

# Caterpillar Inc. Sustainability Commitment

## Gas Generator Sets

“Our vision is to contribute, through our diverse businesses, to a society in which people’s basic needs are not only met but fulfilled in a way that sustains the environment.”

**SHAPE**  
2007 SUSTAINABILITY REPORT

**THE POSITIVE IMPACT OF A RELIABLE** and adequate power supply is clear even in the underdeveloped regions of Senegal thanks to six CAT engine generators that have kept pace with a 20 percent increase in the local power demand.

Previously, only about 10 percent of Senegal's entire population of 10 million has access to reliable electricity. Much of the region has experienced a prolonged power crisis brought on by extreme drought conditions and other natural catastrophes. An adequate and reliable source of electric power is the crucial foundation for economic and commercial development.

Home to 1.6 million people, Senegal and 1000 firms traditionally lacked reliable electric power supply and infrastructure. A cooperative effort between the local CAT dealer, Marlowe, and Adnan Group, Inc. has ensured the successful commissioning of a plant that is helping to meet the power generation needs of this region. With reliable electricity, industries such as coffee and factories and small enterprises have grown.

**GROWING OUR REMANUFACTURING BUSINESS** by creating distributed energy solutions is one way Caterpillar is enabling development while preserving the environment in the Philippines and other countries.

In 2007, our Remanufacturing Division launched a project that will take end-of-life diesel engines from around the world and remanufacture them into reliable fuel generator sets. These former gas engine will convert methane from refuse into usable energy. The first units will be installed by pig farms in the Philippines beginning in 2008, where they will burn methane, provide electricity and reduce greenhouse gas emissions.

A number of similar projects are planned over the next several years.

**LANDFILL POWER FOR PARIS**

Paris, France

Landfills produce methane gas when organic matter decomposes. Methane is a greenhouse gas (GHG) and a valuable fuel. Outside Paris, France, a Mars™ 100 gas turbine manufactured by Solar Turbines transforms landfill gas into electricity. The turbine reduces GHG emissions equivalent to 58,000 tons of CO<sub>2</sub> per year.

**CATERPILLAR**

**CATERPILLAR**<sup>®</sup>  
TODAY'S WORK. TOMORROW'S WORLD.™

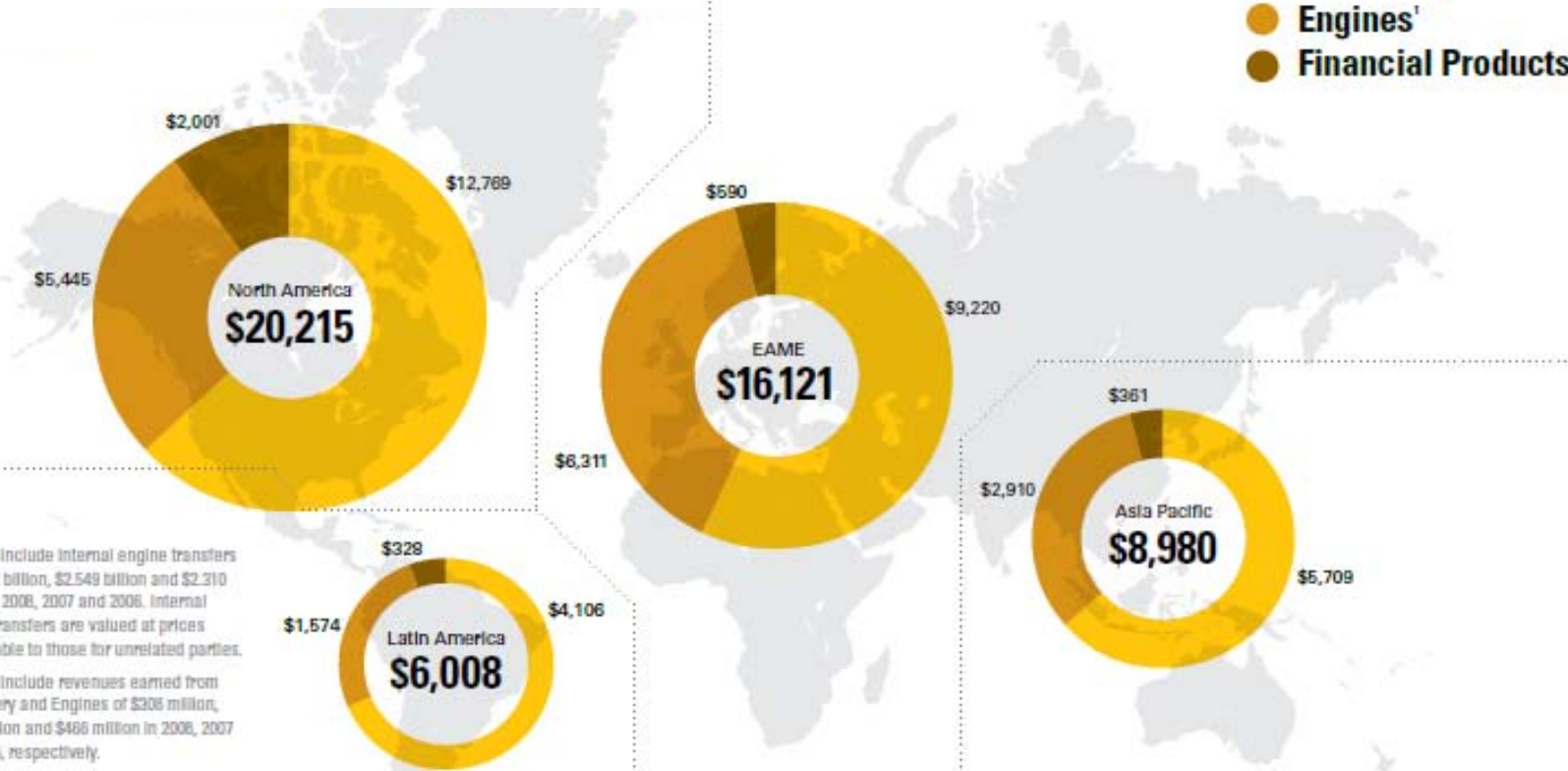
# Topics Covered

- **Caterpillar Inc.**
- **Caterpillar Manufacturing**
- **Low BTU Gas Applications Worldwide**
  - **Low Energy Fuels**
    - Landfill gas to energy
    - Digester Gas
    - Industrial Biogas
    - Ag Biogas
    - Coal Mine Methane
- **Cat Dealer**
  - Experience/Consulting
  - Product Support

# Caterpillar Inc. 2008 Sales & Revenues by Geographic Region

(dollars in millions)

- Machinery
- Engines<sup>1</sup>
- Financial Products<sup>2</sup>



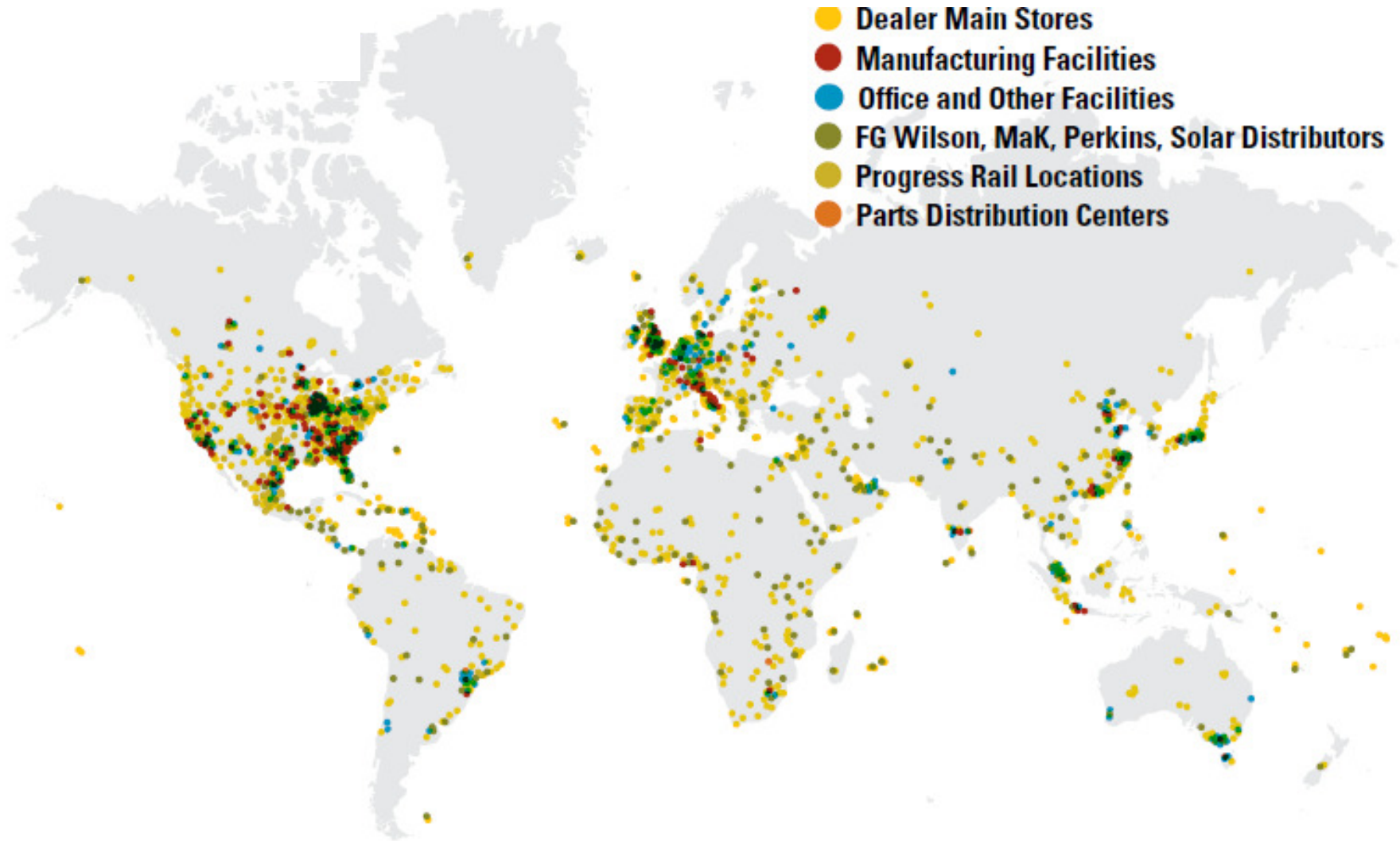
(1) Does not include internal engine transfers of \$2.822 billion, \$2.549 billion and \$2.310 billion in 2008, 2007 and 2006. Internal engine transfers are valued at prices comparable to those for unrelated parties.

