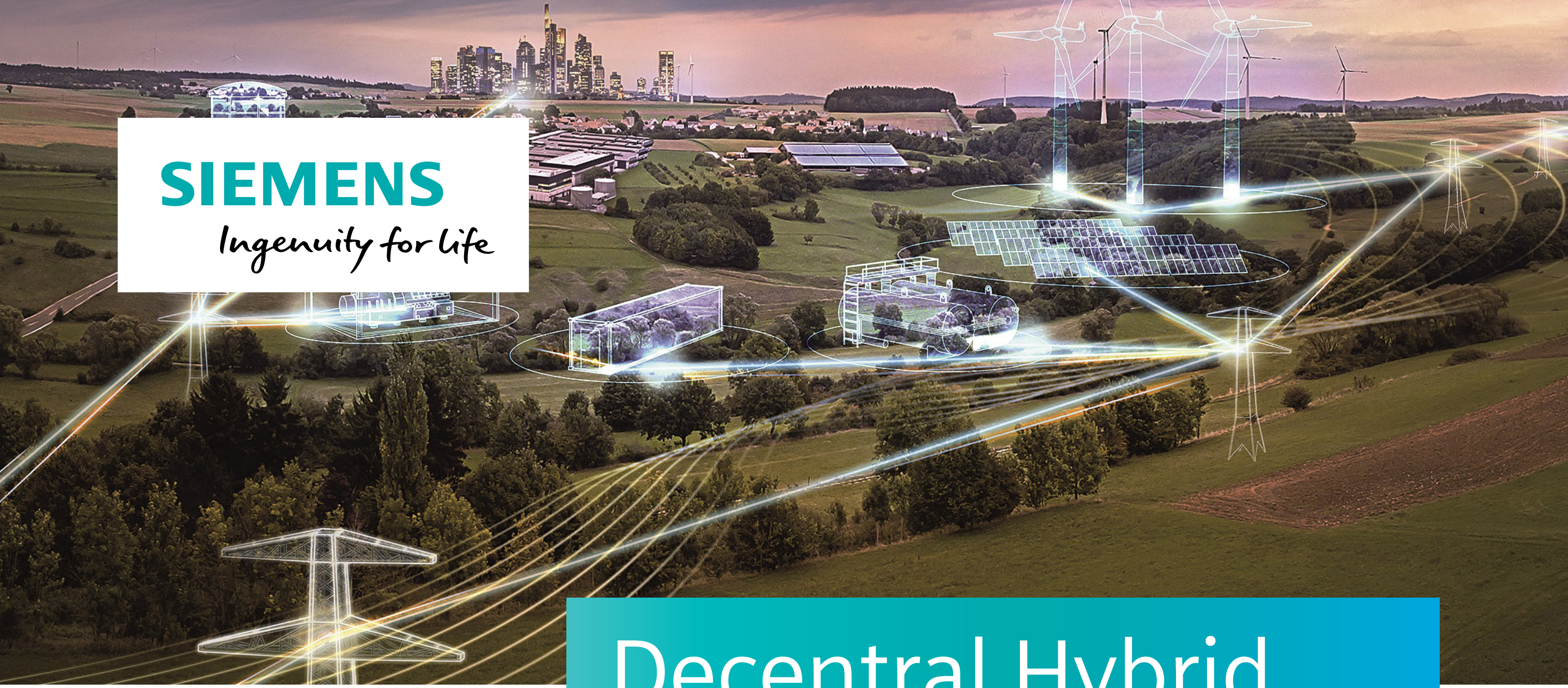

SIEMENS
Ingenuity for life

Decentral Hybrid Solutions

Making a greener energy future a reality.

The electricity grid has been described as the most complex machine humankind has ever constructed, with over 7,300 power plants and 160,000 miles of transmission wires in the U.S. alone. At the macro level, electricity is generated at centralized locations by an array of technologies, fed through substations and transformers into a web of high-voltage transmission lines that typically crisscross regions or nations only to arrive at distant substations before low-voltage distribution to consumers. The central station paradigm of producing electricity by large-scale utility power plants located near fuel sources, moving electricity to the location of the demand via wires, and distributing the electricity to individual consumers has been the model of utility operation for over a century. These large power plants have relied heavily on fossil fuels, especially coal, the most carbon-intensive fossil fuel, to generate electricity and heat. A greener and more modern power plant solution is now possible.

