Microturbines:
Lessons Learned from Early Adopters

An E Source Multi-Client Study

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About This Study

In progress for more than two years, this interview-based Multi-Client Study catalogs experiences of some 52 different early adopters of microturbines. It spans the early market and commercial market phases of this technology and includes data from all the major manufacturers of these power plants. The study consists of an Interview Notebook, which has 52 microturbine user interviews, and this report, which contains five case studies and trend data identified in the interviews. The case studies represent our focused research on aspects of the new microturbine business that we consider highly significant for the future based on our interview findings.

For the interviews, a standard interview question set was developed to guide discussions and ensure that certain information was gathered from all participants. Beyond this guide, interviewers tried to determine what characteristics of an installation were important and unique, what motivated decision-makers to install microturbines, and what lessons from an installation would be of value to others. As the term of the study was fairly extended, most of the early interviews were updated in 2002 to determine the current status of the installation and to add any new information or perspectives that time might offer.

Acknowledgments

Many microturbine users helped us produce this study, and we thank all those interviewed for the time they spent with us and valuable perspectives they shared. All conclusions and inferences are strictly the responsibility of Platts Research & Consulting, but we would like to acknowledge and especially thank several individuals who offered extra time and wisdom both for content and manuscript reviews:

Richard Adamson	Mariah Energy Corp.
Ake Almgren	Capstone Turbines Corp.
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Ross Dueber	Copeland Corp.
Bill Jackson	Apache Canada, Ltd.
George Wiltsee	Formerly of Capstone Turbines Corp.

Executive Summary

By interviewing 52 early adopters of microturbines over the past two years and synthesizing some of the most significant events and trends in this business, we have produced a detailed picture of the birth of a new energy technology industry into the marketplace. Microturbines are alive and kicking. And while they haven't replaced central power plants by a long shot, microturbines have gotten a toehold in the unstable electric power industry of the 21st century. Like any new technology, microturbines suffered through early market challenges, including business shakeouts (Honeywell left the business), technical problems, and undeveloped market channels. In addition, this technology faced the large barriers that all distributed generation equipment does—tough interconnection standards and cost competition from the incumbent utility—and survived. Microturbines, as a new entrant in a huge and entrenched industry, became niche players—they found places in the energy economy where underserved markets exist and exploited those opportunities.

Our study shows that microturbines shine in applications where their unique attributes give them advantages over competitors. With lots of clean, hot exhaust gas compared to other generation technologies; microturbines can provide heat to a huge variety of applications, from directly heating greenhouses out of the tailpipe (yes, the plants thrive), to cooling buildings via heat-driven absorption chillers. Microturbines have also moved in to exploit the free fuel from many smaller landfills, sewage treatment plants, and oil and gas wellheads where these resources were previously wasted because there was no economical means to use them. While most early microturbines were financially supported in tests and demonstration projects, more recently they have begun to make their own way and have even created new markets for other businesses to grow in—a strong sign that they are here to stay.

Study Methods

1. Microturbine user interviews: Our study is based on 52 in-depth interviews with end users of microturbines. A standard interview question set was developed to guide discussions and ensure that certain information was gathered from all participants. The information gathered included:

- *Contact information:* Dates of interviews (many were interviewed more than once), names of organizations involved, and names of key staff
- *Application:* the microturbine type, what it is being used for, and how
- *Acquisition process:* who motivated the installation, why, what goals were set for the installation, and how the acquisition went
- *Installation:* how the system was actually implemented; successes and pitfalls
- *Experience with the microturbine:* how it has worked since installation
- *Economics:* where available, as much economic data as was offered

- *Future plans:* what the organizations involved in the installation plan to do with microturbines going forward.

Beyond this guide, interviewers tried to determine what characteristics of an installation were important and unique, what motivated decision-makers to install microturbines, and what lessons would be available from an installation that would be of value to others.
As the term of the study was fairly extended, most of the early interviews were updated in 2002 to determine the current status of the installation and to add any new information or perspectives that time might offer.

2. In-depth case studies: As a last step in the study, we reviewed all the interviews and identified general trends and the most intriguing developments in this industry. These were used to identify subjects for deeper study in the five case studies. The topics chosen are listed below:

- **Mariah Energy Corp**.
  A profile of this market leader that has built a business model based on microturbines with discussion of key business model elements
- **Combined cooling, heating, and power (CCHP)**
  Investigation into key technical and market aspects of this attractive application of microturbines' waste heat
- **Direct use of exhaust gases**
  Profile of several direct heating applications including greenhouses and product drying, with discussion of technical underpinnings and other practical applications
- **Landfill and digester gas.**
  An overview of leading applications with discussion of technical issues
- **Resource recovery**
  Overview of early applications in several types of resource recovery applications with discussion of technical issues

Study Trends

Despite limitations of a small sample, we believe some trends from the 52 interviews are likely to be generally valid. Error around such statistics must be presumed to be large. But if the percentage differences are large between groups compared, as some below are, data may be said to support the difference directionally.

