWORKS

The recent growth in popularity of distributed generation is analogous to the historical evolution of computer systems. Whereas we once relied solely on mainframe computers with outlying workstations that had no processing power of their own, we now rely primarily on a small number of powerful servers networked with a larger number of desktop personal computers, all of which help to meet the information processing demands of the end users.

Figure 1, below, shows how a traditional, central-station generating system looks before and after the addition of distributed resources to the power grid. While the central generating plant continues to provide most of the power to the system, the distributed resources meet the peak demands of local feeder lines or major customers. Computerized control systems, typically operating over telephone lines, make it possible to operate the distributed generators as dispatchable resources, generating electricity as needed.

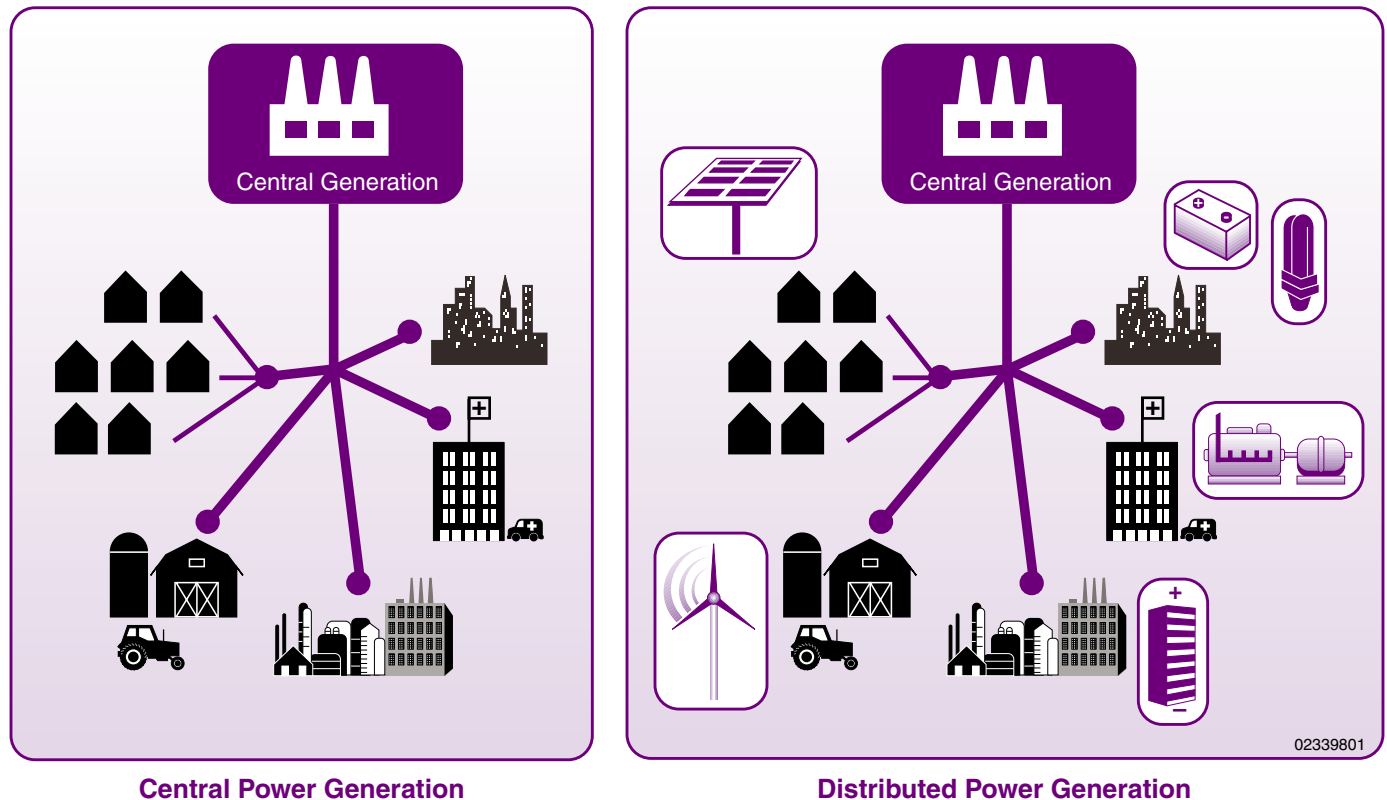


Figure 1. Distributed generation involves adding small, modular electricity generators throughout the distribution grid to augment the electricity supplied by a large, central-station power plant.

