SIEMENS energy

Bioenergy

Covering By-Product Biomass Waste into Value

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Efficient power and heat

Biomass – it's a cross-vertical term that covers a wide range of technologies and markets, so at first it may seem hard to define. Broadly speaking, though, it's any organic matter derived from plants or animals that can be used as fuel to produce energy or "bioenergy". Biomass includes crops grown specifically for the production of energy, as well as agricultural waste, byproducts from forest harvesting and wood processing, and even municipal waste or what we usually call "trash".

In fact, the conversion of waste into energy is radically changing the way we think of power generation. Industries producing a large amount of process waste are finding that they can convert it into carbon-neutral energy to power their facilities or sell into the grid for additional revenue. Some industries, such as sugar processing, are even converting their waste into biofuels such as ethanol. And because the fuels and electricity generated from waste can significantly slash carbon emissions, governments are also providing additional incentives to increase the amount of bioenergy in the energy mix.

Additionally, most of those manufacturing plants which biomass or biowaste, also require electricity and heat (or hot steam) to run their manufacturing processes. Using this biomass generated as a by-product to produce the electricity and heat needed by themselves; not only solving the problem of biowaste management but also providing significant saving

Bioenergy is already one of the most important sources of renewable power. It accounts for roughly one-tenth of the world's total energy supply today – far more than wind and solar combined – and will only continue to grow as the world seeks to feed an ever-increasing demand for energy while drastically reducing carbon dioxide (CO_2) emissions.[1] With decades of experience, Siemens Energy is driving the trend with cost-effective and highly efficient biomass power plant technology solutions that can be tailored to companies' respective business models and industry requirements.

1 https://www.iea.org/fuels-and-technologies/bioenergy

Content

1. Biomass as a valuable fuel

The value of biowaste in power generation

In the past, the term "waste" in mills and factories referred to matter no longer thought to have value or use after the completion of a process. For example, the dry, pulpy residue left after the processing of sorghum into syrup or sugar cane into sugar – known as bagasse – was customarily thrown away, burned, or left in piles to rot. But bagasse and other biowaste byproducts such as husks, seeds, fiber, and wood chips are valuable sources of biomass that can be used to provide reliable, environmentally-friendly baseload power for process industries. In many cases, the use of biomass will even generate surplus power that can be sold into the grid, or further processed into biofuels.

More reliable than intermittent renewable energy sources such as wind and solar power, biomass can be stored and used as needed. Plus, it has the potential to considerably reduce greenhouse gas emissions while providing users with a self-sufficient energy system that can quickly adapt to changing conditions and needs. The advantages of biowaste as fuel are numerous, and, consequently, more and more governments are supporting biomass power generation.

Green power

When carefully planned, grown, and harvested in a sustainable manner, the resources for biomass are nearly unlimited. New energy or food crops and trees can always be grown – and, of course, biowaste will always exist. Burning it as a source of fuel lowers energy use by eliminating the need for waste disposal. Moreover, although the burning of these materials does release CO_2 emissions into the atmosphere, photosynthesis causes new crops and soil to absorb emissions, making biomass carbon-neutral and, in some cases, as with bioenergy power generation with carbon capture and storage (BECCS), even carbon negative.

Circular economies

Biowaste requires no further processing to be fed back into manufacturing as a source of power and creates a self-sustaining energy system that maximizes resources and energy efficiency while minimizing costs. This moves us away from the "take-make-dispose" model of linear economies and closer to true circular economies where all waste and byproducts are recycled as fuel or food for other applications. It also opens up the possibility for new business opportunities. Already today, more and more sugar cane mills are producing and selling bioethanol as engine fuel or fuel additive.

The increased energy efficiency, reduced energy costs, and a relatively inexpensive and secure baseload (costs will no longer depend on availability or decisions made by utilities), combined with low maintenance and service costs, offset the initial investment needed for installing a biomass power plant on-site, making energy-from-waste an economically viable solution. In addition, carbon pricing, feed-in tariffs, and other regional policies are making it increasingly more attractive.

Flexibility

Biomass power plants can also run on diverse biomass feedstocks, which adds to its viability and allows owners to adapt and change as necessary. Some seek more power for industrial processing, while others want to conserve and optimize resources. Others still are looking to supplement their revenue with power generation or biofuels.

In the sugarcane industry, for example, bagasse is only available as a feedstock during the six months of harvesting between June and December. However, because biomass can be gathered and transported, feedstocks other than bagasse are available for mill owners to continue to generate power or produce bioethanol throughout the year as an additional source of revenue.

Converting biomass into energy

The use of biomass to produce energy is nothing new. Strictly speaking, biomass has been used as a source of heat since we first discovered fire. New processes, fuels, and technologies for conversion, of course, have developed over the years, and there are currently four types of conversion technologies available. These include (1) direct combustion to produce heat, (2) thermochemical conversion to produce solid, gaseous and liquid fuels, such as syngas and hydrogen, (3) chemical conversion to produce biodiesel, and (4) biological conversion to produce liquid and gaseous fuels such as ethanol and biogas.

Direct combustion and steam turbines

Direct combustion is the simplest and most common method, and all biomass can be burned in a boiler to produce industrial process heat and high pressure steam to feed into a turbine connected to a generator. As the turbine rotates, the generator turns and electricity is produced. Efficiency is, of course, key, and any steam turbine should be tailored to meet the operator's specific demands and needs, including a customized steam path calculated individually for every project.

An industry example: Inside the sugar mill

Typically, in a sugar mill a cane shredder, powered by a small steam turbine, is used to crush the sugarcane before it goes into the milling train to extract juice and sugar. At the end of the milling train, rollers push out the residual fiber – or bagasse – left over the sugarcane extraction process. The bagasse can then be sent immediately into a boiler to generate the needed electricity and steam for the manufacturing process. Increasingly, more and more mill operators are turning to this method to generate carbon-neutral power for their own mills and open up new forms of business.On average, a small sugar mill might crush around 1,000 tons of sugarcane per day. Using all the biomass collected, it can generate up to 8 megawatts of power in full condensing cycle, maximizing the energy extracted from the steam. Because, in this case, the amount of electricity generated is more than what the mill requires for operation, the mill can use only part of the energy to generate steam, which the sugar manufacturing process also needs, and sell the rest into the grid for additional revenue.

The process is the same for medium-sized and larger sugar mills. In a medium-sized plant that can crush, for example, 6,000 tons of sugarcane per day, up to 49 megawatts of power can be generated. And in a large plant with a capacity of crushing 20,000 tons of sugarcane per day, up to 162 megawatts of power can be generated – all from by-product biowaste being used as biomass.

Average biomass yields in agricultural industries

Common examples of agricultural industries that generate by-product biowaste include sugarcane, rice, palm oil, and fiber. In nearly all of these production processes, around 30 percent of the incoming product's total mass after processing is leftover biomass. For example, for every ton of sugarcane crushed, around 70 percent of the mass is juice and sugar, while the remaining 30 percent – some 300 kilograms – is bagasse that can be used to generate power. This means that a medium-sized sugar mill with the capacity to crush 6,000 tons of sugar per day (tcd) can produce up to 49 megawatts of power and generate enough process steam to heat and cook the extracted sugar juice.

By comparison, the processing of rice produces 25 percent biomass as straw and husks, wood 35 percent as wood waste, and palm oil 41 percent as kernels and fiber – each with an attractive potential as bioenergy. One ton of rice husks, for example, can produce 410 to 570 kilowatt-hours of electricity and 290 kilograms of straw can produce 100 kilowatt-hours.

Energy harvested by area

Similarly, we can look at the potential yield of biomass through the typical amount of energy harvested per hectare (2.471 acres). Here, naturally, deviations will exist as climate, soil, and agricultural techniques change and develop, but on average we see a calorific value of approximately 20 megajoules per kilogram when the crop is completely dehydrated.

The potential of biomass

Fast facts about crops used for biomass

Energy harvested by area

* High deviations exist because of climate, soil and agricultural techniques. Yield ranking is not the same for a single field. Calorific value approx. 20 MJ / Kg, when completely dehydrated. One of the challenges is producing a pre-defined grade of biomass.

Bioenergy market forecasts and trends

In its June 2020 *Bioenergy Power Generation Tracking* report, the International Energy Agency (IEA) found that bioenergy electricity generation had increased by more than 5 percent in 2019. This was just shy of the 6 percent annual growth rate the IEA says is needed to keep the world on track to reaching climate change targets. In general, the IEA recommends that bioenergy should provide nearly 17 percent of final energy demand by 2060 to keep an increase in the global average temperature below 2°C above pre-industrial levels,1 and growth in bioenergy power generation in the coming years will continue to steadily rise, supported by new policies and market development.

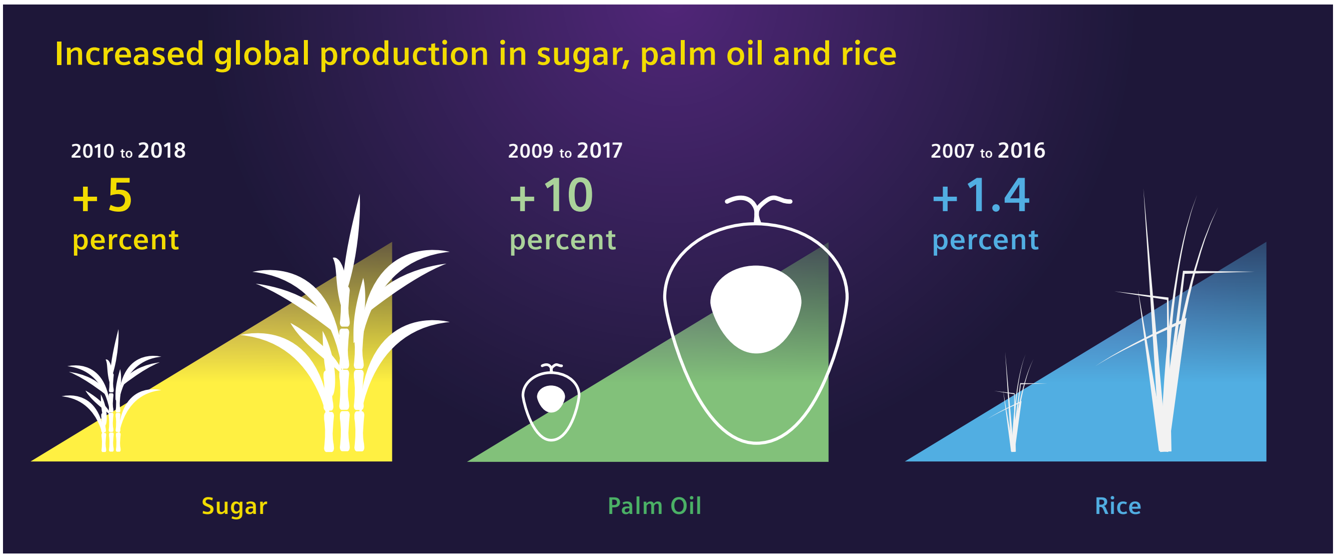
Feed-in tariffs and national climate action programs

In Japan, for example, the government is offering a high biomass power generation tariff of €0.20 per kilowatt, nearly double compared to traditional power generation. And in Thailand, Small Power Producer (SPP) and Very Small Power Producer (VSPP) programs have been launched to support the private sector in developing renewable resources such as biomass.

Similar support is occurring in the Philippines where the government has set renewable biomass portfolio standards to increase renewables in the national energy mix; and in Vietnam the Ministry of Industry and Trade has increased feed-in tariffs for biomass combined heat and power projects. Market developments in China, too, indicate that the use of bioenergy for power will continue to rise, with the introduction of a new clean-heat initiative. And in Brazil, the largest producer of sugarcane, the implementation of a federal program to curb carbon emissions by 10 percent in 2028 is expected to increase the production of transport biofuels and electricity generation from bagasse in existing and new mills.[2]

Increased global production in sugar, palm oil and rice

These are just a few examples of the various incentives and programs that countries worldwide are using to encourage biomass-based power generation. Other countries around the world, including India, Mexico and Turkey are also providing support for bioenergy development, especially as the amount of agricultural products such as sugar, palm oil, and rice have been rising over the past decade. From 2010 to 2018, the production of sugar increased by 5 percent. From 2009 to 2017, the production of palm oil increased by 10 percent. And from 2007 to 2016, the total consumption volume of rice increased at an average annual rate of 1.4 percent, with a steady rise in consumption expected to continue through to 2025. All of this means that we will continue to have more biomass available for energy production, and in regions where these industries are strong we can expect government policy to support biomass.



1 https://www.ieabioenergy.com/wp-content/uploads/2017/11/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf
2 https://www.iea.org/reports/bioenergy-power-generation

2. Biomass plant operators

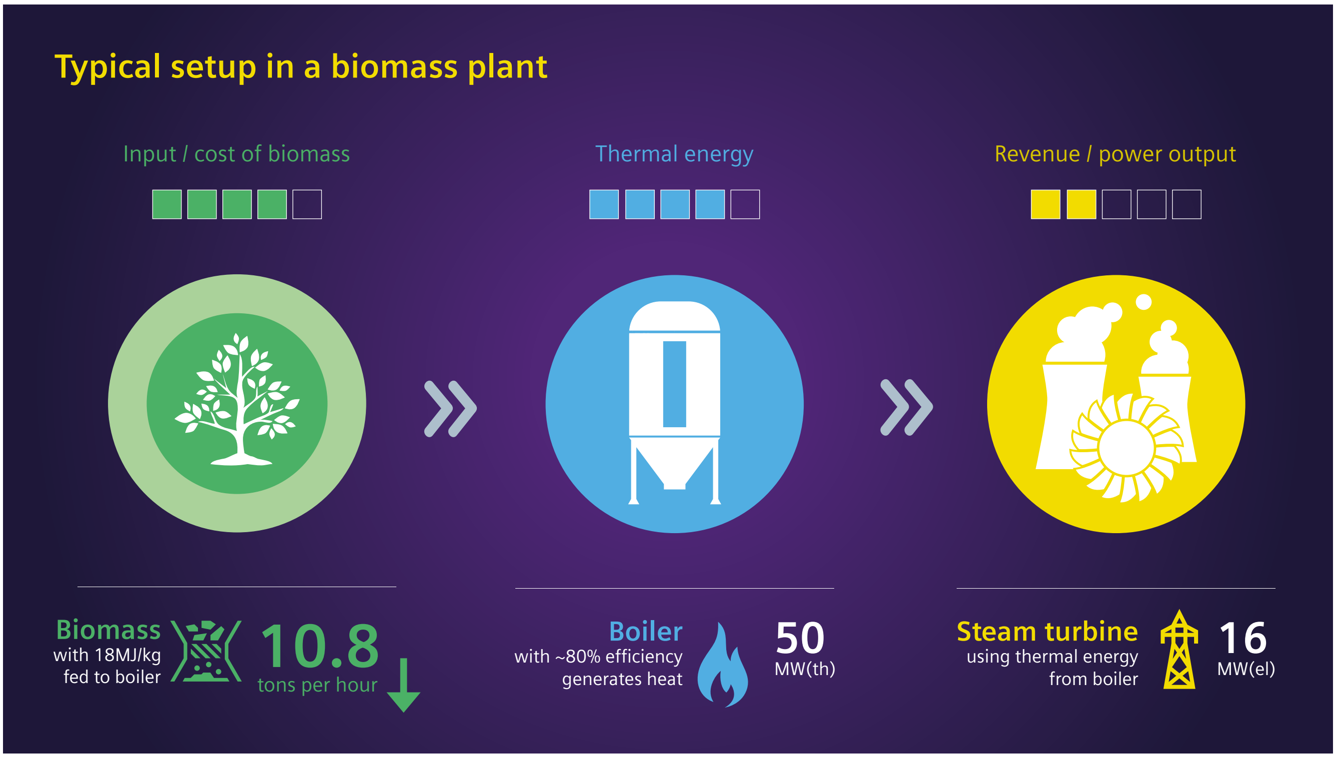
Operational targets: save fuel or increase output?

Depending on regional policies, operational conditions and business strategy, biomass plant operators will have different targets in focus. Some operators will want to reduce the cost of their fuel while maintaining the amount of power they generate. Others will want to increase power generation while maintaining the amount of fuel they use. This might be a more attractive option for the plant's bottom line, influenced by feed-in tariffs or internal demand.

Possible power output in a standard configuration

For example, if we look at a general overview of a typical sugarcane ethanol plant, we see that there are three important pillars: (1) the biomass, (2) the boiler, and (3) the steam turbine. The biomass is the power plant input, which is fed into the boiler and transferred into steam, and the steam causes the turbine to rotate, generating electricity. In a standard configuration, the plant would take in its full capacity of 12.5 tons of biomass per hour (18 megajoules per kilogram) and feed it into a boiler operating at around 80 percent efficiency. The thermal energy from the boiler rotates the blades in the steam turbines, creating around 16 megawatts of electricity.

One option for this configuration is to lower the cost of fuel, using less biomass input but harvesting the same amount of power. In this case, we could reduce the biomass input to 10.8 tons per hour while the boiler's operational capacity would remain the same and the steam turbine would continue to generate 16 megawatts of electricity. Another option is to generate a higher power output while using the same amount of biomass fuel – and hence to increase revenue. Here, the input and the boiler's operational capacity remain the same, but the steam turbine produces 18.5 megawatts of electricity. This might be a more attractive option for the plant's bottom line, depending on feed-in tariffs or internal demand.



Efficiency is key

The key for both options lies in efficiency. With reliable equipment and an optimized cycle, operators can increase efficiency in fuel and output by up to 7 percent, optimizing availability, costs and the amount of bioenergy sold into the grid

How to reach low fuel costs and increased power

Determine an optimal water-steam cycle

Bear in mind that planning a biomass power plant requires meticulous coordination and advanced technical expertise; the logistics involved can be demanding and – because of seasonal changes – biomass is subject to varying quality and availability. An experienced consultant can help you choose the right equipment and configuration that meets your company's needs. For us, the path to efficiency and maximal operations starts with determining the optimal water-steam cycle.

The water-steam cycle refers to the transfer of heat from the boiler to the steam turbine, as well as the eventual condensation that goes back to the equipment; it is the interplay of biomass conversion into energy and, in many ways, crucial to the efficiency of your plant. We determine your optimal water-steam cycle by looking at your main driver: Is it lower fuel costs? Increased power? Or overall plant efficiency? Your answers can help us establish the right combination of boiler and steam turbine based on power output, heat and emission requirements. Some customers will also want to evaluate a dollar- or euro-per-kilowatt value of their newly planned facility by maximizing the electrical output at a given amount of fuel or minimizing the fuel needed at a requested electrical output.

Other factors unique to each company and site will also influence your optimal water-steam cycle, including fuel costs, feed-in tariffs, the given space at the plant site, and whether it is a greenfield or a brownfield site, as well as ambient conditions (for example, in regions where weather varies from season to season, summer and winter use cases will have to be determined). And, of course, investment costs play a key role as well. After all, the solution not only needs to meet your requirements, it needs to be profitable, too.

Reheat or non-reheat solution?

Designing the best solution for your needs will also come down to collaboration with boiler suppliers, and Siemens Energy works with several leading boiler producers to deliver the best fit boiler for each application. In most cases, a one-pressure cycle boiler can be used, but will it be with or without a reheat steam cycle? This is an important question to answer. A reheat steam cycle removes moisture after the steam has expanded in the turbine, preventing condensation that can damage turbine blades while improving efficiency. Integrating a steam reheat system is one of the best ways to increase overall plant performance because raising the temperature of steam that flows from a high- to a low-pressure turbine allows for greater output using the same amount of fuel. It also allows less steam to flow directly to the condenser and requires a smaller cooling system. Here, again, investment costs will also guide your decision. Together with a boiler supplier, we prepare several options for our customers and then optimize their preferred solution. This includes finding the optimal feedwater end temperature in the cycle and the right number of bleeds and pre-heaters (three to seven) to be installed in the overall cycle for the best possible rate.

A case study: Saving fuel or increasing output

Let's take an example from a recent customer as case study. In this particular case, Siemens Energy was given the following situation: The customer required 100 megawatts electrical for operation; all options needed to use a water-cooled condenser; and, according to the team from the boiler supplier, inlet steam would be available at 540 °C / 130 bar.

The first option our engineers suggested was a single-casing direct-driven steam turbine, non-reheat cycle, with four bleeds / pre-heaters and a heat rate of 8,531 kilojoules per kilowatt-hour. The second option, however, aimed for higher efficiency with a more expensive reheat cycle, seven bleeds / preheaters, a dual-casing steam turbine, and, because of the reheat application, offered a much lower heat rate of 8,235 kilojoules per kilowatt-hour.

Looking at the boundary conditions, fuel cost, feed-in tariff and space requirements, along with overall investment costs, the customer ordered the first, less expensive option. Both options were viable, but the first better suited the customer's business case.

3. Increasing efficiency with reheat

It bears repeating: A reheat steam cycle is one of the best ways to increase overall plant performance. Set up with a dual-casing reheat turbine, reheat takes the “live” steam (aka high-pressure steam or HP steam) generated in the super heater and feeds it into the turbine for expansion. The steam is then taken to a reheater, maintaining a stable pressure but increasing the temperature of the steam again to its initial value. Reheated, the steam is sent into a combined intermediate pressure / low pressure (IP / LP) turbine, increasing the overall efficiency of the plant and preventing potential damage to turbine blades. Depending on your specific situation, a reheat system can make a big difference, especially if you have high fuel costs or high feed-in tariffs that increase the value of the electricity you produce.

Single-casing reheat vs. dual-casing reheat

Reheat steam turbines can be designed in different ways. There is a dual-casing solution (DCRH, the path of the steam is explained above), with a HP and a IP / LP turbine. Depending on the available steam volume flow and cooling conditions, it is beneficial to run the HP turbine and the IP / LP turbine geared, the HP turbine geared and the IP / LP turbine direct driven or, above a certain volume flow, the HP and IP / LP turbine both direct driven. So a range of 20 megawatts up to 250 megawatts can be covered in a best fit way. The dual-casing solution also contributes to overall plant efficiency, and losses in the steam path and sealing are significantly minimized.

The single-casing solution (SCRH) combines the HP and IP turbines into one machine, which means that operators will have to manage two inlets in a single turbine: The “live” steam goes into the turbine, then to the cold reheat line before going back to the boiler and returning with the hot reheat line back into the turbine. It’s a delicate technical solution, ranging from 75 to 175 megawatts, but for some customers the benefits outweigh any drawbacks.

For example, unlike the dual case, where both the HP and IP turbines have an optimal project-specific turbine size due to our comprehensive building block design philosophy, the SCRH’s selected size depends primarily on exhaust volume and rotor stability / rotodynamic behavior. The SCRH is also only feasible with a fixed speed 3000 / 3600 rpm, whereas the HP turbine in a DCRH can be an optimum speed turbine coupled to a gearbox if required (a gearbox is mandatory for power ranges below 100 megawatts). And each HP and IP turbine in the DCRH will have its own bearings, often allowing for smaller turbine sizes and smaller rotor diameters compared to SCRH. Currently, Siemens Energy is the only company offering a reheat option for smaller power units.

So with the DCRH solution you can have a well-optimized, project-specific turbine with higher overall efficiency, but the SCRH isn’t without its advantages either. For one, it has a smaller footprint and avoids taking up space in your plant. And because it has only one casing and two bearings (as opposed to two casings and four bearings), the service costs over the lifetime of the solution will be less.

Whether you opt for a reheat steam cycle or not, our steam turbines also have additional advantages that allow for steam extraction to be used for other industrial processes or sent to a boiler feedwater heater to improve overall cycle efficiency.

4. Siemens Energy portfolio for biomass

The main components in a biomass-based power plant are the fuel storage, the fuel handling plant, the boiler, the steam turbine generator (STG) island, and how power is sent to the grid. Siemens Energy's expertise covers all aspects of biomass power plant technology, and we can provide consultancy at an early stage, along with project development from beginning to end, expertise in environmental, health and safety concerns, and help with financing options. As an experienced manufacturer, we also offer a wide range of products for biomass power applications.

Our steam turbines: A range of benefits

Our steam turbines, for example, are the result of decades of experience in supplying, installing, and servicing equipment in biomass plants; with their leading efficiency profile and minimal outages, Siemens Energy steam turbines are exceptionally well suited to pure power and heat generation. Our turbines come with an enhanced lifespan, some 200,000 operating hours over the average steam turbine life of 25 years. They have quick ramp-up times and part-load operation capability to optimize efficiency and power output when there is not enough biomass, making sure that results are consistent from season to season. And they only require short installation times and no personnel with advanced skills.

In addition, Siemens Energy has been able to develop steam turbines that can achieve up to 180 bar / 565°C, a high temperature and pressure range that was once considered applicable only to coal-based power plants. Because of these high temperature parameters, we're able to improve the efficiency of the entire power plant and are more effective in reducing CO_2 emissions by up to 15 percent. All our steam turbines are also designed with a customized steam path, which is calculated individually for every project. In addition, we can extend major servicing schedules from six to eight years up to ten to twelve years. Thus, we manage to extract the maximum for our customers.

Our service through the entire life cycle

Along with state-of-the art equipment, we offer customizable service through the entire life cycle of our turbines, including modernization and upgrades, performance maintenance service programs (i.e., field factory repair, specialty services, and diagnostic solutions) that range from parts-only to operations and maintenance, plus customer training and plant assessments.

With turbines and services designed to accommodate customizable features and specific industries, we're confident of helping you find a configuration that achieves the optimum balance between highest efficiency and lowest cost – and moves us all closer to realizing a sustainable energy world. Siemens Energy can help you reach your targets.

Published by

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