- **Most of the end users we interviewed (44) had a generally positive view of the experience, whether or not they judged their microturbine installation as successful.**

- **Capstone installations dominated the interviews, as would be expected,** given their estimated 84 percent market share. Thirty-three of the sites contacted were using Capstones, 10 had Honeywells, 3 had Bowman, 3 had Elliott, 2 had Turbec, and 1 had

Ingersoll-Rand. This distribution, while not exactly representative of the breakdown of the actual population of microturbines by manufacturer, is surprisingly close.[i] In fact, the distribution of interviews was also somewhat influenced by manufacturers' willingness to share customer names with us.

- **By far the largest numbers were baseloaded (49), with only 3 being operated as peaking plants.** This supports the common wisdom that microturbines are best for baseloaded applications.

- **Also strongly dominant were grid-paralleled applications (46).** This is generally because isolating from the grid implies total dependence on the microturbine system for reliable power. As at Harbec Plastics Inc. (Interview Notebook, p. 61), grid independence will require substantial reserve power for step load changes such as motor starts and for backup to ensure reliability. Such a strategy is typically not cost-effective, although Harbec claims its CCHP system is, largely because of its high net efficiency.

- **The survey (and population of applications) is truly international**: of the 52 interviews, 41 were in the U.S., 5 in the UK, 3 in Canada, and 1 each in Denmark, Sweden, and Spain.

- **The total number of microturbines involved in the study was 229, greatly exceeding the number of interviews.** This is because several developers were installing large numbers at various times. The total installed capacity involved was 9.4 megawatts (MW).

- **Twenty-seven sites used only the electric power, while 21 were CHP, and 4 were CCHP.**

Although the capital costs of microturbines are all reasonably close to each other (for obvious competitive reasons), installed costs varied widely:

- **The 4 CCHP installations (which are mostly test sites) were by far the most expensive, averaging $4,400 per installed kilowatt (kW).** This number is heavily influenced by one "gold plated" test site, however.

- **The 10 biogas (landfill and digester gas) sites were also expensive, averaging $2,660 per installed kW**. These higher costs are for the gas cleanup ancillaries associated with such sites and are typically more than offset by the low to even negative effective costs of fuel in biogas applications.

- **21 CHP applications had installed costs averaging $2,206 per kW.**

- **The 17 "electric-only" installations that were not biogas fueled averaged an installed cost of $1,659 per kW.**

User Experiences: Why Were Some Good, Some Bad, and Some Ugly?

Our in-depth interviews with end users uncovered that most users were overall quite happy with their microturbines. Thirty-eight (73 percent) described their experiences in positive terms, and eight appeared noncommittal. A few (six) clearly were not happy. What makes the difference?

Reliability. The number one reason that six of those interviewed described their experiences with the microturbine as “bad” or “terrible” was because the unit was not reliable.

Responsiveness to problems. Manufacturers and distributors have to be very responsive when something goes wrong with any major building equipment, and particularly so with a new technology. They have to have someone sent out to the site within a day to repair it, and they should provide a replacement unit if necessary.

Clear up-front expectations. End users need to know all pertinent information upfront. In particular, manufacturers and distributors need to be clear about what ancillary equipment will be necessary (for instance, a gas compressor, or gas clean-up), the first cost of this equipment, and the parasitic losses of the equipment. They need to know details that affect the performance or output of the equipment—for instance, that the output decreases as the ambient temperature increases. They need to know all maintenance requirements, and the timing and cost of those.

A champion at the site. End users who were happy with their microturbine system tended to have a “champion” within the organization. Often, this champion already liked the idea of microturbines before purchasing one.

Heat recovery. Twenty-five of those interviewed were using the waste heat from the microturbine for water heating, space heating, or cooling. None of these described their experiences as bad, despite the increased complexity of CHP systems.

Few interconnection hassles and delays. The 11 users interviewed who had lengthy and complicated procedures and paperwork for interconnecting their microturbine to the grid often ended up frustrated with the project, regardless of how well the unit operated once it was finally up and running.

Grants. It’s no surprise that end users who received grants to defray some or all of the capital costs of the microturbines tended to be happier with the system and tended to be far less worried when the system encountered any sort of problem. Manufacturers and distributors should assist end users with finding grants.