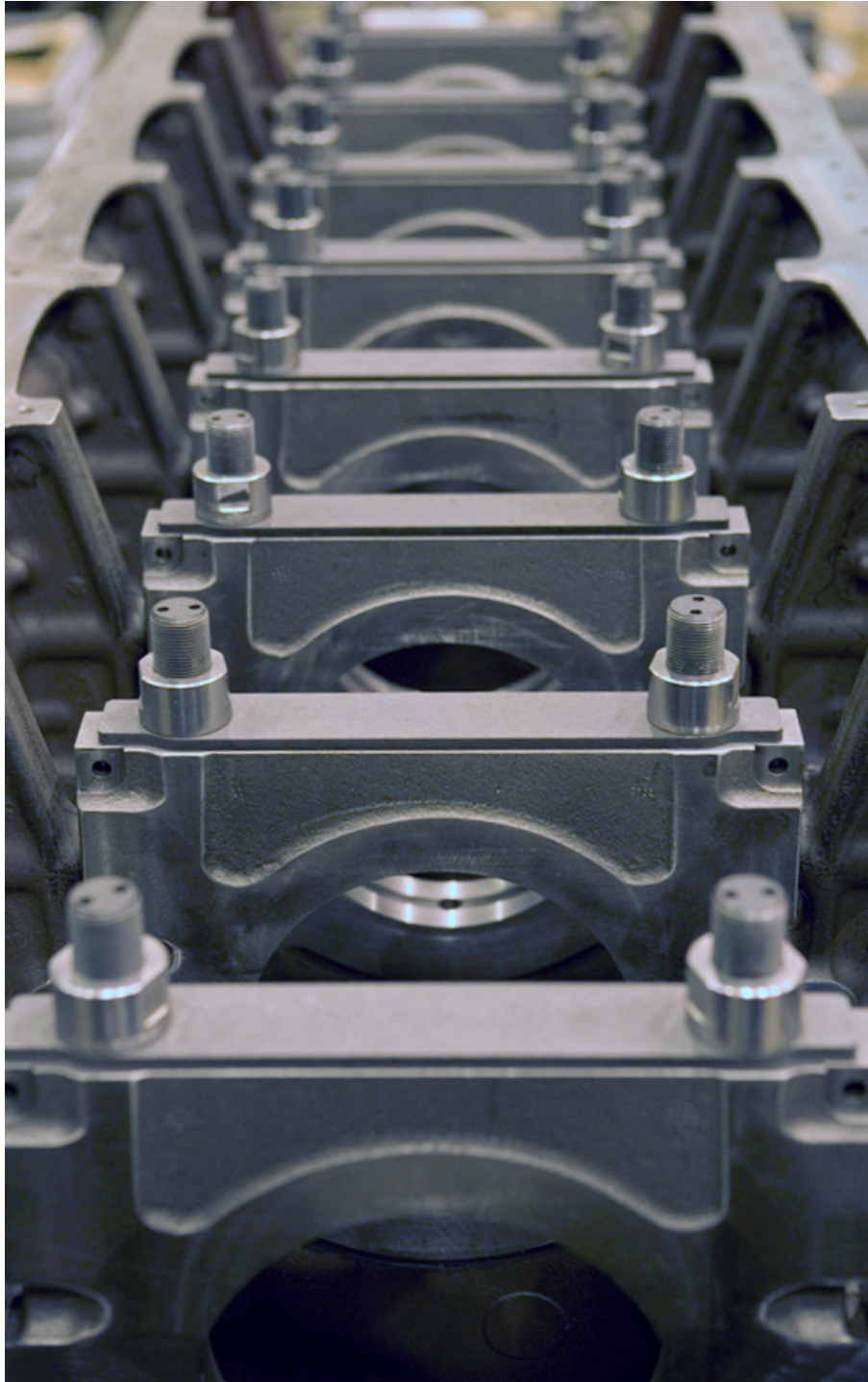
(2) Does not include revenues earned from Machinery and Engines of \$308 million, \$400 million and \$466 million in 2008, 2007 and 2006, respectively.

	North America			EAME			Asia Pacific			Latin America			Total Sales & Revenues		
	08	07	06	08	07	06	08	07	06	08	07	06	08	07	06
Machinery	\$12,769	\$12,596	\$14,215	\$ 9,220	\$ 8,588	\$ 6,223	\$ 5,709	\$ 4,026	\$ 3,080	\$ 4,106	\$ 3,149	\$ 2,544	\$31,804	\$28,359	\$26,062
Engines	\$ 5,445	\$ 5,092	\$ 5,940	\$ 6,311	\$ 5,245	\$ 4,064	\$ 2,910	\$ 2,136	\$ 1,701	\$ 1,574	\$ 1,130	\$ 1,102	\$16,240	\$13,803	\$12,807
Financial Products	\$ 2,001	\$ 2,007	\$ 1,852	\$ 590	\$ 479	\$ 377	\$ 361	\$ 240	\$ 224	\$ 328	\$ 270	\$ 195	\$ 3,280	\$ 2,996	\$ 2,648
<b>Total</b>	<b>\$20,215</b>	<b>\$19,695</b>	<b>\$22,007</b>	<b>\$16,121</b>	<b>\$14,312</b>	<b>\$10,664</b>	<b>\$ 8,980</b>	<b>\$ 6,402</b>	<b>\$ 5,005</b>	<b>\$ 6,008</b>	<b>\$ 4,549</b>	<b>\$ 3,841</b>	<b>\$51,324</b>	<b>\$44,958</b>	<b>\$41,517</b>

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™

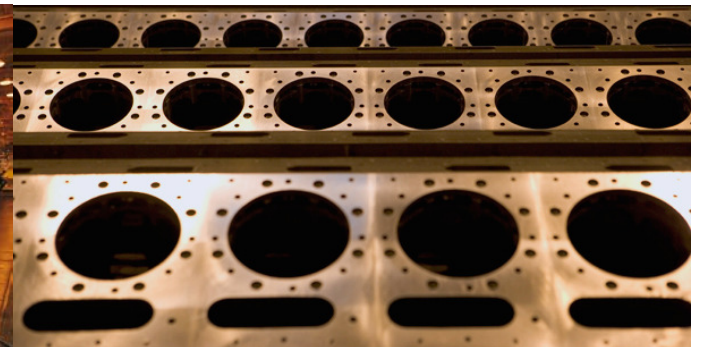
# Caterpillar Worldwide Locations





## Manufacturing Caterpillar Technology Leadership

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



# Caterpillar Gas Engines



- **All Caterpillar gas engines are built on the frame of diesel engines for:**
  - Strength and long life
  - Large active engine population
  - Application synergy
  - Better parts availability
- **80% parts commonality with diesel engines**
  - Engine block
  - Crankshaft
  - Main bearings
  - Connecting rods
  - Cylinder heads