THE NEED FOR DISTRIBUTED POWER

It is much cheaper and easier to meet a growing local demand for electricity by adding new generators close to the load than by adding transmission capacity. This is partly because of the lengthy permitting process required for new transmission lines. Modular power plants — using natural gas or solar resources, for example — can be approved and sited close to a new load in a matter of months, versus several years for transmission line upgrades. Transmission

networks are also inherently expensive to build and maintain. According to the Pacific Gas and Electric Company, some utilities spend \$1.50 to distribute power for every \$1.00 they spend producing it, a perspective that is supported by data from the Energy Information Administration. The benefits of distributed power systems are summarized in the text box, below, with an emphasis on PV systems.

NATURAL GAS — A BRIDGE TO A RENEWABLE ENERGY FUTURE

The 1980s witnessed a complete reversal in a 50-year trend of increasing economies of scale in electricity generation, from community-sized systems in the 1930s to large, centralized power plants in the 1970s. This reversal was sparked by improvements in gas exploration and recovery technologies that secured an abundant supply of natural gas, creating an incentive to develop improved combustion turbines. The advent of reliable and efficient combined-cycle natural-gas generation lowered the optimal size for a generating plant — based on cost per megawatt — from 1000 MW in 1980 to 100 MW in 1990. Smaller turbines now on the market have pushed the optimal plant size below 10 MW and manufacturers are demonstrating microturbines designed to produce tens of

kilowatts — small enough to power individual office buildings. Faced with the prospect of industry restructuring, electric utilities have become increasingly cost-conscious in recent years. One consequence of this has been their growing reliance on distributed natural-gas turbines to meet new demands for power. This has spurred the development of the system management technologies that are necessary to synchronize the frequency and output of many small generators operating in a decentralized configuration, which in turn makes it easier to add more small generating units to the grid. As a result, emerging competition in the electricity industry has opened the door to a variety of small-scale distributed generation technologies, including those using renewable sources of energy such as sunlight.

Benefits of PV as a Distributed Resource

- Avoided energy losses in T&D lines
- Modularity enables capacity additions and reductions in small increments, closely matched with demand
- Cleaner, quieter operation — reduced environmental impacts
- Modular nature means less capital is tied up in unproductive assets
- Potential to free up transmission assets for increased wheeling capacity
- Greater market independence and consumer choice — empowered customers
- Mitigation of energy price risks — costs are predictable, unlike fossil fuels
 - Avoided fuel transportation costs — everywhere the sun shines ...
 - Reduced operating and maintenance costs to the local utility
 - Additional capability to meet peak daytime power demands
 - Avoided T&D system (line and substation) upgrades
 - Faster permitting than transmission line upgrades
 - Enhanced power quality and reliability

PHOTOVOLTAICS — CROSSING THE BRIDGE

Natural-gas turbines are currently favored for distributed generation, and PV power systems have many characteristics in common with gas turbines. Both are clean, relatively quiet, and don't require on-site storage of fuel or waste, which makes it feasible to locate the systems at, or close to, the point of electricity consumption. They can be ordered and brought into operation relatively quickly, making them easier to finance in a competitive environment. And they are modular, so adding capacity as demand grows at a given location is relatively straight-

forward, reducing the need to install excess capacity just to handle uncertain future loads.