Breaking the Centralized Utility Model

The conventional station utility model for many years has relied on the combustion of fossil fuels, principally coal-fired generation, that produce greenhouse gases (GHG). Many scientists believe there is a strong link between GHG emissions and rising global temperatures, which has led many governments to institute decarbonization policies to encourage a shift from coal to renewable energy and natural gas. Some governments have gone so far to institute a ban on the construction of new coal-fired power plants.

Siemens wide portfolio of technologies can be integrated into a decentralized hybrid solution meeting the requirements of grid operators and also the needs of individual users of highly flexible, reliable, green, and reasonably priced electricity.

Government subsidies, liberalizing of regulatory policies, and the rapidly falling cost of wind and solar photovoltaics have produced the expected shift from coal to renewable energy electricity production as evidenced by its rapid growth over the past decade. Also, many countries have switched from coal to natural gas for existing and new construction of baseload power plants as natural gas produces about half the GHGs compared to coal per unit of energy consumed.

However, the intermitent nature of renewables has created operating challenges for many grid operators who are responsible for ensuring electricity supply always meet electricity demand. This endless balancing act is critical for efficient and reliable grid operation as transmission-level energy storage technology is in its infancy. Grid operators and power plant owners favor increased construction of more decentralized, dispatchable greener energy power plants that are capable of supporting reliable grid operation. For users, grid outages or disruptions cause expensive production losses and volatility in prices. In response, Siemens has a wide portfolio of technologies that can be integrated into a decentralized hybrid solution that addresses not only the requirements of the grid operator for locally dispatchable resources for grid stability but also the needs of users for highly flexible, reliable, green, and reasonably priced electricity.

Decentral Hybrid Solutions – The New Paradigm

Siemens Decentral Hybrid Solutions (DHS) is a customized energy system consisting of one or more power generation technologies electrically connected through a microgrid and managed by a proprietary Siemens master system controller to economically optimize operations for the owner. Figure 1 illustrates how a variety of power generation technologies may be integrated within a microgrid to form a DHS.

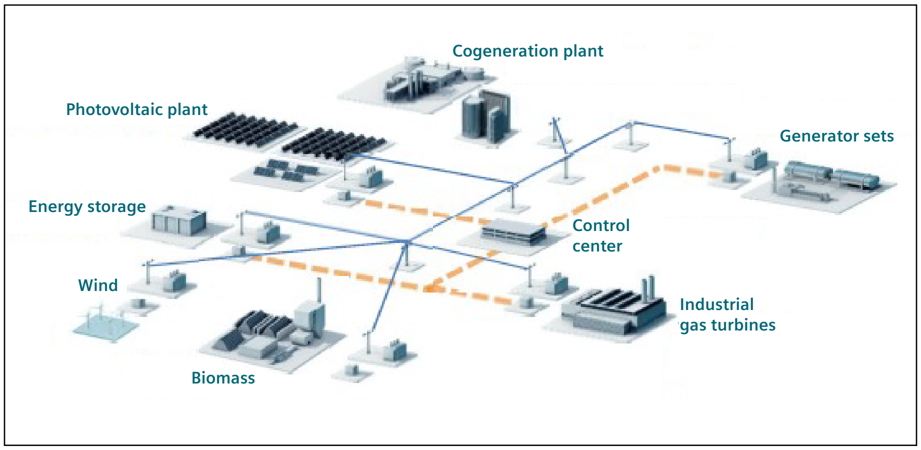

Figure 1: Integrating proven energy technologies with a Siemens custom-designed DHS.

A cogeneration or combined heat and power (CHP) plant may also be connected to an industrial host producing the facility's capacity and covering its demand requirements as well as supplying its thermal energy needs, such as steam or hot water. At a location where grid reliability is foremost, equipment may be configured to provide internal redundancy or to produce electricity with a minimum carbon footprint. The volatility of electricity prices may also cause some businesses to consider self-generation as an attractive risk-mitigating alternative or to reduce overall electricity costs. The equipment alternatives available are limited only by the customer's desires. As a fully-integrated power system supplier, Siemens can develop the entire project, from concept, financing, implementation, to commercial operation (Figure 2).

Figure 2. Siemens Joint project approach and project development concept.