Stable gas costs. Neither end users nor manufacturers or distributors have any control over commercial gas costs. This was nonetheless one of the factors involved in end users’ satisfaction—or lack thereof—with their microturbine system. Some end users found that gas costs had risen (or power prices dropped, as in Europe) substantially since they had first run economic calculations and purchased a unit.

Summary Conclusions

From our study, we have drawn a number of broad conclusions:

- **Microturbines are a successful new technology, but occupy a niche in the electric power generating business.** Applications are primarily baseloaded (those with long running hours) and/or use low or no-cost fuel to offset their market barriers.
- **Like all new technologies, microturbines have had some early reliability problems.** Later models appear to be much better.
- **As with other combustion turbine technologies, use of exhaust heat is important to project economics.**
- **Low awareness of microturbines and combined heat and power (CHP) in North America (51 and 56 percent awareness, respectively, among surveyed commercial and industrial customers on the continent) is currently limiting their penetration.** Relatively few smaller CHP systems exist in this region, (which we believe are the largest potential market for microturbines).[ii]
- **A "very focused"[iii] design philosophy held by a number of the market leaders, notably Capstone Turbines, set standards for NO_x exhaust emissions that are among the lowest in small power plant technologies.** Two microturbines from Capstone and Ingersoll-Rand guarantee NO_x emissions below 9 ppmV. This does not appear to substantially affect their efficiency as compared to their competitors with higher emissions.
- **Microturbines' very low emissions have resulted in larger markets and also in new market opportunities.** One notable new market is in direct use of exhaust for such high-value applications as greenhouse heating, where the carbon dioxide (CO_2) in the exhaust is actually a valuable constituent, helping to speed plant growth.
- **Grid interconnection barriers—including unreasonable utility rules, large charges for studies, backup charges, and so on—although still existing in many areas, apparently are becoming less of a problem.** Utility resistance was not as serious as expected among those interviewed, perhaps because of the small capacity of microturbines and their use of inverters to generate grid-synchronized power. This study may present an incomplete perspective on this issue, however. The sites interviewed represented successful installations, and utility resistance may have resulted in some projects being canceled—which means, naturally, they were not interviewed.
- **Although the numbers and ages of microturbines operating preclude final judgment, the manufacturers' claims of high reliability appear to be coming true.** The longest-running Capstone in the field has 32,000 hours on it, and at least six others exceed 20,000 hours. Capstone's fleet (by far the largest in the industry) exceeded 3 million running hours before the end of 2002. Most of the users interviewed indicated that their microturbines were reliable.

Case Study Highlights

Mariah Energy: A Microturbine Business Model

Building a new type of business is a challenging proposition under any circumstances; using a new technology and business model to do so makes the challenge even more daunting. But Mariah Energy Corp. is doing just that. The company is successfully growing a build-own-operate independent power producer business at a very small scale, a venture it describes as a “distributed micro-utility.” Mariah has taken a simple idea and realized it with an elegant execution.

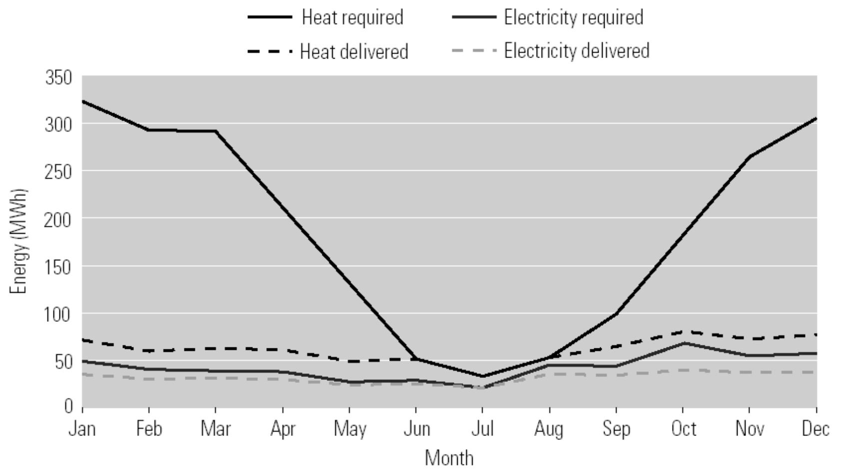
Profile: Near Continuous Space Heating Provides Good Application for Heat PlusPower

Inuvik, Northwest Territories, is located over 100 miles north of the Arctic Circle. Buildings in this community require heating 9 or 10 months of the year. Mariah Energy recently installed two 60/30 Heat PlusPower units at the Midnight Sun Recreation Complex and Convention Center there. The facility, which opened in 1997, houses a community center, arena, curling rink, and conference and convention center.