The two systems are not fully comparable, however. Unlike natural-gas turbines, PV systems are completely noiseless, emit no greenhouse gases or other atmospheric pollutants in operation, and don't require fuel delivery. While natural gas is dispatchable and generally more cost-effective, PV can have the upper hand when aligned with complementary distributed resources, as the Mazama Feeder case study (overleaf) illustrates.

FOCUS ON WASHINGTON STATE — THE MAZAMA FEEDER

When local demand for electricity threatens to outstrip the carrying capacity of the T&D system, the power provider is faced with the choice between upgrading the power lines or finding an alternative method to meet the growing demand. This is the case with the Okanogan County Electric Cooperative (“Co-op”), which serves 2100 members in Washington state.

One of the Co-op’s feeder lines serves customers in the Mazama Valley, a relatively isolated community that currently accounts for less than 15% of the Co-op’s total electricity consumption. But almost half of the Co-op’s increase in demand is occurring on this one feeder, primarily due to new residential customers. The planned addition of 1000–1500 homes in this area would increase the load on the Mazama Feeder by as much as 500%, a load it could not handle.

It would cost an estimated \$2.3 million to meet projected demand by building a 14-mile transmission line from the Winthrop substation and a new substation at Mazama. Calculated over a 10-year period, the feeder upgrade has a net present value (NPV) of negative \$1.2 million. This is because, while the cost of the feeder is \$2.3 million, the service access fees collected from 1500 homes over 10 years has a present value of only \$1.1 million. In an effort to find a viable alternative for the Co-op, the National Renewable Energy Laboratory (NREL) commissioned a study to evaluate the technical and economic feasibility of using distributed resources to satisfy the increased demand.

The NREL study found that a combination of three measures — energy efficiency improvements, PV, and cogeneration of heat and electricity with propane — could provide a very close match between electricity supply and demand year round (see Figure 2), avoiding the need for a line

upgrade altogether, and saving the utility money. The technologies would need to be applied as follows:

- ❑ **Efficiency** — Moderate energy efficiency in all 1500 new homes, including insulation, fluorescent lighting, high-efficiency refrigerators, and propane clothes dryers.
- ❑ **Cogeneration and district heating** — Propane-based district cogeneration for 1000 homes, generating 2 MW of electricity and saving the Co-op’s customers 20% on the cost of electric heat.
- ❑ **Propane space and water heating** — Provided by the Co-op at a reduced rate to the remaining 500 homes.
- ❑ **PV** — The Co-op would waive the system access fee for homeowners installing a 1 kW or larger PV system; assuming one out of every three homes took up this offer, total generation would be 0.5 MW.

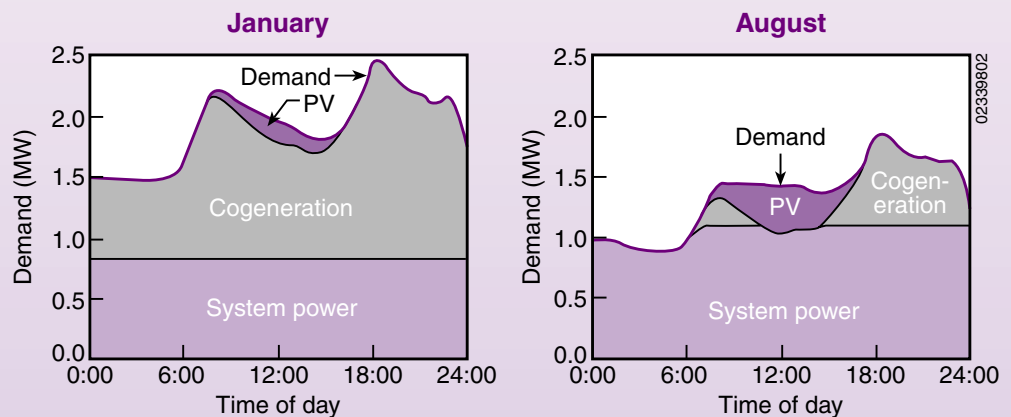


Figure 2. Distributed resources provide a close hourly match between electricity demand and supply during both winter and summer months.