# Caterpillar Electric Power Experience

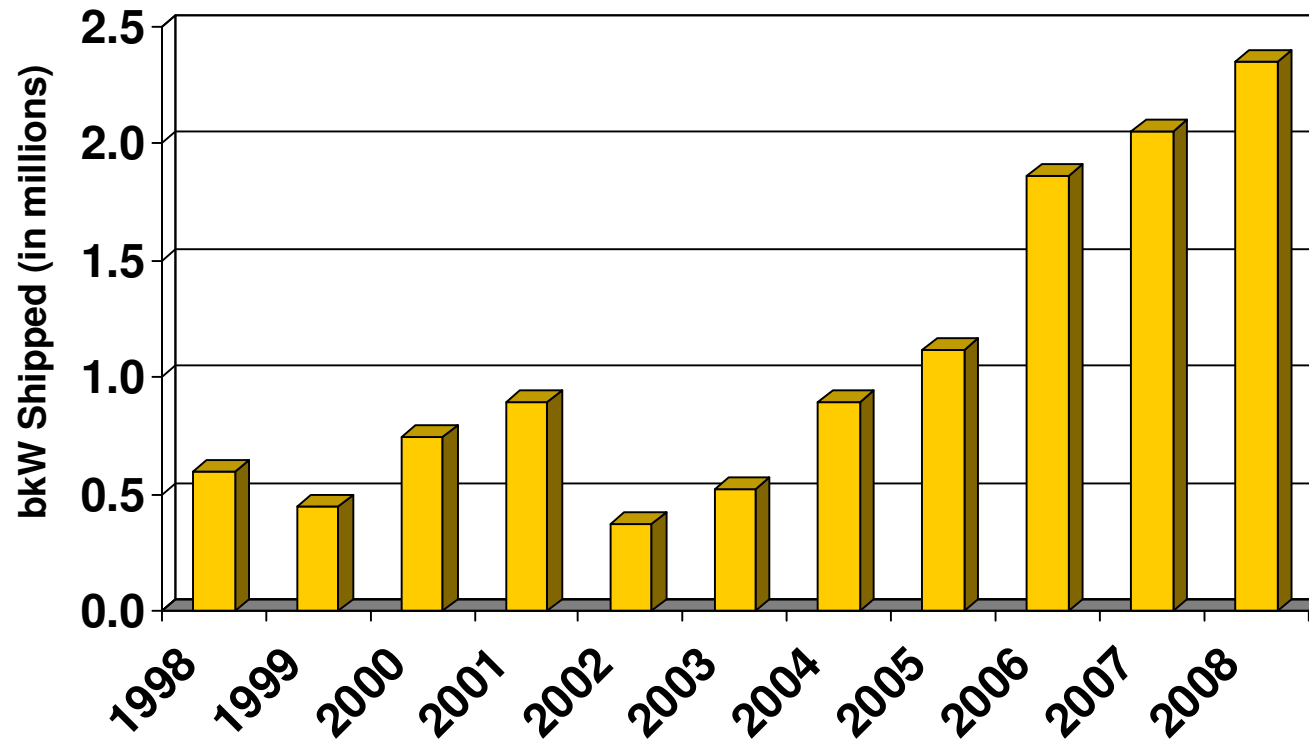


**70 Years Experience (1939 - Present)**  
**Over 450,000 Gas and Diesel Installations**  
**Worldwide**  
**(Installations over 350 kW)**  
**243,000 MW Installed Worldwide**

Cat brand electric power products

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™

# World Leader in Heavy-Duty Gas Engine Sales

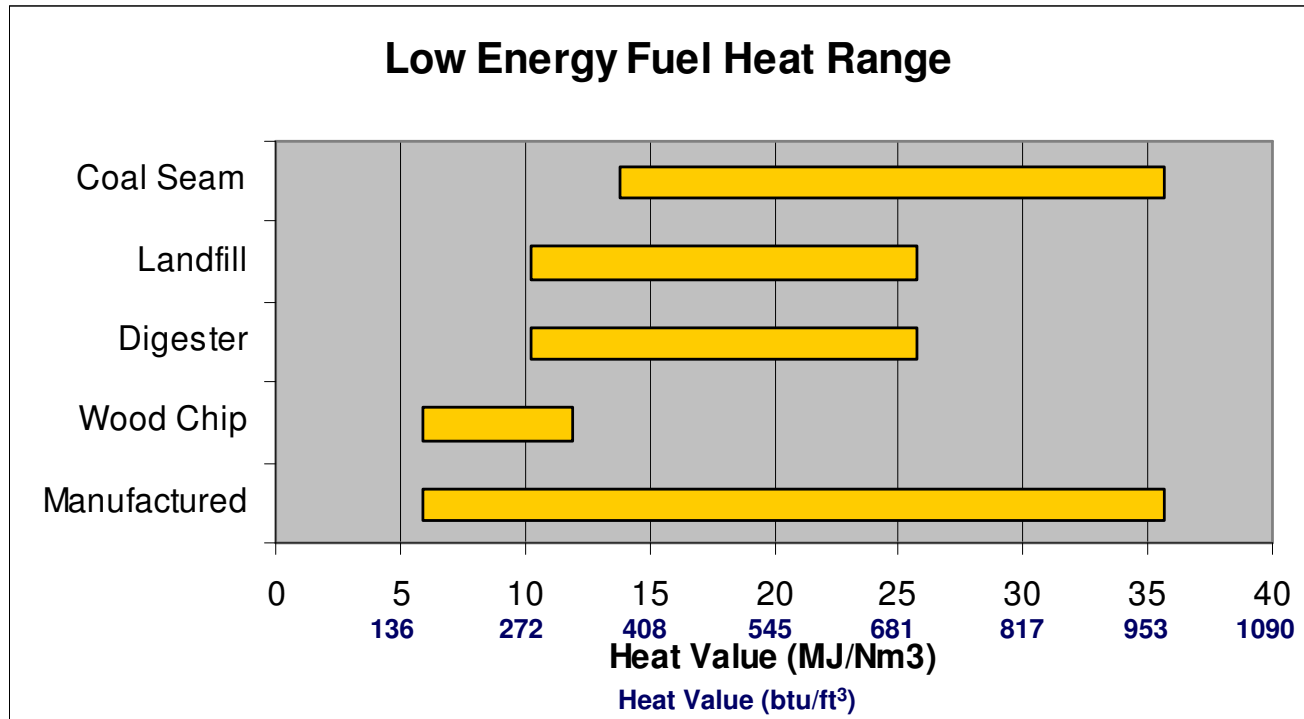


## EXPERIENCE

- **Caterpillar Shipped >11,200,000+ Gas bkW in Last Decade**
  - More than 42,000 stationary gas engines shipped
  - 2.9 billion estimated operating hours
  - 2.35 million bkW in gas engines shipped in 2008 alone



# Low Energy Fuels



- **Low Energy Fuel Heat Range**

- **Coal Seam Gas** 13.8-35.6 MJ/Nm<sup>3</sup> (370-955 btu/ft<sup>3</sup>)
- **Landfill Gas** 10.2-25.7 MJ/Nm<sup>3</sup> (275-700 btu/ft<sup>3</sup>)
- **Digester and Biogas** 10.2-25.7 MJ/Nm<sup>3</sup> (275-700 btu/ft<sup>3</sup>)
- **Syngas / Wood Chip Gas** 4.0-11.9 MJ/Nm<sup>3</sup> (160-320 btu/ft<sup>3</sup>)
- **Manufactured Gas** 4.0-35.6 MJ/Nm<sup>3</sup> (160-955 btu/ft<sup>3</sup>)



## Landfill-Gas-to-Energy

**CATERPILLAR**<sup>®</sup>  
TODAY'S WORK. TOMORROW'S WORLD.™



# Landfill Gas-To-Energy

## Description

Sanitary landfills produce large amounts of methane and CO<sub>2</sub> gas due to the natural biological digestion of the organic materials incorporated in the fill. Internal combustion engines are used to consume (destroy) the Landfill gas extracted from landfills with the aid of a gas collection system. The gas produced is composed of about 50 percent methane, about 50 percent carbon dioxide and a small amount of non-methane organic compounds.

## Industries

### Applications

Municipal Landfills

Private Landfills

### Heat Intensive Applications

Locations close to the landfill

Greenhouses

Chemical Processes

Food Processing

# Landfill Gas-To-Energy

## Caterpillar Advantage

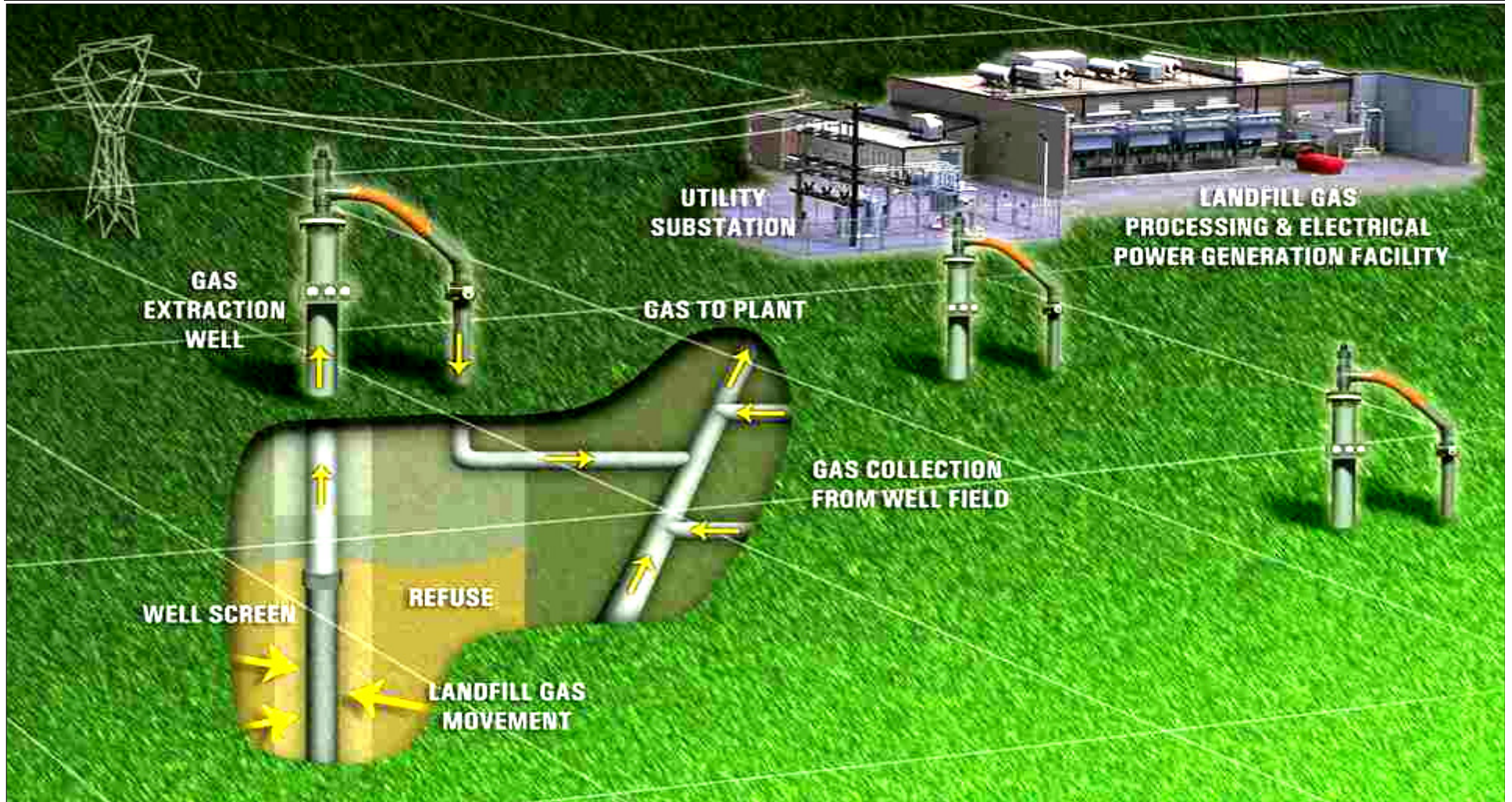
- 30+ years experience in the industry
- Engines designed to tolerate fuel contaminants (modified cooling systems, improved metallurgy)
- Factory supplied mobile solutions available
- Competitive owning and operating costs
- Total system efficiencies to 90+% with heat recovery
- Designed for utility parallel operation
- Systems backed by superior Cat parts and service networks