The Heat PlusPower units operate continuously during the heating season. During this period, the two Heat PlusPower units provide half the building’s space heating. Additionally, these units provide about three-quarters of the electricity needed by the facility. Currently, the system only operates when there is a thermal load, but this may change to allow for summer operation or for backup power, when only electricity is needed. The unit is owned and serviced by Northwest Territories Power Corp. and is separately metered so effectively all electricity is exported all the time, though just to the local host facility. A Heat PlusPower monthly operation simulation is shown in Figure 4.

Figure 4: Thermal and electric loads and CHP supply to the Midnight Sun recreation center

Baseloading CHP to deliver less than all of the heat required usually results in highest efficiency.



Source: Mariah Energy Data [25]

The units have been operating only since September 2002 so not much real world data is currently available. However, with electricity prices in Inuvik hovering around C30¢ per kilowatt-hour (US20¢ per kWh) annual savings are expected to be about C$40,000 (~US$26,000).

Combined Cooling, Heating, and Power with Microturbines

In 1999, a microturbine was installed in a Walgreens store in Merrillville, Indiana, by a subsidiary of NiSource Inc., a gas utility. This unit drew wide attention because it cooled the store using exhaust heat from the microturbine while also producing power on-site. This configuration—known as combined cooling, heating, and power (CCHP)—was not entirely new, but it had not been seen in a commercial installation using a microturbine.

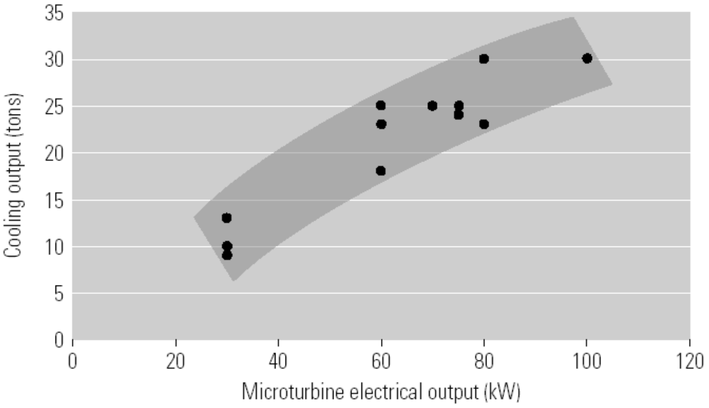
The Walgreens pilot made a splash in energy circles primarily because of one compelling fact: The coincidence of utility peaks with the hottest days is a direct result of power required for cooling. **So when a cost-effective device that can cool and generate electricity becomes available, it will find a huge and receptive market. According to Ake Almgren, CEO of Capstone Turbines, CCHP potential "has been a major driver in the reasons for the alliance between Capstone and United Technology," the parent company of Carrier, a major air conditioning manufacturer.**[iv]

Microturbine CCHP Cooling Capacity

Data collected from a number of CCHP projects (Figure 11) indicate that the thermal energy recovered by an HRHX from a microturbine can power an absorption chiller to produce about 1 ton of cooling for each 3 kW of electrical output. The largest currently available microturbines, 100 kW, can therefore power an absorption chiller of about 35 tons.

Figure 11: Cooling capacity vs. electrical output of microturbines

Data collected from various CCHP projects indicates that about 1 ton of cooling can be produced for every 3 kW of electricity generated. Data is limited, so this should be used as a guideline only.



Source: Platts

Microturbine manufacturers are continuously pushing to produce larger electrical capacity machines, several are developing units in the 200 to 250 kW range; Ingersoll-Rand will release a 250-kW turbine in the near future. On the basis of its research, Capstone estimates that microturbines can grow to around 400 kW.[v] These units are likely to be more efficient electrically and therefore may have less available thermal energy for powering absorption chillers. However, for a 250-kW microturbine, it is reasonable to expect at least 70 to 80 tons of cooling capacity.

More important, development efforts are underway to directly utilize the microturbine's exhaust in direct-fired absorption chillers and so more fully exploit the available energy it contains. These systems will likely increase system efficiency, operating flexibility, and reduce first costs.

Direct Use of Microturbine Exhaust

Keep it simple is one of the great laws of technology. So it is with CHP schemes using microturbines: The direct use of the heat and gases from a microturbine's exhaust stream offers some of the most cost-effective applications for microturbines, as a number of operational projects demonstrate.

Direct firing is heating in which the flame of combustion is not separated from the air stream being heated. Residential gas stoves are perhaps the most common example of this, but many other types of direct-fired heaters exist. A large number of commercial and industrial processes require heat, frequently at relatively low temperatures, in the range of 100° to 500°F (38° to 260° Celsius). Exhaust emissions from natural gas combustion are often low enough not to cause adverse health effects or product damage in many applications where human exposure is limited. In such cases, direct-fired heating is common.

Microturbine exhaust is a practical source of direct-fired hot air, because, when fueled by natural gas, microturbines have very low exhaust emissions, ranging between about 3 and 25 ppmV, which compares very favorably with residential kitchen stoves, at around 50 ppmV.[vi] Additionally, because the exhaust gas from a microturbine is rich in CO_2, agricultural applications that can utilize both the thermal energy and CO_2 further increase the microturbine's exhaust value. Some of the currently identified applications where microturbines have been installed include greenhouses, product drying, and cooking and baking applications.

- **Greenhouses.** Optimal plant growth requires, among other things, the proper combination of light, heat, water, nutrients, and CO2. Microturbines can increase availability of all these needed conditions. Additionally, plant growth rates are significantly enhanced as the CO2 levels they are exposed to increase, potentially by as much as 30 percent.

- **Product drying.** Many industrial processes require hot air at relatively low temperatures, on the order of a few hundred degrees Fahrenheit in order to dry products. Often, natural gas is burned to produce this heat; this is inherently wasteful of the full potential of the gas's energy, because the flame temperature is above 1,000°F and more work can be extracted from it without losing the drying effect. Microturbines can exploit this "high quality" heat, providing valuable electricity in addition to a hot air stream for drying.

- **Cooking and baking.** Cooking and baking require clean heat. Direct-fired combustion of natural gas or electricity is typically used in these applications. Using natural gas with its high-temperature potential for cooking and baking is an inefficient application of this energy source. Although there are sometimes application-specific reasons to do so (typically the need for very accurate temperature control), electric heating is even more inefficient for these low-temperature heating applications.

Figure 14: Bowman microturbine at a brickworks

The 80-kW Bowman microturbine provides hot air to dry bricks before firing. System net efficiency is over 90 percent.

Courtesy: Bowman Power Systems [47]

Profile: Brick Manufacturer Uses Microturbine for Drying Bricks

A brick manufacturer installed a Bowman microturbine at its brick manufacturing facility. The microturbine is a Bowman 80-kW nonrecuperated unit, and its exhaust is directly ducted to the brick-drying kiln (Figure 14). Thermal energy produced by the microturbine offsets a portion of the energy that would otherwise have been obtained from burning natural gas and enables increased throughput while reducing operating costs. The microturbine runs 24 hours per day, and all exhaust heat is used in the drying process. Overall system efficiency is greater than 90 percent, resulting in attractive project economics (Table **8**).[vii]

Landfill and Digester Gas

Running microturbines on the waste gas from landfills and wastewater treatment plants is a compelling application and one that we believe will continue to grow both in North America and globally. **Our findings in this case study are based on common threads from interviews with 10 landfills and wastewater treatment plants (see Table 9) and one on-site visit to a landfill. The sites had a combined total of 60 Capstone microturbines. We also held discussions with landfill and digester gas industry leaders and other microturbine manufacturers.** Key conclusions include the following:

- Microturbines do provide advantages over other technologies for generating electricity with low-quality gas and are especially well suited for smaller sites.

- **Early landfill and digester installations had some start-up problems, including compressor failures, but those problems have been resolved for existing and new sites. End users report few problems with the operation of the Capstone microturbines.**

- New Capstone installations have a standardized gas-processing system that is simpler, more compact, and more reliable.

- Landfill and digester sites are reporting quite significant cost savings from using microturbines, especially with grants available to help cover the capital costs of the equipment.

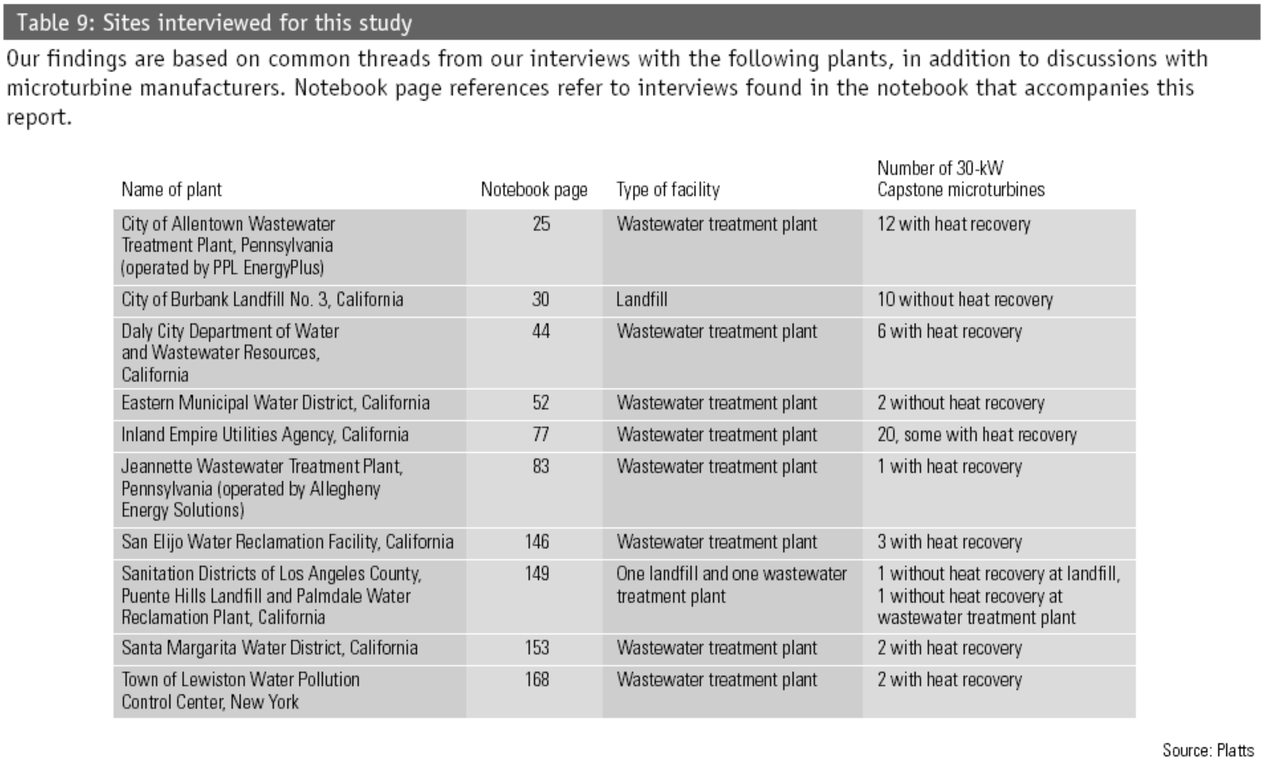


Table 9: Sites interviewed for this study

Our findings are based on common threads from our interviews with the following plants, in addition to discussions with microturbine manufacturers. Notebook page references refer to interviews found in the notebook that accompanies this report.

Name of plant	Notebook page	Type of facility	Number of 30-kW Capstone microturbines
City of Allentown Wastewater Treatment Plant, Pennsylvania (operated by PPL EnergyPlus)	25	Wastewater treatment plant	12 with heat recovery
City of Burbank Landfill No. 3, California	30	Landfill	10 without heat recovery
Daly City Department of Water and Wastewater Resources, California	44	Wastewater treatment plant	6 with heat recovery
Eastern Municipal Water District, California	52	Wastewater treatment plant	2 without heat recovery
Inland Empire Utilities Agency, California	77	Wastewater treatment plant	20, some with heat recovery
Jeannette Wastewater Treatment Plant, Pennsylvania (operated by Allegheny Energy Solutions)	83	Wastewater treatment plant	1 with heat recovery
San Elijo Water Reclamation Facility, California	146	Wastewater treatment plant	3 with heat recovery
Sanitation Districts of Los Angeles County, Puente Hills Landfill and Palmdale Water Reclamation Plant, California	149	One landfill and one wastewater treatment plant	1 without heat recovery at landfill, 1 without heat recovery at wastewater treatment plant
Santa Margarita Water District, California	153	Wastewater treatment plant	2 with heat recovery
Town of Lewiston Water Pollution Control Center, New York	168	Wastewater treatment plant	2 with heat recovery

Source: Platts

Market Size and Sales Data

Capstone. Capstone currently has 54 microturbines operating at wastewater treatment plants, 71 at landfills, and 10 running on farm manure or food processing waste, for a total of 135 units. Those units, plus units shipped but not yet installed, make up more than 10 percent of the total 2,400 microturbines that Capstone has shipped to date. All of the landfill and digester gas Capstone microturbines are rated at 30 kW. Capstone's 60-kW microturbine isn't available yet for waste gas. It is expected by the end of March 2003.[viii] For most Capstone biogas applications, OEMs and distributors package the microturbines with a fuel skid—compressors, dryers, siloxane filtration, plus a heat recovery unit if needed.