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Table 1 illustrates a partial list of potential technologies that may be integrated into a Siemens DHS. Diverse equipment may be synchronized to the microgrid for many purposes, including distributed generators (e.g., biogas-fired reciprocating engines and natural gas-fired combustion turbines) for peaking, equipment that provide baseload electricity and thermal energy, wind and solar resources producing intermittent power, possibly a natural gas-fired combined cycle power plant for baseload generation, and perhaps a battery storage system for peak shaving and load shifting.

Table 1. DHS Options

There are many combinations of well-proven Siemens technologies that can be integrated into a single system to serve the customer's energy needs. The application "type" for a particular technology is shown in parentheses. A DHS may consist of multiple technology types to satisfy a variety of demand types, such as system reliability, operating flexibility, desired emissions profile, or available fuel.

Technology Type		Demand Type
Gas-fired Cogeneration (Aero and industrial turbines)	→	Electricity (baseload) + Thermal energy (steam, hot water) and/or absorption chillers (cooling)
Gas-fired Combined Cycle	→	Electricity (efficient, baseload) + Thermal energy (steam)
Gas- or Diesel-fired Engines	→	Electricity (efficient, fast start, peaking) + Thermal energy (hot water) and/or absorption chillers (cooling)
Wind and/or Solar (PV) + Batteries	→	Electricity (intermediate load + peak shaving + load shifting)
Solar (Thermal) + Thermal Energy Storage	→	Electricity (intermediate load + peak shaving + load shifting) and/or Electricity (baseload with natural gas supplemental firing)
Solid Fuel/Biomass Steam Generators	→	Electricity (base or intermediate load) + Thermal energy (steam, hot water)
Solid Fuel/Biomass Gasification	→	Electricity (base or intermediate load) + Thermal energy (steam, hot water)
Geothermal	→	Electricity (baseload)
Small-scale Local Hydro Power	→	Electricity (peaking)

DHS Adapts to Shifting Requirements

Extending the power grid to unserved populations has been public policy in most countries for many years. It has also been an effective solution for meeting soaring electricity demand in the past until more power plants could be built; however, small-scale operation of dispersed power generating equipment connected to a regional grid and controlled by a single balancing authority has proved to be a better solution for some customers. Better still, the Siemens DHS concept selects the optimum power generation technologies interconnected via a microgrid system so that the most economic system operation is achieved even as site-specific variables change.

Siemens DHS concept selects the optimum power generation technologies interconnected via a microgrid system so that the most economic system operation is achieved even as site-specific variables change.

The DHS has the further benefit of connecting, from the viewpoint of the grid, as a single unit to the grid and dispatched as such by a remote system operator. Further, the DHS may disconnect from the grid as a single entity and continue to operate autonomously during grid outages, periods of grid instability, or for other reasons. This capability is particularly important for critical applications, such as command centers, hospitals, or municipally-owned energy systems.

Regions that are isolated from the grid and are facing capital-intensive grid extensions may find DHS as a more economical alternative. Other isolated systems, such as those found on many Pacific islands, may integrate renewable wind and solar generation with refuse-derived biomass gas for power generation paired with advanced energy storage and controllers to eliminate expensive fuel oil imports.

This DHS arrangement will economically optimize the cost of electricity and improve system reliability for its residents (Figure 3).

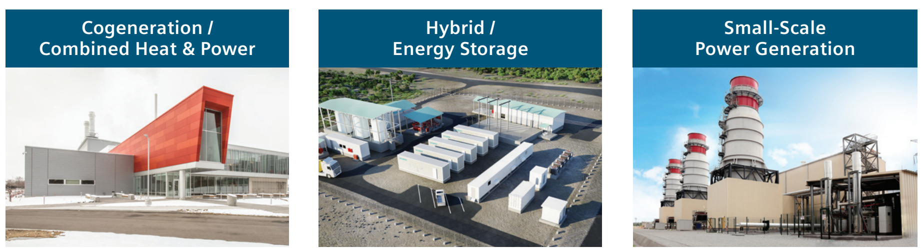

Figure 3. Siemens Decentralized hybrid systems enable various applications with different power plant sizes.

DHS Offers Vital System Integration

Superintending the DHS is a computer control and monitoring system that continuously optimizes the operation of the entire system. Economic optimization is based on the site's unique design requirements and considers internal variables (purchased fuel cost, electrical and thermal load, renewable energy output, load shifting and demand response potential, etc.) and external variables (cost of retail power purchases, the purchase price of ancillary services, demand charges, etc.). The Siemens Control Center (SCC) can operate the power plant at high efficiency to produce the customer's desired energy mix.The SCC monitors the power plant's performance with minute-level resolution to provide the greatest economic value to the owner.

The DHS may service geographic regions experiencing significant load growth must faster than new central station power plants or major transmission additions could be constructed.

The DHS controls can also be used predictively, such as preparing day-ahead and week-ahead schedules based on load demand and weather forecasting. However, its primary strength is in its ability to flexibly operate the integrated DHS over a wide range of steady-state and transient loads, including automatically importing and exporting electricity when the local grid tariffs offer sufficient financial incentives and "islanding" the DHS when necessary. If the load demand exceeds the capability of the DHS when the main utility grid trips, then its control system is capable of immediately shedding lower priority loads so that the DHS will continue to reliably service critical loads until the main utility grid is restored and the DHS is resynchronized to the grid.

The Siemens DHS designs are sufficiently flexible for multiple applications in difficult climates. Alaska, for example, is exploring the use of integrated power generation and thermal energy equipment in remote areas where the grid service disruptions are life-threatening events. These applications require reliable islanding operation and continuous seasonal heating steam heat. Other locations may have an abundance of wind power available and, when paired with energy storage, can supply reliable and resilient power to a microgrid. This design flexibility allows an owner to select the best equipment available to build the most efficient, cost-effective, and secure energy system possible.

Also, for many nations, grid optimization for renewable energy integration is occurring during periods of significant load growth. India, for example, is experiencing accelerated energy use per capita as its economy and population grow and electrification of many parts of the country continues to expand. The DHS, for example, may service geographic regions experiencing significant load growth much faster than new central station power plants or major transmission additions could be constructed. Highly flexible power plants are also desirable for industrial centers in the future as India moves from a service-based economy to one that is increasingly reliant on manufacturing and that continues to grow its export of such goods. The DHS is also a more environmentally acceptable option for meeting India's increasingly stringent emission laws and lowering its dependence on coal.

For other locations, physical security of operations may be paramount. Local Siemens DHS systems connected to a microgrid are more easily protected than generating assets located in different remote locations. The same may be said of cybersecurity. Another advantage of the DHS is electricity is generated in proximity to its usage thus avoiding energy losses that occur with long-distance transportation over transmission lines. For other applications, amalgamating renewable resources through a microgrid gives the owner maximum operating flexibility, from preferentially using green energy internally to selling the power to the utility grid to take advantage of green-energy subsidies, when available.

Siemens DHS Case Studies Demonstrate Flexible Design Possibilities

Siemens applications engineers can develop a site-specific DHS design that will meet your unique specifications and requirements. The following four case studies are illustrative of the flexibility of the DHS concept in different applications.

Industrial Cogeneration Power Plant

The typical industrial cogeneration power plant is connected directly to the grid and provides thermal energy as either steam or hot water to industrial processes. In this design, steam is also used for power generation in a steam turbine. This equipment arrangement is much more economical than purchasing electricity from the grid at retail price and firing a standalone steam generator. A battery energy-storage system enables the system to peak shave and shifts loads from peak to off-peak hours (Figure 4). The benefit of this system for a customer is a significant reduction in the cost of electricity and thermal energy.

A battery energy-storage system enables the system to peak shave and shifts loads from peak to off-peak hours.

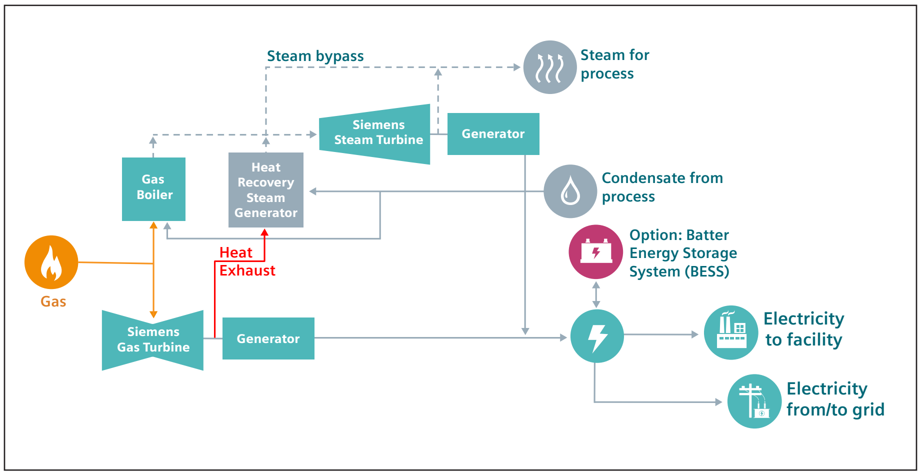

Figure 4. A typical industrial cogeneration power plant.