## Cat Product Available

kW range: 350-2000 kW



# Landfill Design



# Landfill Experience

- First commercially available landfill gas generator sets installed in Chicago Illinois USA in 1983.
- Over 1,550 MW of landfill product installed worldwide.
  - Continue to add over 150 MW/year
- Over 55,000,000 hours of operation on landfill gas.

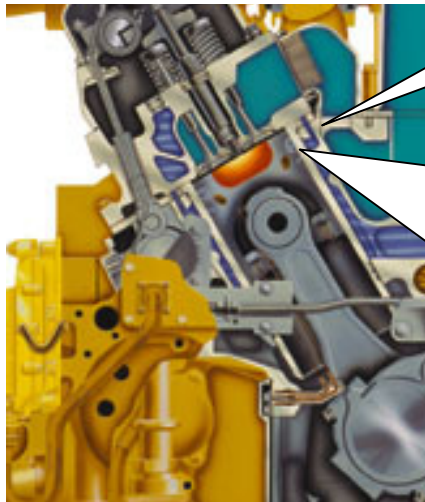


# Caterpillar Solutions to Landfill Gas Contaminants

- **Landfill gas contains corrosive contaminants**
  - 4 categories of corrosive contaminants:
    - Sulfur compounds
    - Halide compounds
    - Acids
    - Silicon compounds
- **Engines designed to optimize engine operation in landfill environment**
  - Corrosion resistant A/C core
    - Match current Caterpillar corrosive fuel requirements
  - Oversized corrosion resistant fuel system for very low inlet fuel pressure
  - Bright metals removed from areas that might contact fuel, blow-by with fuel borne contaminants

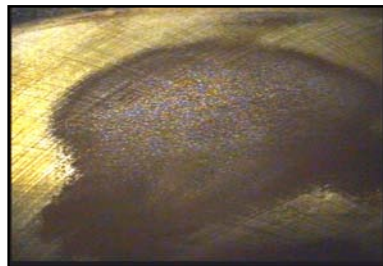
# Optimized Engine Jacket Water Temperature

- **110°C (230°F) Jacket Water outlet temperature**
  - Protects internal engine components from corrosion by preventing condensation of water, not allowing sulfuric and other acids to form
- **Positive crankcase ventilation**
  - With warmed intake air to prevent condensation and corrosion from blow-by gasses with fuel borne contaminants
  - Extends oil life



Piston Cooling Shelf: High water volume for proper top of liner cooling

Liner corrosion from condensed fuel contaminants at standard jacket water temperature





# Landfill Customer: Biogeracao Energia S.A.

## powerprofile LANDFILL

**CUSTOMER:** Biogeração Energia S.A.  
**LOCATION:** São Paulo, Brazil  
**MARKET SEGMENT:** Landfill

**Customer Requirement:** Continuous Power Using Landfill Gas  
**Scope of Supply:** Equipment –  
24 Cat® G3516 Generator Sets

**Services –**  
Engineering planning  
Project and logistics management  
Civil Construction  
Equipment testing  
Delivery, setup and installation  
Product support and maintenance  
Plant operation and monitoring

**Cat Power Dealer:** Sotreq S.A.  
São Paulo, Brazil



One of the world's largest single landfill-gas powered thermoelectric plants was commissioned in January 2004.

### POWER NEED

The transformation of domestic waste into a valuable commercial product is a necessity today. And for the city of São Paulo, Brazil, it is a reality that was created in a mere three months.

The Aterro Sanitário Municipal Bandeirantes landfill is the one of the largest sanitary landfills in the country of Brazil. The landfill receives approximately 7,000 tons of waste daily, which amounts to half of what is produced in the city of São Paulo (one of the world's largest cities, with a population of 16 million people.)

The Bandeirantes landfill was built 30 years ago. Its capacity to receive waste will come to an end in the year 2006 when the landfill will contain more than 30 million tons of waste. Over the years this waste will generate millions of tons of gases. These gases, if left untreated or flared (as was the landfill's previous practice), will contribute to global warming, as well as subject nearby communities to the negative effects of methane and carbonic gases.

The city of São Paulo, in cooperation with the landfill concession operator and with Biogas (the company that

owns and operates the landfill's gas collection and processing facilities) opted to take global warming prevention action with a landfill gas power generation plant. The 22 MW power plant has resulted in social, ecological and economic benefits for the city and its residents.

"The transformation of waste into sellable electrical energy is a worldwide need. The environmental advantages from collecting and utilizing methane as a power generation fuel have contributed to the reduction of hazardous gas emissions to the atmosphere," confirms Walter Amadera, Power Systems manager for Brazil.

### TOTAL SOLUTIONS

The landfill concession operator enlisted the assistance of Sotreq S.A., the Cat dealer for 75% of Brazil, including the city of São Paulo. Sotreq was selected to supply the power generation equipment and build the landfill gas power plant. The 22 MW installation consists of 24 Cat G3516 generator sets, rated at 925 kW continuous power. All the



Biogeração Energia S.A.  
São Paulo, Brazil

24 Cat gas gen sets producing 22 MW

- 170,000 MW-hrs/yr  
(enough energy for 58,000 homes)
- Reduces 1.5 MMt/yr CO<sub>2</sub>e initially
- 16 MMt CO<sub>2</sub>e in the next 16 years
- CER CO<sub>2</sub> value ~ \$240 mil (at \$15/Mt)

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



## Digester Gas

**CATERPILLAR**<sup>®</sup>  
TODAY'S WORK. TOMORROW'S WORLD.™



# Digester Gas

## Description

Sewage treatment, or domestic wastewater treatment, is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants.

## Industries

### Applications

Wastewater treatment facilities

### Heat Intensive Applications

Locations close to the landfill  
(Used to improve landfill gas quality)

Greenhouses

Chemical Processes

Food Processing

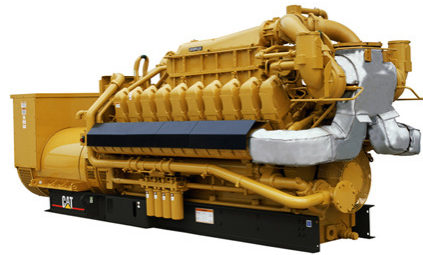
# Digester Gas

## Caterpillar Advantage

- Engines designed to tolerate fuel contaminants (e.g. high temp cooling)
- World class fuel efficiency
- Competitive owning and operating costs
- Total system efficiencies to 90+%
- Designed for utility parallel or 'island mode' operation
- Systems backed by superior Cat parts and service networks

## Cat Product Available

kW range: 50-4000 kW



**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™

# Digester Gas Customer: City of Hamilton

## powerprofile DIGESTER GAS

**CUSTOMER:** City of Hamilton  
**LOCATION:** Ontario, Canada

**Customer Requirement:** Win Ontario Ministry of Energy renewable energy program contract for digester-gas-fueled cogeneration system

**Scope of Supply:** Equipment –  
One Cat® 1.6 MW gas generator set powered by a Cat G3520C low-energy-fuel engine  
Fuel conditioning system, heat recovery equipment, switchgear and utility interconnections, PLC-based controls, and a sound-attenuated enclosure

**Services –**  
Turnkey design, construction, operation and maintenance with fixed-fee Customer Service Agreement

**Cat Dealer:** Toromont Power Systems  
Concord, Ontario, Canada



Toromont Power Systems installed this turnkey 1.6 MW digester-gas-fueled cogeneration system at the Woodward Avenue Wastewater Treatment Plant in Hamilton, Ont. It's powered by a Cat® G3520C gas engine configured for low-energy fuel.

City of Hamilton  
Ontario, Canada

One Cat 1.6 MW gas generator set, fuel conditioning system, heat recovery equipment, switchgear and utility interconnections, PLC-based controls, and a sound-attenuated enclosure

### POWER NEED

When the Ontario Ministry of Energy announced a renewable energy initiative in 2004, the City of Hamilton saw an opportunity.

Anaerobic digesters at the city's Woodward Avenue Wastewater Treatment Plant produced 6 million cubic meters of biogas per year at 65 percent methane. The plant burned some of the gas in a boiler for heating, but flared the majority of it.

Seeing the gas as a source of renewable energy, the city responded to a Request for Proposals from the Ministry of Energy with plans for a 1.6 MW cogeneration facility fueled exclusively with digester methane. The project would also ultimately meet a need for increased backup generation at the treatment plant, as identified by a power study.