Ingersoll-Rand. Ingersoll-Rand currently has four of its PowerWorks microturbines running at one landfill and six running at another landfill. All have been in operation since spring 2002. Ingersoll-Rand's landfill gas model has been offered commercially since the beginning of 2002. Ingersoll-Rand is also testing a microturbine at a wastewater treatment plant to determine the characteristics of the gas and its effect on the microturbine. That unit has been running since September 2002. It does not have any units running on other types of waste gas, such as from agricultural operations or food processing plants, but it would consider it on a case-by-case basis.[ix]

Turbec. Turbec's first T100 unit running on landfill gas is in operation on a site outside Dresden, Germany. Turbec recently signed an agreement to work cooperatively with the Germany-based company Pro2 Anlagentechnik GmbH to develop the Turbec microturbine for waste-gas applications. Through this agreement, additional units are on their way to being installed at sewage and coalbed methane sites.[x]

Resource Recovery

Microturbines can run on gas produced at oil and gas wells and coalfields that would otherwise likely be wasted. This case study is focused on a number of allied applications that recover valuable usable energy while often reducing emissions. **These applications make up one of the largest and fastest-growing markets for microturbines that is profitable, and as yet this market is still virtually untapped.** Grid-parallel and stand-alone applications exist and are sure to increase in numbers in North America and worldwide as the search for oil and gas accelerates.

Profile: Multiple Values from a Single Microturbine

As part of an acquisition, Apache Canada had two Capstone 30-kW microturbines at their Consort site in Alberta. Even though only enough gas was available to support one microturbine, two units were installed for reliability reasons; specifically it was thought by the original owners that oil could not be extracted unless the associated natural gas was utilized, thus eliminating flaring. While this was indeed the case, regulations do allow continued oil production during equipment downtime for maintenance and other reasons. During these brief periods flaring is allowed.

Because the primary reason for the second microturbine no longer existed and the unit could provide greater value at another site, it was disconnected and moved to Apache's Zama facility in northwest Alberta. At Zama it was reinstalled, where it is currently operating to eliminate gas flaring there.

Noteworthy points in this application are:[xi]

- **Microturbines utilize inexpensive, readily available gas.**
- **Elimination of flaring is a priority in many areas.**
- **Cost of downtime (where a real threat) is great enough for firms to support a standby microturbine.**
- **Microturbines are easy to move from one site to another, whether it is because the grid caught up, plant requirements declined, or other reasons.**

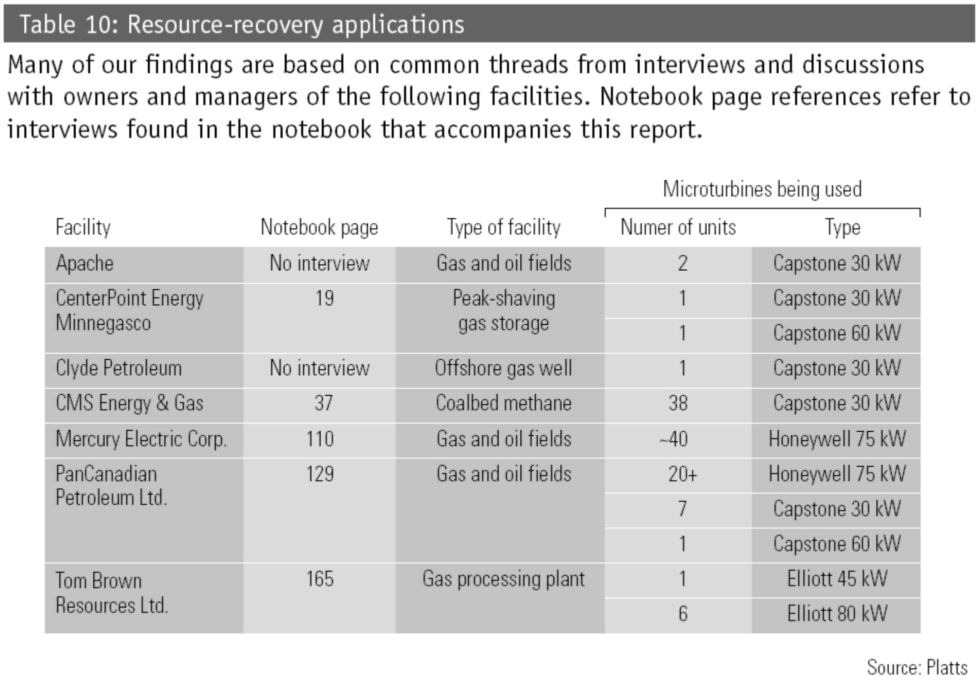


Table 10: Resource-recovery applications

Many of our findings are based on common threads from interviews and discussions with owners and managers of the following facilities. Notebook page references refer to interviews found in the notebook that accompanies this report.