A variety of different power-generation technologies can be integrated into a common microgrid.

Small-Scale Power Plant with Islanding Capability

The cogeneration power plant illustrated in Figure 5 can also be designed to operate independently of the grid in the event of a grid outage, low voltage/frequency conditions, or when the grid is unstable. The integrated controls will sense a drop in voltage and/or frequency on the grid and open the main breaker. Also, the control system must continuously monitor the individual loads in the facility and the load produced by the turbines. When the main breaker opens, the control system will shed internal load by opening individual breakers in reverse order of service priority until load balancing is reached. When grid conditions allow, the power plant may again be synchronized to the grid and internal loads restored.

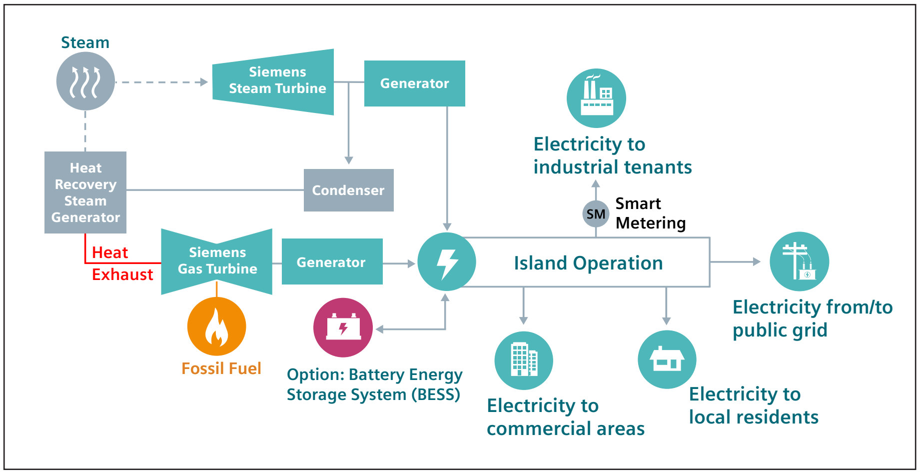

Figure 5. A typical cogeneration power plant with islanding capability.

Typical Hybrid Power System

The typical hybrid system, shown in Figure 6, illustrates how a variety of different power-generation technologies can be integrated into a common microgrid. Because the combustion turbines and diesel generators are capable of operating on speed control, islanding operation of this system is possible. A battery-storage system is also included for peak shaving and load shifting operations. When grid operations are restored, the combustion turbines and engine will shift back to frequency control and resynchronized to the grid.

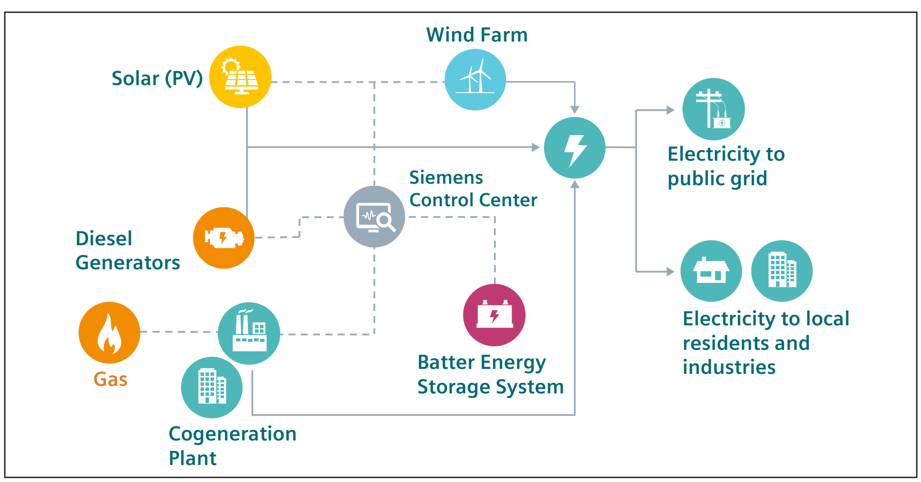

Figure 6. A unique hybrid power system.