The ministry selected the city's proposal through competitive bidding based on the price of energy per kilowatt-hour. It was one of ten winning projects totaling 395 MW of renewable generating capacity. The city then turned back to Toromont Power Systems in Concord, Ont., which had developed the project proposal, to build, operate and maintain the cogeneration plant.

### SOLUTION

To generate electricity, the city formed a corporate entity under the Ontario Business Corporations Act (OBCCA) called Hamilton Renewable Power Inc. (HRPI), with the City of Hamilton as the sole shareholder. Toromont Power Systems, which in 2002 had supplied the city with a 3.5 MW Cat® G3616 gas generator set for a district energy project in the downtown area, took turnkey responsibility for renewable energy project. The local office of Conestoga Rovers & Associates provided engineering and project management support through construction.

Toromont delivered the complete cogeneration system in a stand-alone module with a sound-attenuated enclosure. At the heart of the system is a Cat G3520C gas engine in a configuration designed to be durable and reliable in burning low-energy fuels without needing extensive fuel conditioning.

A specially designed cooling system elevates jacket water to the optimum temperature to prevent condensation of fuel-borne sulfur compounds and the formation of sulfuric acid, which can damage engine components. A crankcase ventilation pump ejects potentially acidic blowby gases and draws in fresh, filtered air. In addition aluminum and

"The dealer delivered the complete cogeneration system in a stand-alone module with a sound-attenuated enclosure. At the heart of the system is a Cat gas engine in a configuration designed to be durable and reliable in burning low-energy fuels without needing extensive fuel conditioning."  
"The facility operates continuously, fulfilling nearly all of the wastewater treatment plant heat load and 20 percent of its electrical load. Total cogeneration plant efficiency exceeds 80 percent. Projected simple payback on the cogeneration equipment is five years."

**CATERPILLAR®**

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



## Industrial Biogas

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



# Industrial Biogas

## Description

Water is often used in the processing of foods, beverages and ethanol made from agricultural crops. The waste water from the process is collected and treated as effluent in a digester plant. The anaerobic digestion of the effluent creates a biogas that consists of varying amounts of methane and  $\text{CO}_2$ . The methane can be collected for consumption in a gas generator set to create electricity while enabling emissions credits.

## Industries

### Applications

Food processing  
Beverage processing

### Heat Intensive Applications

Heat for facility process or cleaning  
Locations close to the facility  
Greenhouses  
Chemical Processes  
Food Processing

### Commercial Byproducts

Fertilizers  
Soil enhancement products  
Animal bedding

# Industrial Biogas

## Caterpillar Advantage

- World class fuel efficiency
- Competitive owning and operating costs
- Total system efficiencies to 90+%
- Systems backed by superior Cat parts and service networks

## Cat Product Available

kW range: 350-2000 kW



**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



# Industrial Biogas Customer: Guangzhou Zhujiang Brewery

Market Segment: Industrial Biogas

## POWER PROFILE

Guangzhou Zhujiang Brewery Group Co. Ltd.

### POWER NEED

Established in 1985, Guangzhou Zhujiang Brewery Group Co. Ltd. (GZBC) is a state-owned enterprise that brews, bottles and packages beer. With an annual production capacity of 15 million hectoliters, GZBC is the second largest brewery in China.

GZBC also prides itself on adopting innovative technologies and production techniques to enhance efficiency. For example, GZBC was the first Chinese brewery to adopt low-temperature membrane filtration technology and sterilization and antibacterial equipment in its bottling and packaging processes.

Since 2002, when GZBC collaborated with Belgium-based InBev (formerly Interbrew S.A.) to establish Guangzhou Zhujiang Brewery Joint Stock Co., Ltd., the company has continued to employ the most advanced brewing technologies from abroad to ensure GZBC's continued role as a leader in developing and manufacturing premium beer with highly efficient and environmentally responsible production processes.

In pursuit of such environmental responsibility, in 2005 GZBC began looking for a combined cooling, heating and power (CCHP) generator set system to enhance its current power capabilities. Because the production of biogas from grain and yeast byproducts at the brewery is seasonal, the design of the power system would need to accommodate variable load conditions.

GZBC turned to The China Engineers, Ltd. (CEL), and CEL sales manager Lin Wen Sheng, to provide a comprehensive CCHP system. CEL has more than 40 years of experience providing Caterpillar products and services to thousands of customers in Southern China. "CEL strives to offer excellent and timely services to customers," said Sheng. "And its enduring partnership with Caterpillar helps both Caterpillar and CEL deliver exceptional quality and support."

Another benefit CEL was able to offer GZBC was proximity: the distance between the brewery and CEL's maintenance workshop is only 6 kilometers. "It only takes 15 minutes to get to the site from CEL's repair center in Guangzhou, so we can respond very rapidly if GZBC needs us," said Sheng.

### SOLUTION

CEL began by presenting a comprehensive cost analysis to GZBC, including initial investment and operating costs, estimating that up to 95% of GZBC's biogas methane could be used by the new system. The new generator sets would make use of the plant's recovered biogas to generate power and would transfer waste heat (produced from the cooling and exhaust systems of the engine) into a cooling source.

To compensate for the variable biogas supply at the brewery, CEL provided generator sets of different output ratings: one Cat® G3508 gas generator set with a 460 kW, 380 V output rating and one Cat G3516 gas generator set with a 960 kW, 380 V output rating. Currently, the overall efficiency of the generator sets is up to 80%.

### RESULTS

GZBC has completed testing of the Cat generator sets and is in the process of completing their phased integration into the power supply of the brewery.

Caterpillar and CEL were able to design the CCHP system and its installation to meet the customer's unique demand that the power generation capacity be scalable to take advantage of the variable gas supply. The custom system has been a success—GZBC's current cost savings from the system is an estimated RMB400,000 (over USD58,000) per month.

For more information, please visit [www.caterpillar.com/ce](http://www.caterpillar.com/ce)



### CUSTOMER

Guangzhou Zhujiang Brewery Group Co. Ltd.

### LOCATION

Guangzhou, People's Republic of China

### CUSTOMER

#### BUSINESS ISSUE

Power generation for the cooling, fuel and waste-heat recycling systems for a brewery in the People's Republic of China.

### SOLUTION

- One Cat® G3508 460 kW gas generator set
- One Cat G3516 960 kW gas generator set

Design and economic analysis

### CAT DEALER

Lin Wen Sheng, Sales Manager,  
The China Engineers, Ltd. (CEL)

Guangzhou Zhujiang Brewery Group Co. Ltd.  
Guangzhou, People's Republic of China

Cat 460 kW generator set  
Cat 960 kW generator set

"The Cat dealer began by presenting a comprehensive cost analysis to the brewery, including initial investment and operating costs, estimating that up to 95% of their biofuel methane could be used by the new system. Currently, the overall efficiency of the generator sets is up to 80%. The brewery's current cost savings from the system is an estimated RMB400,000 (over USD58,000) per month."

LDX0019-00 October 2008  
© 2008 Caterpillar All Rights Reserved.  
CAT, CATERPILLAR, their respective logos, "ACTRA", "Caterpillar Yellow" and the POWER EDGE trade dress, as well as corporate and product identity used herein, are trademarks of Caterpillar and may not be used without permission.

CATERPILLAR®

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



## Ag Biogas

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



# Ag Biogas

## Description

Organic matter is flushed or loaded into large lagoons (pits), or sealed containers where bacteria in the natural anaerobic digestion process produce biogas (typically 65% methane and 35% CO<sub>2</sub>). The effluent can be heated to accelerate the process (38 degrees C or 56 degrees C). In many parts of the world, ag biogas is responsible for up to 10% of greenhouse gases. The methane can be collected for consumption/ destruction in a gas generator set to create electricity while enabling emissions credits.

## Industries

### Applications

Swine Farrowing/ Feeding  
Cattle Feeding & Milking  
Fowl Brooder House/ Feeding

### Heat Intensive Applications

Locations close to the operation  
Heat for operation facilities  
Heat for improved digester operation  
Greenhouses  
Food Processing  
Etc.

### Commercial Byproducts

Fertilizers  
Soil enhancement products  
Animal bedding

# Ag Biogas

## Caterpillar Advantage

- Extensive experience - unattended engine applications
- World class fuel efficiency
- Competitive owning and operating costs
- Designed for utility parallel operation
- Systems backed by superior Cat parts and service networks