Cogeneration would be higher in the winter months when there are both space- and water-heating demands, and would substantially reduce the peak winter load on the feeder. PV produces more electricity in the summer, addressing summer peaking needs.

The combination of these distributed resources was found to have an NPV of \$0.2 million, which means that the Co-op could save \$1.4 million by choosing distributed resources over a line upgrade.

SOURCES OF INFORMATION

Christy Herig
National Renewable Energy Laboratory
National Center for Photovoltaics (NCPV)
1617 Cole Boulevard • Golden, CO 80401
303-384-6546 • 303-384-6490 (fax)
e-mail: christy_herig@nrel.gov

Distributed resources: A potentially economically attractive option to satisfy increased demand on Okanogan County Electric Cooperative's 'Mazama Feeder' line by Thomas E. Hoff. Clean Power Research, October 1998.

“Who’s afraid of natural gas?” by Walt Patterson. *Renewable Energy World*, January 1999.

The Mazama study and other utility-oriented PV publications are available on the NCPV Web site at: www.eren.doe.gov/pv/onlineutil.html

Other papers by Clean Power Research on distributed generation and minigrids are available from the company’s Web site at: <http://www.clean-power.com/research.htm>

Additional copies of this brochure are available on the internet at <http://www.nrel.gov/ncpv/pdfs/23398a.pdf>

Cover photo credits (clockwise from top): Nos. 1–5: Warren Gretz, NREL/PIX00003, 01002, 04134, 00072, 00083; No. 6: Tim Ellison, ECD/PIX04473.



Produced for the U.S. Department of Energy
1000 Independence Ave., S.W. • Washington, D.C. 20585
by the National Renewable Energy Laboratory,
a DOE national laboratory
DOE/GO-10098-657 • September 1999



Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste.

DISTRIBUTED GENERATION IN MINIGRIDS

A minigrid — a set of generators that supply the entire electricity demand to a localized group of customers — represents one of the best near-term prospects for renewable energy technologies in general, and photovoltaics (PV) in particular. By avoiding the cost of transmitting electricity from a distant central-station power plant, or transporting fuel from a distant supply source, a minigrid can significantly improve the economics of generating electricity with PV.

Distributed generation involves adding modular electricity generators close to the point of consumption on a power grid. Minigrids typically use the same technologies employed by electric utilities in distributed power applications, but are not always connected to the central grid. In some cases, the generators are

installed to relieve utility constraints on the existing grid, with a view to possibly disconnecting these generators and their load from the grid at a later date. In other cases, an electrically isolated minigrid is created; this minigrid may then be integrated with the central grid if that option becomes attractive. The essential point is that the generators in a minigrid are capable of serving their load independently.

Using a mix of generating and demand-side-management technologies gives the power supplier the flexibility to meet a wider range of loads, and aligning with other technologies enables PV to reach new markets. Minigrids thus represent an important market for PV power systems, which are already cost-effective in many such applications, as the Block Island Power case study, below, illustrates.

FOCUS ON RHODE ISLAND — BLOCK ISLAND POWER

Block Island, located about 10 miles off the coast of the Rhode Island mainland, is a good example of a community that already has its own electrically isolated minigrid. The island obtains its electricity from diesel generators, meeting some of its heating needs with propane. Bringing all this fuel from the mainland by boat is costly, giving Block Island one of the highest electricity costs on the East Coast — three times higher than mainland rates during summer peak season.

Due to pollution from the diesel generators, the island has not been in compliance with the Clean Air Act, and Block Island Power Company (BIPCO) was recently faced with the prospect of

either installing a submarine cable to carry electricity from the mainland, or purchasing a new fleet of cleaner diesel generators. Both options threatened to drive the island's electricity rates up even higher than they already were. Islanders turned to the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) for help.