Typical Hybrid Carbon-Neutral Power Plant

A carbon-neutral power generation facility is also possible, integrating biofuel-fired engines with solar and battery storage (Figure 7).

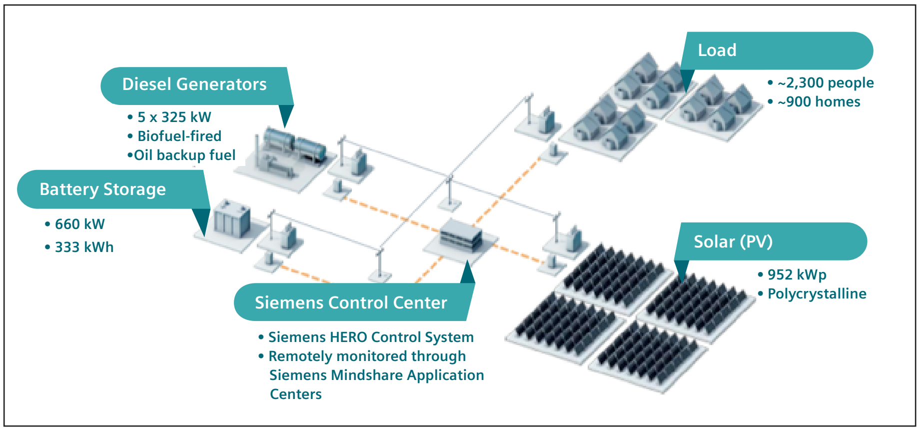

Figure 7. A unique hybrid carbon-neutral power plant.

Another important feature of the DHS is its ability to leverage multiple fuels as a means of risk mitigation or perhaps enable diversification away from fossil fuels.

Siemens DHS Bridges Institutional Barriers

Many developing countries have already embraced the fundamental transformation of their electricity supply systems away from the central station model towards decentralization power generation assets. However, successful decentralization of power generation has historically occurred with the convergence of three criteria: removing technological barriers, the availability of financing, and governmental regulation and policy support. The renewed interested in decentralizing power generation assets adds a new criterion: Sustainable energy solutions must be reliable and provide flexible operation, which are already features of the DHS concept.

Technological Barriers

Perhaps the most attractive characteristic of DHS is its use of technology proven in hundreds of installations. The Siemens product line includes combustion and steam turbines in various size ranges, heat recovery steam generators, as well as many other pieces of equipment in common use in the global power market today. Another important feature of the DHS is its ability to leverage multiple fuels as a means of risk mitigation or perhaps enable diversification away from fossil fuels.

Redundancy and reliability are built into the DHS design as an outage in one area doesn't cause an outage of the entire DHS. Siemens has one of the largest portfolios of decentral power generation products in the world today. Siemens also has the technological tools to integrate and optimize these products to produce a custom solution that will maximize the power plant's value to the customer.

Regulatory and Policy Barriers

Institutional barriers to decentralized power plants still exist across the globe, such as lack of feed-in tariffs and net metering agreements, little clarity about interconnection requirements, resistance to siting and permitting new facilities, exorbitant fees for standby power, and few utility offers of lower rates to retain potential DHS customers. Siemens has significant experience working with local authorities to obtain the necessary permits and regulatory clearances to construct power-generation projects and can thoroughly analyze power-plant operating economics.

Financial Services

Financing remains a roadblock for potential early adopters of DHS technologies because of high up-front and transaction costs, lenders inexperienced with DHS technologies, and lenders overestimating project risk. Siemens has successfully constructed DHS projects worldwide for many years and offers attractive project financing packages, from concept to operation.

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Making Energy Greener through Decentral Hybrid Solutions

Siemens DHS addresses multiple societal needs beyond merely generating electricity, from the production of thermal energy for space heating or other industrial uses to integrating renewable energy sources, such as solar and wind, with perhaps a form of energy storage added. Other "green" fossil fuel sources may also be included in this diverse mix of technologies, from biogas production and the use of unique indigenous fuels to natural gas-fired combustion turbines.

The challenge posed by this new decentralization paradigm is how to integrate existing, well-proven technologies under the umbrella of a smart control system capable of optimizing many combinations of disparate technologies to deliver clean, reliable, and economical power. The Siemens decentralized hybrid model offers a tailored customer solution from a company with an unmatched presence in the global power-generation industry.

Siemens Energy
4400 North Alafaya Trail
Orlando, FL 32826, USA

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