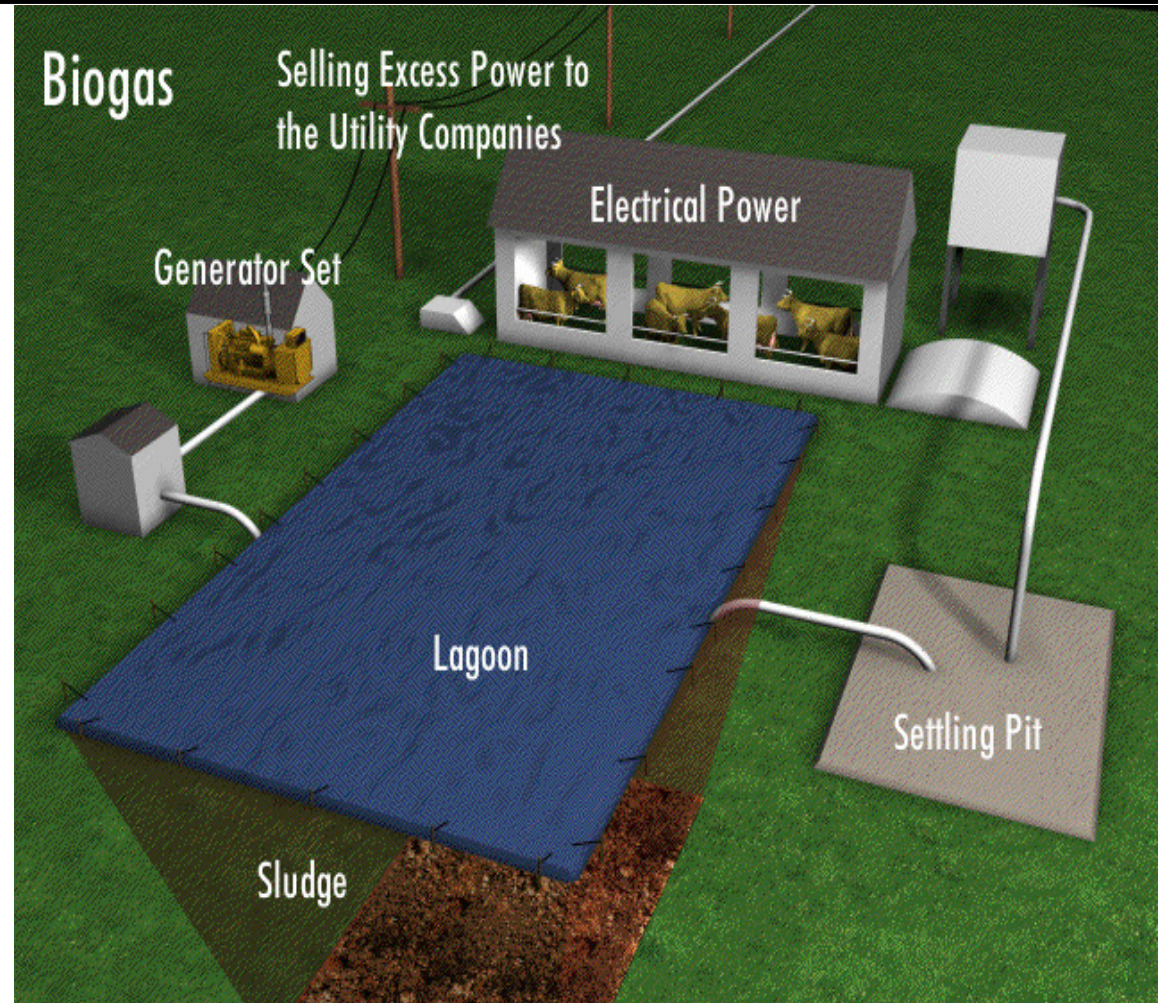
## Cat Product Available

kW range: 50-2000 kW



# Ag Biogas Plants

- **Biogas plants**
  - Methane and H<sub>2</sub>S generated during decomposition of organic wastes
  - Rarely will blowers be used to aerate effluent
    - Not cost effective... can hold effluent for longer periods of time
  - Engine heat is sometimes used to warm the mixture, promoting faster decomposition



# Ag Biogas Customer: Nong Rai Farm

Market Segment: Biogas/Sustainable Development

## POWER PROFILE

Nong Rai Farm

### POWER NEED

Nong Rai Farm was seeking a means of tapping its biogas resources to fuel electrical generators for on-site power. The farm partners with the CP Group, one of the largest food suppliers in Thailand, operates a feeder operation for more than 30,000 hogs in Rayong, Thailand. Nong Rai Farm consumes approximately 200 kW of power for blowers, drying systems, and other auxiliary needs associated with its operations. The manure produced by its hogs is piped into a digester pond, where it generates biogas that is used to fuel the generator sets. The generators produce power sufficient for all of Nong Rai Farm's electric power requirements.

Nong Rai Farm selected Caterpillar generator sets because of the anticipated long-term benefits of using their high-quality and reliable generator sets over other, low-cost gas generators, often modified from automotive engines. While Nong Rai Farms recognized that the initial investment in Caterpillar biogas-fueled generator sets would be higher, it was confident that the long-range savings associated with a reliable, durable platform would be significant. As the generator sets would be running continuously, it was important to work with a supplier that could provide guidance on engine care and also have parts available in a timely manner when necessary. Caterpillar was chosen because of its reputation for quality power generating equipment and extensive field validation of similar units operating on methane gas. Another consideration was its capability to provide local service and technical support for the installation through its factory-trained design and maintenance personnel at

Metro Machinery Co., Ltd. in Bangkok. In addition, the dealership possessed the experience and expertise necessary for both commissioning and maintaining power projects utilizing ag-biogas.

### SOLUTION

Metro Machinery Co., Ltd., installed two biogas-fueled Caterpillar generator sets at Nong Rai Farm. These gas generator sets are capable of producing a total of nearly 200 kW. In addition, control panels and automatic transfer switches were installed to ensure that the power generated is distributed reliably and efficiently. This project exemplifies sustainable development. It involves the capture of a waste gas, circumventing the harmful effects on the environment associated with methane migration. Furthermore, any energy created by the methane conversion in the generator set offsets the emissions that would be created if power was supplied by a standard coal-fired facility.

### RESULTS

Installation of the Caterpillar power system was designed to cut costs for electricity as well as utilize existing on-site biogas resources at Nong Rai Farm; it has met both of these goals. The Nong Rai Farm installation was completed in mid-2005 and has been operating successfully since it came online. Not only is the Nong Rai Farm power plant meeting all of the farm's electric power needs, it is saving the farm approximately 2.8 million baht annually that would have otherwise been spent purchasing electricity from the local power grid.



Nong Rai Farms

### CUSTOMER

Nong Rai Farm

### LOCATION

Rayong, Thailand

### CUSTOMER BUSINESS ISSUE

Continuous power generation for use by a feeder operation for hog production

### SOLUTION

- One Cat® G3406 gas generator set (105 kW)
- One Cat G3306 gas generator set (70 kW)

Design, installation, and commissioning of two generator sets and their control panels and automatic transfer switches, as well as periodic maintenance and overhaul services.

### CAT DEALER

Metro Machinery Co., Ltd., Bangkok, Thailand.

Nong Rai Swine Farm  
Rayong, Thailand

Cat® 105 kW generator set  
Cat® 70 kW generator set

“As the generator sets would be running continuously, it was important to work with a supplier that could provide guidance on engine care and also have parts available in a timely manner when necessary. Caterpillar was chosen because of its reputation for quality power generating equipment and extensive field validation of similar units operating on methane gas.”

EX30002-01 August 2006  
© 2006 Caterpillar All Rights Reserved.  
CATERPILLAR, the respective logos, "ACERT", "Caterpillar Yellow" and the POWER EDGE trade dress, as well as corporate and product identity used herein, are trademarks of Caterpillar and may not be used without permission.



# Application Leading – Agriculture (Methane Gas-to-Energy)

Biogas resources, these plants not only avoid the costs of purchasing heavy fuel oil and electricity but also reclaim valuable land that would otherwise have to be used to purify the factory's wastewater. By utilizing an anaerobic digestion system, organic matter decomposes in a contained environment to produce methane that is then consumed by the engine, thus virtually eliminating odor and pest issues caused by large scale decomposition of organic material.

## Using Biogas

Because of the impurities and inconsistencies in biogas, it must be either pretreated before use or used in engines that have been designed specifically for it.

A front-end gas-processing (or pretreatment) system can add significantly to a project's capital cost. System components must be chosen based on their function, reliability and resistance to corrosive damage from the impurities they remove. In theory, pretreatment should deliver near pipeline-quality gas, but that is seldom, if ever, economical. Therefore, the pretreatment system design usually requires a compromise: production of fuel pure enough to enable reliable engine performance under a reasonable maintenance regimen.

The level of pretreatment required is directly related to the quality of the biogas generated. For example, installations utilizing fuel with less than 80 percent relative humidity may not require any water filtration. However, fuel with 80 percent or more relative humidity or condensate may need to include a system that incorporates coalescing filters or cyclones to remove water droplets from the gas and trap solid matter. In addition, a gas compressor may be necessary to deliver fuel to the engine at the necessary volume and pressure.

The second option for ensuring the reliability of biogas-fueled engines is to design and build them to meet the more rigorous demands imposed by their fuel. While these modified low-energy fuel engines will function with untreated biogas, they will still require fuel conditioning and compressing, and they may need other fuel treatment steps under certain fuel conditions. These modifications add to the capital cost of the installation, but the capital and maintenance costs of pretreatment equipment can be reduced, sometimes significantly. The main design goals of engines that run on biogas are the following:

<http://www.cat.com/cda/layout?m=39300&x=7>



李长颖 / John C.Y. Lee

职位: 资深工程师  
**Position: Sr. Principal Engineer**  
**Caterpillar (卡特) Inc. and formerly**  
**with Solar (索拉) Turbines**  
**Incorporated**

学位: 华盛顿大学, 博士  
**Education: Ph.D., Univ. of**  
**Washington**

专长: 燃料, 燃烧, 系统整合  
**Specialty: Fuels, Combustion and**  
**System Integration**





## Coal Mine Methane

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™





# Coal Mine Methane

## Description

Methane gas is naturally occurring in coal seams. It is released during coalification process. One of the ways Kyoto participants pursue the goal of carbon reduction is through the Clean Development Mechanism (CDM). One of the most promising and effective greenhouse gases used in CDM projects is coal mine methane (CMM). Cat gas engines can “destroy” the methane gas to create electric energy while enabling emissions credits.

## Industries

### Applications

- Privately held coal mines
- State-owned coal mines
- Abandoned coal seams

### Heat Intensive Applications

- Locations close to the sight of generation
- Mine facilities heating and cooling
- Chemical Processes
- Food Processing

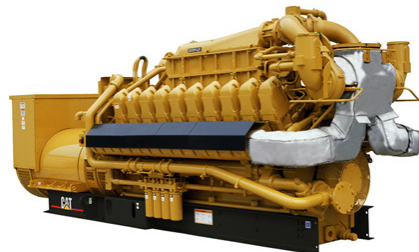
# Coal Mine Methane

## Caterpillar Advantage

- Engine tolerance with changing methane concentrations
- World class fuel efficiency
- Proven lowest owning and operating costs with maximum reliability
- Total system efficiencies to 90+% - proven combined cycle application
- Designed for utility parallel or 'island mode' operation
- Systems backed by superior Cat parts and service networks

## Cat Product Available

kW range: 50-4000 kW



# Coal Mine Methane Customer: Energy Developments Ltd.

Market Segment: Coal Seam Methane

## POWER PROFILE

Energy Developments Limited

### POWER NEED

Coal seam methane, viewed for years as a hazard requiring removal from underground mines, has become a viable fuel source for generating a significant amount of electricity at the Appin and Tower coal mines in New South Wales, Australia.

Located near vast reserves in the world's major coal-producing regions, BHP Billiton's Appin and Tower longwall mines produce two million tons per year of clean coking coal within the 2.1m- to 3.5m-thick Bulli Seam that is part of the 49,000 m<sup>2</sup> Sydney Basin. A March 1996 report by the New South Wales Department of Mineral Resources estimates that the Sydney Basin and two other New South Wales basins have the combined potential to yield as much as 511 billion m<sup>3</sup> of recoverable gas.

The Appin and Tower sites constitute what is arguably the largest coal seam gas energy project in the world, and one of the world's largest reciprocating engine-generator installations of any kind. Consuming 600,000 m<sup>3</sup> of coal seam gas per day (supplemented when necessary by natural gas from Moomba, Australia), the generating equipment delivers a combined 94 MW of continuous capacity to the local utility grid.

To convert the Appin and Tower coal mines into this significant energy-generating resource, Energy Developments Ltd. (EDL), based in Brisbane, Queensland, looked to Cat dealer Energy Power Systems Australia to provide a total of 94 Cat® G3516 natural-gas-fueled generator sets driven by lean-burn, low-emission

reciprocating engines. Dedicated to driving positive and sustainable change, these generator sets were designed by Caterpillar for coal seam methane energy projects and other low-energy fuel applications. An ideal fit for the Appin and Tower project, these engines would be capable of operating on methane gas, as a reliable and economic solution.

### SOLUTION

The coal seam energy project began in 1994 with EDL's installation of two prototype Cat generator sets at the Appin site to test their performance on the coal seam methane. Previous engineering and feasibility studies had also evaluated the use of large-scale gas turbine prime movers. Despite some concern that multiple reciprocating generator sets would pose challenges with service, parts and consumable supplies, analysis found that the engine-based system was the most attractive solution based on both capital and long-term operating costs.

This initial evaluation was followed in December of 1995 by Energy Power Systems Australia's shipment of the production generator sets. 54 of the G3516 generator sets were delivered and installed at the Appin site, with the remaining 40 going to the Tower site.

The G3516 generator sets are driven by 16-cylinder, lean-burn engines operating at 1,500 rpm and rated to produce 1,030 kW of continuous power. The engines' lean fuel mixture is controlled by an electronic system designed by EDL that regulates the air/fuel ratio for maximum performance and minimum emissions under varying load, fuel and temperature conditions.



Aerial view of the Appin Power Station showing Caterpillar generator sets.

### CUSTOMER

Energy Developments Limited

### LOCATION

BHP Billiton's Appin and Tower Coal Mines  
New South Wales, Australia

### CUSTOMER BUSINESS ISSUE

Coal seam gas reciprocating engine-generator installation

### SOLUTION

94 Cat® G3516 reciprocating engines (coupled to SRA brushless generators)

### CAT DEALER

Energy Power Systems Australia

CATERPILLAR®

Energy Developments Limited  
BHP Billiton's Appin and Tower Coal Mines  
New South Wales, Australia

94 Cat 1,030 kW generator sets

"Consuming 600,000 m<sup>3</sup> of coal seam gas per day (supplemented when necessary by natural gas), the generating equipment delivers a combined 94 MW of continuous capacity to the local utility grid."  
"Through a progressive maintenance program, EDL has safely extended time between major overhauls from the standard 40,000 hours to more than 60,000 hours in some cases."

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™

# Coal Mine Methane Customer: Jincheng Sihe Mine



Jincheng Sihe Mine  
Shanxi Province, China

60x 2 mW Cat gen sets in a combined  
cycle steam turbine application producing  
120MW @ 1060m (3,500 ft) altitude

- Largest CMM project worldwide
- 840,000 MW hrs/yr sold to utility
- 233,600 GJ heat recovered (winter only)
- System efficiency of 80%
- 2.9 MMTCO<sub>2</sub>e CERs
  - Economic value: \$45.3M/yr @\$15US)

<http://www.cat.com/cda/layout?m=8703&x=7&f=177263#/methane/>

# Application Leading – Mining (Coal Mine Methane Gas-to-Energy)

## Sustainable Application of Reciprocating Gas Engines Operating on Coal Mine Methane Gas

John C.Y. Lee, Caterpillar (China) Investment Co., Ltd., johnylee@cat.com  
 Thomas Teo, Caterpillar (China) Investment Co., Ltd., tao.thomas@cat.com  
 Choon Hwa Tney, Westrac Inc., Caterpillar Dealer, N.E. China, ch.tney@westrac.com.cn

### Abstract

Coal provides 25 percent of global primary energy needs and generates 40 percent of the world's electricity, according to the World Coal Institute. The People's Republic of China produces the largest amount of hard coal – an estimated 2.5 billion metric tons in 2006 alone.

The anthropogenic release of methane (CH<sub>4</sub>) into the environment is a byproduct of the coal mining process and the global warming potential of this methane continues to draw attention globally. Stakeholders responsible for coal and power production are looking for ways to safely and economically mitigate the release of coal mine greenhouse gases.

Sequestering coal mine methane (CMM) as an alternative fuel for reciprocating gas engine generator sets is a mature and proven technology for greenhouse gas mitigation. Prior to commissioning CMM-fueled power systems, the methane gas composition must be evaluated. The project is then developed by utilizing an integrated systems approach.

As with any type of alternative energy, the economics of electric power CMM projects play a major role in the success of the project. Profiles of existing applications that document reliable and efficient utilization of CMM for gas reciprocating engines will be offered to illustrate the success of such systems.

There is considerable opportunity for growth in the Asia-Pacific region for electric power applications using CMM. Caterpillar's experience in this type of power generation has been proven successful at several sites in China and beyond, where the growing economy demands sustainable solutions to meet rising power needs.

**Keywords:** coal mine methane, reciprocating gas engines, sustainable development, alternative energy, electric power, system integration

### Introduction

The restructuring of China's economy and the resulting rapid growth of both agriculture and industry have contributed to a more than tenfold increase in gross domestic product (GDP) since 1978 – and that figure grows at a higher rate each year. In 2007 alone, the real growth rate of China's GDP was an estimated 11.4 percent. Measured on a purchasing power parity basis, China stands as the second-largest economy in the world after the United States. [1]

With this very swift economic growth comes swiftly increasing demands for power from both industries and consumers – China's energy consumption has more than quadrupled since 1980. In 2006, China's electricity usage reached 2,859 trillion kWh and natural gas consumption was approximately 55.8 billion cubic meters; estimated 2007 oil consumption equaled 5.93 million barrels per day. [1]

China's government recognizes the need for environmental responsibility in the pursuit of greater power production. The government has taken action with official governmental management programs like the nationwide campaign to reduce energy consumption launched in 2006. [2] The Kyoto Protocol, perhaps China's most important environmental commitment, is an international agreement under the United Nations Framework Convention on Climate Change that requires participating developed countries to reduce their greenhouse gas emissions below levels specified for each of them. These targets must be met within a five-year time frame between 2008 and 2012. [3]

<http://www.cat.com/cda/layout?m=39300&x=7>

Figure 1. Typical Fuel (CMM) Composition and Physical Properties

Component	Symbol	Units	Pipeline Natural Gas	CBM	CMM*
Methane	CH <sub>4</sub>	vol %	92.3	85.9	40.0
Ethane	C <sub>2</sub> H <sub>6</sub>	vol %	2.5	3.8	---
Hydrogen Sulfide	H <sub>2</sub> S	vol %	---	---	---
Oxygen	O <sub>2</sub>	vol %	---	2.1	12.6
Nitrogen	N <sub>2</sub>	vol %	3.5	8.2	46.8
Others	---	vol %	1.8	0.0	0.6
Lower Heating Value	LHV	MJ/Nm <sup>3</sup>	33.2	32.5	13.4
Caterpillar Methane Number	MN	---	80	86	100

\*Represents one particular site at one particular time

Figure 2. Methane Emissions [Metric Ton of CO<sub>2</sub> Equivalent (MtCO<sub>2</sub>eq)] from Coal Mining Activities