			Microturbines being used	
Facility	Notebook page	Type of facility	Numer of units	Type
Apache	No interview	Gas and oil fields	2	Capstone 30 kW
CenterPoint Energy Minnegasco	19	Peak-shaving gas storage	1	Capstone 30 kW
			1	Capstone 60 kW
Clyde Petroleum	No interview	Offshore gas well	1	Capstone 30 kW
CMS Energy & Gas	37	Coalbed methane	38	Capstone 30 kW
Mercury Electric Corp.	110	Gas and oil fields	~40	Honeywell 75 kW
PanCanadian Petroleum Ltd.	129	Gas and oil fields	20+	Honeywell 75 kW
			7	Capstone 30 kW
			1	Capstone 60 kW
Tom Brown Resources Ltd.	165	Gas processing plant	1	Elliott 45 kW
			6	Elliott 80 kW

Source: Platts

Profile: Microturbine Meets Offshore Wellhead Power Needs Cleanly and at Low Cost

Not all natural gas is on land, and, indeed, many of the new gas discoveries are offshore, presenting a new set of challenges for providing the required power needed to extract, process, and compress this fuel before it enters a pipeline.

Clyde Petroleum in The Netherlands installed a Capstone 30-kW microturbine fueled directly from the gas produced by one of its offshore gas wells. The wet gas is simply dried before it is routed into the microturbine. Before installation on the production platform, the reliability of the unit operating on this fuel was verified by more than 6,000 continuous operating hours. Additionally, the Capstone microturbine emits only 25 percent of the NOx emissions allowed by the Dutch emissions rules for this type of application.[xii]

Of note, this unit uses Capstone's optional Steel Wheel compressor wheel, which is made of steel rather than the aluminum that is typically used. Steel will stand up better to the harsher climate encountered in offshore applications.

NOTES

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[i] According to Platts Research & Consulting's estimates, which are based on manufacturers' reports, Capstone has 84 percent market share and was 63 percent of the interviews; Honeywell has closed and was 19 percent of the interviews (because many interviews occurred while they were a dominant market player); Turbec has 5 percent market share and was 4 percent of interviews; Bowman and Elliott each have 4 percent of market share and each got 6 percent of the interviews; and Ingersoll-Rand has 3 percent of the market and got only 2 percent of the interviews.

[ii] Tia Hensler, Bill LeBlanc, and Scott Landreth, "Estimating Markets for Distributed Energy Resources and Power Reliability Services," *E SOURCE Large Commercial and Industrial Multi-Client Study* (December 2002), p. 29.

[iii] Ake Almgren, personal communication (November 15, 2002), CEO, Capstone Turbine Corp., Chatsworth, California, tel 818-734-5300, web www.capstoneturbine.com.

[iv] Ake Almgren [2].

[v] Ake Almgren [2].

[vi] "Commercial Cooking Stove with Internal Multiple Flame Port Burners with High Efficiency and Low NOx Emission," from www.osakagas.co.jp/rd/sheet/062e.htm (accessed November 12, 2002).

[vii] Bowman press release, article prepared for *Brick News*, the newsletter of the U.S. Brick Industry Association (April 5, 2002).

[viii] George Wiltsee [64].

[ix] Jim Watts, personal communication (October 29, 2002), Marketing Manager, Ingersoll-Rand Energy Systems, Portsmith, New Hampshire, tel 603-430-7020, e-mail jim_watts@irco.com, web www.irpowerworks.com.

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[x] “Turbec AB Signs Cooperation Agreement on Biogas” (September 26, 2002), from www.turbec.com/news/news.asp (accessed October 31, 2002).

[xi] Bill Jackson, personal communication (November 14, 2002), Business Development, Apache Canada Ltd., Calgary, Alberta, Canada, tel 403-261-1200, e-mail bill.jackson@apachecorp.com, web www.apachecorp.com.

[xii] “Capstone Sets New Standard at Clyde Petroleum,” Geveke Power Systems press release, from www.capstoneturbine.nl/news/default.asp (accessed November 29, 2001).