Christopher Wainell/PIX08092

PV panels outside a Block Island residence

A study commissioned by NREL found that distributed resources provide a technically and economically viable alternative method for meeting the island's heating and power needs. Islanders would need to implement the following changes (percentages indicate the relative contribution of each element to meeting the total load):

- *Energy efficiency* — Replace 20,000 incandescent light bulbs with compact fluorescents (or their equivalent), roughly two lights for each person during the peak summer months. Replace existing refrigerators with high-efficiency models for all year-round residents. (Total contribution: 25%)
- *Renewable energy* — Install 1 MW of PV (21%) and 1 MW of wind power (19%). (Total contribution: 40%)
- *Cogeneration of electricity and hot water with fuel cells* — Install 1.5 MW of cogeneration to serve commercial customers (29%) and 0.3 MW to serve year-round residential customers (8%). (Total contribution: 37%)

Note: Totals add up to more than 100% to cover system losses.

With this scenario, there would be a very close monthly match between electricity generation and demand. As Figure 1 shows, the diesel generators would have to be operated only during extreme peaks or emergencies, which would meet EPA emissions requirements. The study noted that, as most of the technologies evaluated are nondispatchable, a more in-depth evaluation would be necessary to ensure that there would also be a close hourly match between supply and demand. Total annual costs of the distributed resource approach were found to be less than the cost of the submarine cable.

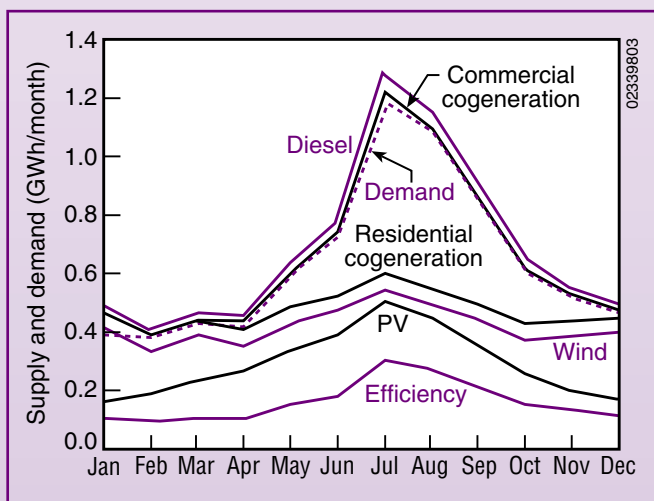


Figure 1. Distributed resources provide a very close monthly match between electricity supply and demand. The dramatic variation in load during the year is because the island's base population of 800 residents swells to roughly 10,000 during the summer months.

To find out if the distributed resource approach would meet local needs, Rhode Island was granted \$400,000 by DOE to develop diesel displacement projects — such as photovoltaics, solar hot water, and wind — on Block Island.

SOURCES OF INFORMATION

Christy Herig
 National Renewable Energy Laboratory
 National Center for Photovoltaics (NCPV)
 1617 Cole Boulevard, Golden, CO 80401
 303-384-6546
 303-384-6490 (fax)
 E-mail: christy_herig@nrel.gov

A Preliminary Analysis of Block Island Power Company's Use of Clean Distributed Resources to Provide Power to Its Customers by Thomas E. Hoff. National Renewable Energy Laboratory, August 1998.

Distributed Generation and Micro-Grids by Thomas E. Hoff, H. J. Wenger, C. Herig, and R. W. Shaw, Jr. Presented at the 18th USAEE/IAEE, San Francisco, CA, September 1997. This paper provides a method to evaluate the technical and economic feasibility of minigrids.

These and other utility-oriented PV publications are available on the NCPV Web site at: www.eren.doe.gov/pv/onlineutil.html

Additional copies of this brochure are available on the internet at: <http://www.nrel.gov/ncpv/pdfs/23398b.pdf>



Produced for the U.S. Department of Energy
 1000 Independence Ave., S.W.
 Washington, D.C. 20585
 by the National Renewable Energy
 Laboratory,
 a DOE national laboratory
 DOE/GO-10098-657
 September 1999



Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste.