Turbines for biomass plants

Siemens Energy
Oil & Gas Division

E O IP ST
Several factors are driving a change in energy consumption

<table>
<thead>
<tr>
<th>Demographic dynamics</th>
<th>Scarce resources</th>
<th>Climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population growth</strong> 7.5 bn. in 2020 (+1.1 bn.)</td>
<td><strong>Geopolitics</strong> 70% of global oil and gas reserves are located in just a few countries</td>
<td><strong>Climate goals</strong> Political programs aimed at long-term reduction in CO₂ emissions</td>
</tr>
<tr>
<td><strong>Megacities</strong> (&gt;10 mill. people) 27 megacities by 2025</td>
<td><strong>Oil price fluctuations</strong></td>
<td></td>
</tr>
</tbody>
</table>

Rising energy consumption

Due to efficiency increases: Growing electrification of society

Growing demand for "clean" electricity
A paradigm shift can lead to a sustainable energy system

<table>
<thead>
<tr>
<th>19th century</th>
<th>20th century</th>
<th>Start of 21st century</th>
<th>End of 21st century</th>
</tr>
</thead>
</table>
| Electrification of society | Large-scale generation of electrical energy | Challenges force process of rethinking:  
  - Demographic shift  
  - Resources becoming scarce  
  - Climate change | The new power age  
Electricity becomes the form of energy for most applications in daily life |

<table>
<thead>
<tr>
<th>19th century</th>
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</thead>
<tbody>
<tr>
<td>&quot;Age of coal&quot;</td>
<td>&quot;Age of fossil fuels&quot;</td>
<td>Increasingly decentralized, fluctuating power generation through renewable energies</td>
<td>Intelligent grids enable high percentage of renewable energies, e.g. with eCars and heat pumps</td>
</tr>
</tbody>
</table>

- **Energy system not sustainable**
  - Power supply limited to individual regions or urban areas
  - Fossil fuels, water power
  - No environmental concerns

- **Sustainable energy system**
  - Interconnected network grids, centralized power generation by "estimated" consumption
  - Fossil fuels, water power, nuclear power
  - Environmental awareness
  - Renewable energies, "clean" coal, gas, nuclear power

- **Challenges force process of rethinking**
  - Demographic shift
  - Resources becoming scarce
  - Climate change
<table>
<thead>
<tr>
<th>Siemens: Sectors and Divisions</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Energy</th>
<th>Healthcare</th>
<th>Industry</th>
<th>Infrastructure &amp; Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divisions</td>
<td>Divisions</td>
<td>Divisions</td>
<td>Divisions</td>
</tr>
<tr>
<td>Fossil Power Generation</td>
<td>Imaging &amp; Therapy Systems</td>
<td>Industry Automation</td>
<td>Rail Systems</td>
</tr>
<tr>
<td>Wind Power</td>
<td>Clinical Products</td>
<td>Drive Technologies</td>
<td>Mobility and Logistics</td>
</tr>
<tr>
<td>Solar &amp; Hydro</td>
<td>Diagnostics</td>
<td>Customer Services</td>
<td>Low and Medium Voltage</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>Customer Solutions</td>
<td></td>
<td>Smart Grid</td>
</tr>
<tr>
<td>Energy Service</td>
<td></td>
<td></td>
<td>Building Technologies</td>
</tr>
<tr>
<td>Power Transmission</td>
<td></td>
<td></td>
<td>OSRAM*</td>
</tr>
</tbody>
</table>

* In March 2011, Siemens announced its intention to publicly list OSRAM and, as an anchor shareholder, to hold a minority stake in OSRAM AG over the long term.
Biomass to energy: 
Main drivers

Emissions

- Combusting biomass feedstock to create electricity does not contribute to global warming
- avoids the release of other harmful emissions

Finances

- viable fuels are produced in many industries with no additional processing costs involved and further strengthening the financial viability of new plants on favorable sites
- many countries established subsidies to make biomass based power generation economically viable.

Fuel

- The possibility of firing a biomass plant on diverse feedstocks is an additional support for project economics and ensures security of fuel supply.
Reasons to use biomass for power generation

Biomass is a green fuel
- CO₂ neutral
- Promotes healthy forests
- Efficient waste disposal
- Promotes material re-use

Biomass is an economic fuel
- Baseload (24/7) power generation
- Gives value to waste
- Efficient use of by-products
- Supports many indirect jobs

Biomass is a flexible fuel
- Biomass can be converted to biofuels
- Biofuels can be used for transportation and power generation
- Biofuels can be solid, liquid, or gaseous
Biomass fuels

Some common fuels are
- forestry by-products
- agricultural wastes
- municipal wastes
- landfill gas
- syngas

There are also many next generation biomass feedstock in different stages of commercialization. These new fuels can dramatically scale plant sizes and the feedstock supply chain, creating significant opportunities for additional generation fleet expansion.
### Biomass combustion technology

#### Most common technologies

<table>
<thead>
<tr>
<th>Stoker Boiler</th>
<th>Fluidized Bed Combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Stoker Boiler Image" /></td>
<td><img src="image2.png" alt="Fluidized Bed Combustion Image" /></td>
</tr>
</tbody>
</table>

- **Stoker Boiler**
  - Direct fire combustion of solid fuels with excess air
  - Hot flue gases produce steam in the heat exchange section of the boiler

- **Underfeed**
  - Fuel and air under the grate

- **Overfeed**
  - Fuel from above the grate, air from below the grate

- **Fluidized Bed Combustion**
  - **Circulating Fluidized Bed (CFB)**
    - Most common technology used for fuels with variable characteristics
    - High relative efficiency
    - Low relative emissions of MACT pollutants
  - **Bubbling Fluidized Bed**
    - Requires auxiliary power for operation
    - Low relative emissions of MACT pollutants
Siemens solutions for biomass power plants

Whichever combustion technology is used in your biomass plant, a Siemens steam turbine will ensure high plant performance.

The flexible machines can even optimize electric output in plants which have steam parameters affected by inconsistent feedstock moisture content.
Siemens components for biomass power plants

Turboset:
- Steam Turbine
- Generator
- Control System
- Applications

Process Control:
- Automation
- Instrumentation
- Process Control

Transformers:
- Low Voltage
- Medium Voltage
- High Voltage

Switchgear:
- Busway
- Circuit Protection
- Panelboards
- SMARTGRID
- Switchgear

Operations:
- Balance of Plant Services
- Preventive Maintenance
- Remedial Maintenance
- Security Systems

Cooling Tower:
- Automation
- Drives
- Instrumentation
- Motors
- Motor Control Centers

Superheater:
- Automation
- Circuit Protection
- Drives
- Instrumentation
- Motors
- Process Control

Steam Turbine
Generator
Switchgear
Cooling Tower
Wood Chipper
### Siemens industrial steam turbines

<table>
<thead>
<tr>
<th>Type</th>
<th>Power Output (MW)</th>
<th>Steam parameters up to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST-040</td>
<td>0.3</td>
<td>40 bar, 400°C</td>
</tr>
<tr>
<td>SST-050</td>
<td>0.75</td>
<td>101 bar, 500°C</td>
</tr>
<tr>
<td>SST-060*</td>
<td>6</td>
<td>131 bar, 530°C</td>
</tr>
<tr>
<td>SST-100</td>
<td>8.5</td>
<td>65 bar, 480°C</td>
</tr>
<tr>
<td>SST-110*</td>
<td>7</td>
<td>131 bar, 530°C</td>
</tr>
<tr>
<td>SST-111*</td>
<td>12</td>
<td>131 bar, 530°C</td>
</tr>
<tr>
<td>SST-150*</td>
<td>20</td>
<td>103 bar, 505°C</td>
</tr>
<tr>
<td>SST-200</td>
<td>10</td>
<td>110 bar, 520°C</td>
</tr>
<tr>
<td>SST-300*</td>
<td>50</td>
<td>120 bar, 520°C</td>
</tr>
<tr>
<td>SST-400*</td>
<td>65</td>
<td>140 bar, 540°C</td>
</tr>
<tr>
<td>SST-500</td>
<td>100</td>
<td>30 bar, 400°C</td>
</tr>
<tr>
<td>SST-600*</td>
<td>150</td>
<td>165 bar, 565°C</td>
</tr>
<tr>
<td>SST-700*</td>
<td>175</td>
<td>165 bar, 585°C</td>
</tr>
<tr>
<td>SST-800*</td>
<td>250</td>
<td>165 bar, 585°C</td>
</tr>
<tr>
<td>SST-900</td>
<td>250</td>
<td>165 bar, 585°C</td>
</tr>
</tbody>
</table>

*Steam turbine types mostly used for biomass applications*
E O IP products
Steam turbine special features

Manufacture
- Pre-designed <10 MW
- Tailored from 10-250 MW
- Sales and proposal teams finalize specs with customer

Extraction feature
- Custom extractions and bleeds
- Tailored to specific applications
- Used for heating, cooling, or process steam

Reheat feature
- Can improve efficiency by 3%
- Dual-casing turbine design
- Considered a Siemens competitive advantage

... Siemens Steam Turbines
- Highly efficient, shortening the payback period of investments
- Ideal for Combined Heat and Power (CHP) such as district heating and industrial processes
- Increase in overall efficiency

- Maximizes output even with multiple feedstock
- Reduced fuel costs

- Robust and reliable turbines for a long plant life cycle
- Low total cost of ownership

- Compact, packaged unit design
- Simple installation and maintenance

E O IP is known throughout the industry for high-quality and leading efficiencies, which benefit the customer in both the short- and long-term
Reheat improves efficiency

Integrating a steam reheat system is one of the best ways to increase overall plant performance. Raising the temperature of steam that is going from a high to a low pressure turbine allows for greater output using the same amount of fuel.

- less steam is going directly to the condenser
- Geared single casing reheat solutions up to 60 MW available

smaller cooling system
Gas Turbines for biomass plants

Siemens flexible gas and steam turbines can be used to add value to both landfill gas and digestable feedstock assets.

A Siemens gas turbine can use biomass-derived methane mixed with other fuels. All gas turbines can come equipped with a dry-low emission combustion system which operates in a wide variety of load ranges and fuels.

Digester Systems

Digester systems are used mostly at facilities which have access to large amounts of feedstock that emits methane as part of its decomposition.

One unique feature of this type of gaseous biomass is that it can be used both for steam-generation and as a fuel for gas turbines.

Landfill Gas Fueled Gas Turbines

Landfill gas fueled gas turbines are usually located at existing landfills or in close proximity to facilities which process waste.

At existing landfills, naturally-occurring methane is collected through a piping system, cleaned, and then routed to a combustion turbine to generate power.
Siemens industrial gas turbines

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Type</th>
<th>Power Output (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 Hz</td>
<td>SGT-100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>SGT-200</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>SGT-300</td>
<td>8</td>
</tr>
<tr>
<td>50 Hz</td>
<td>SGT-400</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>SGT-500</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>SGT-600</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>SGT-700</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>SGT-750</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>SGT-800</td>
<td>50</td>
</tr>
</tbody>
</table>
Biomass experiences: Reference examples

Siemens Turbine generator sets have been deployed in over 93 biomass fueled plants in the past decade.

District Heating and Cooling
District heating and cooling using a cogeneration system is one of the most efficient applications of a biomass plant.

Usually a plant generates thermal energy at a centralized location and distributes steam to a larger number of buildings for space and water heating. District heating plants can provide higher efficiencies and better pollution control than localized boilers. The process is normally governed by the total heat load and electrical energy is supplied as an additional benefit.
Igelsta: SST-800
Sweden’s largest biomass plant

Inaugurated in March 2010, the plant uses a biomass fuel mix consisting of about 90% renewable fuels like forest refuse, wood chips, tree bark, and 10% non-recyclable waste paper and plastic.

It produces 200 MW heat and 85 MW electricity, the equivalent of heating 50,000 households and generating electricity for 100,000 residences.

Steam turbine: SST-800
Power output: 90 MW
Inlet pressure: 85 bar / 1,305 psi
Inlet temperature: 540°C / 1,004°F
Eccleshall: SST-110
1st carbon neutral town in UK

SST-110: Biomass Power Plant

The Eccleshall power plant was commissioned in September 2007 and has 13 MW of thermal and 2.65 MW of electrical capacity. The fuels burned range from woodchips, compost oversize, straw to miscanthus. The plant generates enough electricity to power 2,600 homes, equivalent to the local town of Eccleshall, making it one of the first carbon neutral towns in the UK.

Steam turbine: SST-110
Power output: 2.6 MW
Inlet pressure: 41 bar / 595 psi
Inlet temperature: 45°C / 842°F
Durham: SGT-300
Cut of greenhouse gas missions by 40%

The landfill gas fired University of New Hampshire (UNH) cogeneration plant supplies 85% of the heat and 75% of the power demand of UNH Durham. By utilizing a SGT with a Heat Recovery Steam Generator (HRSG), UNH Durham was able to cut their greenhouse gas emissions by 40%. UNH Cogen was recognized by the US Environmental Protection Agency (EPA) as a “Project of the Year 2010” at their Landfill Methane Outreach Program annual conference.

Gas turbine: SGT-300
Power output: 7.9 MW
Combustion system: Dual-fuel dry-low emissions (DLE)
Fuel: Landfill and natural gas, distillate fuel
Siemens Energy also has experience in other parts of the biomass value chain including additional equipment supply, engineering procurement & construction (EPC), and plant service.
Siemens steam turbines used for biomass: SST-110

**Key Values**

The **SST-110** is a dual-casing steam turbine connected to a single gearbox that is coupled with the generator. It can be used for high pressure/low pressure applications. For CSP applications, the SST-110 provides the highest possible cost efficiency and very high performance. The turbine supports the reduction of high heat gradients while providing a controlled extraction capability.

**Technical Data:**
- up to 7 MW
- up to 130 bar/1,885 psi
- up to 530°C/985°F
Siemens steam turbines used for biomass
SST-300

Key Values

- Power output: up to 50 MW
- Speed: ≤ 12,000 rpm

- Life Steam Parameters
  - Inlet Pressure: ≤ 120 bar / 1740 psi
  - Inlet Temperature: ≤ 540°C / 1004°F

- Extraction
  - Controlled (up to 2): ≤ 25 bar / 363 psi
  - Bleed: ≤ 350°C / 662°F
  - ≤ 60 bar / 870 psi

- Exhaust conditions
  - Back-pressure: ≤ 16 bar / 232 psi
  - District Heating: ≤ 3 bar / 34 psi
  - Condensing: ≤ 0.3 bar / 4.4 psi

Mainly applied for:
- District heating
- Industrial power plants, petrochemical, refineries
- Cogeneration, Combined cycle plants
- Biomass plants

The SST-300 is standardized single-casing geared turbine with customized reaction blading for generator or mechanical drive
Siemens steam turbines used for biomass: SST-400

Key Values

- Power output: up to 65 MW
- Speed: ≤ 8,000 rpm
- Live Steam Parameters:
  - Inlet Pressure: ≤ 140 bar / 2030 psi
  - Inlet Temperature: ≤ 540°C / 1004°F
- Extraction:
  - Controlled (up to 4): ≤ 45 bar / 510 psi
  - Bleed: ≤ 60 bar / 870 psi
- Exhaust conditions:
  - Back-pressure: ≤ 25 bar / 363 psi
  - District Heating: ≤ 3 bar / 34 psi
  - Condensing: ≤ 0.3 bar / 4.4 psi

Mainly applied for:
- Power generation industrial power & biomass
- District heating
- Combined cycle
- Mechanical drive

The SST-400 is a single-casing geared turbine with reaction blading
Siemens steam turbines used for biomass:
SST-600

Key Values

- Power output up to 150 MW
- Speed ≤ 18,000 rpm

- Live Steam Parameters
  - Inlet Pressure ≤ 165 bar / 2393 psi
  - Inlet Temperature ≤ 565 °C / 1049 °F

- Extraction (up to 7 in total)
  - Controlled (up to 2) ≤ 72 bar / 1044 psi
  - Bleed (up to 6) various pressure level

- Exhaust conditions
  - Back-pressure ≤ 72 bar / 1044 psi
  - District Heating ≤ 3 bar / 44 psi
  - Condensing ≤ 0.3 bar / 4.4 psi

The SST-600 is a single-casing turbine with front steam admission using reaction blading, geared or direct drive.

Mainly applied for:
- Chemical & petrochemical, pulp & paper
- Industry, steel works, mines, power plants
- Power generation: generator drive, industrial power
- Mechanical drive: compressor drive, BFWP drive
Siemens steam turbines used for biomass:
Industrial Steam Turbine – Enhanced Platform

Key Values SST-600

- **Power output**: 15 – 250 MW
- **Speed**: ≤ 18000 rpm
- **Live steam**
  - Inlet pressure/temp: ≤ 165 bar/≤ 565 °C
  - Inlet pressure/temp: ≤ 2393 psi/≤ 1049 °F
- **Controlled extractions (up to 2)**
  - Pressure, ext. valve: ≤ 72 bar/1044 psi
  - Pressure, int. valve: ≤ 55 bar/798 psi
  - Temperature: ≤ 480 °C/895 °F
- **Bleeds (up to 6)**: various pressure levels
- **Exhaust conditions**
  - Back-pressure: ≤ 72 bar/1044 psi
  - Condensing: ≤ 0.5 bar/7.25 psi
  - District heating: ≤ 3.0 bar/44 psi

**Improvements**

- Power output +75 MW
- Inlet temperature +25 K
- Extraction pressure +20 bar
Siemens steam turbines used for biomass: SST-700

### Key Values

- **Power output**: up to 175 MW
- **Speed**: ≤ 13,200 rpm

**Live Steam Parameters**
- **Inlet Pressure**: ≤ 165 bar / 2393 psi
- **Inlet Temperature**: ≤ 585 °C / 1085 °F

**Extraction (up to 7 in total)**
- **Controlled (up to 2)**: ≤ 40 bar / 580 psi
- **Bleed (up to 6)**: ≤ 415 °C / 779 °F

**Exhaust conditions**
- **Back-pressure**: ≤ 40 bar / 580 psi
- **District Heating**: ≤ 3 bar / 43 psi
- **Condensing**: ≤ 0.6 bar / 8.7 psi

### Mainly applied for:
- Waste-to-energy plants
- Solar-thermal plants
- Combined cycle plants
- Fossil fuel steam plants
- District heating plants

The SST-700 is a dual-casing turbine with impulse blading, consisting of a HP (geared) and LP turbine. Used for generator drive.
Siemens steam turbines used for biomass: SST-800

Key Values

- Power output: up to 250 MW
- Speed: \( \leq 5,000 \) rpm
- Live Steam Parameters:
  - Inlet Pressure: \( \leq 165 \) bar / 2393 psi
  - Inlet Temperature: \( \leq 565 \) °C / 1049 °F
- Extraction (up to 7 in total):
  - Controlled (up to 2): \( \leq 65 \) bar / 943 psi
  - Bleed (up to 7): various pressure level
- Exhaust conditions:
  - Back-pressure: \( \leq 72 \) bar / 1044 psi
  - District Heating: \( \leq 3 \) bar / 44 psi
  - Condensing: \( \leq 0.3 \) bar / 4.4 psi

Mainly applied for:
- Processes in industry and power generation:
  - Compressor drive, generator drive
  - Combined cycle, Seawater desalination, industrial CHP
  - Petrochemical industry, pulp and paper mills, steel works, mines

The SST-800 is a single-casing turbine with center steam admission using reaction blading for mechanical or generator drive.
Do you have any questions?