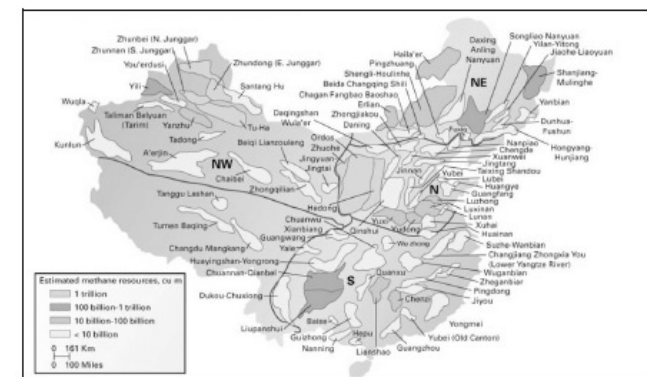
Regions	1990	1995	2000	2005	2010	2015	2020
Africa	9.7	10.7	9.3	8.4	8.2	8.2	8.7
China/CPA <sup>1</sup>	152.1	177.3	145.5	162.5	170.5	196.6	213.9
Latin America	5.4	5.3	6.9	7.6	8.4	9.5	10.7
Middle East	0.3	0.3	0.4	0.4	0.4	0.4	0.5
Non-EU Eastern Europe	1.0	1.0	1.9	2.3	3.0	3.9	5.3
Non-EU FSU <sup>2</sup>	142.0	84.4	67.6	59.5	58.6	57.0	55.6
OECD/DEU <sup>3</sup> & EU	188.0	154.3	124.6	123.2	121.5	116.7	116.3
SE Asia	18.1	18.3	20.8	24.3	27.9	33.1	38.5
World Totals	516.7	451.5	376.9	388.1	407.6	425.6	449.5

<sup>1</sup>CPA = Centrally Planned Asia

<sup>2</sup>FSU = Former Soviet Union

<sup>3</sup>OECD/DEU = Organization for Economic Cooperation and Development (Member States at 1990)

Figure 4. China's Coal Basins and Coal Bed Methane Resources

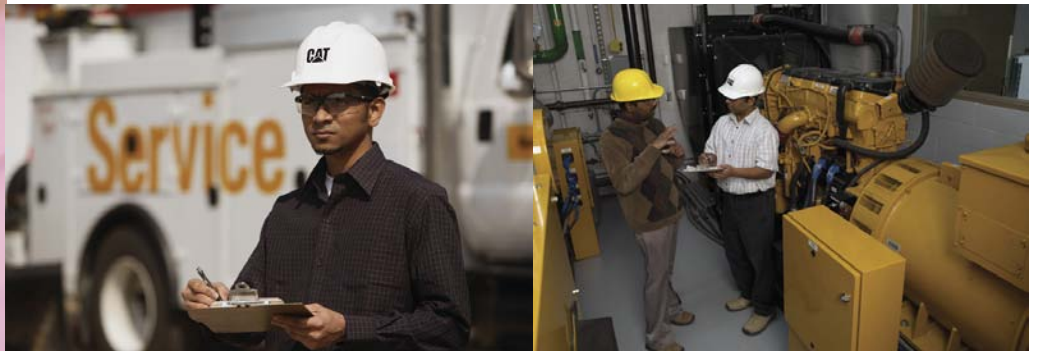


**CATERPILLAR**<sup>®</sup>  
 TODAY'S WORK. TOMORROW'S WORLD.™



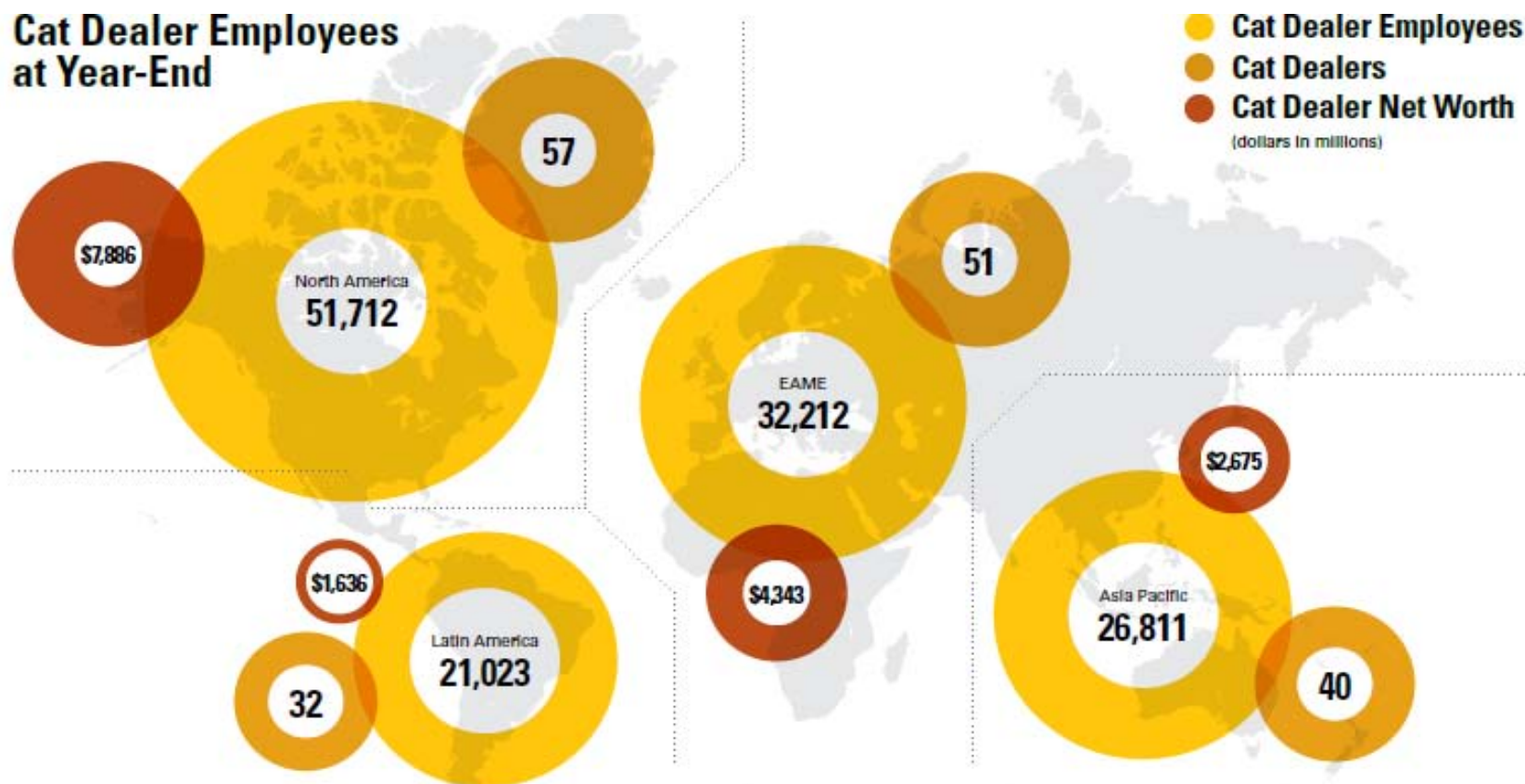
## Dealer Experience/Consulting

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™



# Over 131,000 Dealer Employees to Support Cat Products

## Cat Dealer Employees at Year-End



	North America			EAME			Asia Pacific			Latin America			Total		
	08	07	06	08	07	06	08	07	06	08	07	06	08	07	06
Cat Dealer Employees	51,712	52,583	51,530	32,212	28,796	28,611	26,811	22,518	21,620	21,023	17,485	15,647	131,758	121,362	117,408
Cat Dealers	57	58	59	51	50	50	40	40	40	32	33	33	180	181	182
Cat Dealer Net Worth	\$ 7,886	\$ 7,588	\$ 6,687	\$ 4,343	\$ 3,095	\$ 2,566	\$ 2,675	\$ 2,079	\$ 1,637	\$ 1,636	\$ 1,405	\$ 1,254	\$16,540	\$14,167	\$12,144

**CATERPILLAR®**  
TODAY'S WORK. TOMORROW'S WORLD.™

# Product Support – Operation and Maintenance

## SERVICES

- Oil Analysis
- Coolant Analysis
- I-R Analysis
- Particle Counting
- Product Inspections
- PM Services
- PM Kits
- Customer Service Agreements
- Repair Options
- Exchange Components
- Management Software
- Convenient Locations
- Training Materials
- Training
- Product Support Staff
- Used Equipment
- Quality Rebuilds
- Parts Inventories
- Used Parts
- Field Service
- Quality Repair Facilities
- Genuine Parts
- Salvage Capabilities
- Equipment Management Consultations
- Technical Support
- Trained Professionals
- Reusability Expertise
- Warranty / Goodwill Administration
- Special Tooling
- Inspection Services
- Flexible Financing
- Equipment Rental
- Remote Monitoring



## GUIDANCE

- Application materials written by industry experts, including Application & Installation Guide Books and white papers.



# Why Select Caterpillar Total Gas Power Solutions?

- **PRODUCT**

- Technology leader commitment to R&D
- Broad spectrum of Caterpillar's gas product offering allows best-fit solutions to customers
- Package system solutions
- Cat engines are well known for durability and reliability
- Best island mode performance in industry (DG)
- High temp jacket water for maximum tri-generation/CHP heat recovery
- Optimized corrosion resistance maximizes low energy application performance
- Wide range of gaseous fuel applications

# Why Select Caterpillar Total Gas Power Solutions?

- **PEOPLE**
  - Before the sale:
    - A&I engineering capability and total systems provider
  - After the sale:
    - Strong dealer product support network
    - Qualified field service engineers
  - Enterprise committed to sustainable development

# Why Select Caterpillar Total Gas Power Solutions?

- **EXPERIENCE**
  - Global industry leader
  - 70 years in the business
  - Established relationships with project developers
  - 450,000 gas and diesel installations worldwide
    - Installations over 350 kW
  - 243,000 MW of Electric Power systems installed worldwide

# Why Select Caterpillar Total Gas Power Solutions?

- **DISTRIBUTION**
  - Spare parts availability worldwide
  - Global distribution centers enable timely delivery
  - 131,000 factory trained dealer employees to support your products/applications in region