Waste Heat Recovery with Organic Rankine Cycle Technology

Power Generation with the Siemens ORC-Module
Requirements of the Future: Efficiency

The world is full of energy. However, energy needs to be converted into power in order to make use of it. It is this conversion process that drives us. It needs to be as efficient as possible and particularly economical. It needs to be sustainable and we need to adapt the conversion process to local circumstances.

Siemens has long accepted this challenge and addressed it head-on. Siemens’ technical expertise, fresh ideas, and range of products, solutions, and services have a long-standing tradition of making a difference to the world. It is because of this commitment that Siemens is the number one provider today of environmentally intelligent products and sustainable solutions worldwide.

Waste Heat Recovery

About 50% of the fuel we use to produce power in conventional power plants is wasted due to the limitations of the power conversion processes.

Waste heat recovery is an economic method to increase the overall efficiency of the plant and, thus, to lower fuel demand. Exhaust gas of various processes is carrying a huge amount of energy also referred to as waste heat. Often industrial processes produce enough waste heat to generate electricity. Waste Heat Recovery Units (WHRUs) or heat to power units could recover the waste heat and transform it into electricity by using, for example, an Organic Rankine Cycle (ORC).

Often, waste heat is of low temperature quality. It can be difficult to efficiently utilize the heat contained. In these cases the ORC-Technology can bring an additional benefit to raise the overall plant efficiency. The ORC-Unit utilizes this otherwise wasted energy and converts it into power.

Benefits of Waste Heat Recovery
- Lowering the CO₂ emissions because waste heat is converted into energy
- Reduced demand on primary energy because more power output can be achieved with the same amount of fuel
- Saved natural resources by reduction of fuel demand
- Enhanced sustainability by obtaining highest efficiency of the power conversion cycle

Decentralized Energy Supply

Decentralized Power Supply is another trend in the world’s growing demand for energy. Many regions do not have access to a centralized power supply yet, still the local infrastructure demands electricity. Independent power supply makes use of any available fuels, may it be biomass, household refuses or waste heat within an industrial process.

The Organic Rankine Cycle is a perfect solution for decentralized power supply. The Siemens ORC-Module makes use of medium temperatures around 300°C and transfers them into electricity up to 2 MW. The combination of several ORC-Modules allows higher power output.

Heat for the ORC-Technology can be retrieved from:
- Biomass and biogas
- Sewage gas
- Exhaust gas of gas turbines
- Waste heat of industrial processes, such as glass and cement industry
- Process steam
Our Technological Answer: Organic Rankine Cycle Technology

The ORC-Technology enables Siemens to provide solutions with well-proven components even for heat sources with lower temperatures. Siemens first utilized its Organic Rankine Cycle Technology in 2013. The ORC-Module is capable to generate a power output from 300 kW to 2 MW. The working medium is a chlorine free, non-toxic, substance with a zero ozone depletion potential.

Waste heat with a temperature of 300°C is just enough to drive the ORC cycle process. The recovery process will add to the efficiency of the process and thus decrease the costs of fuel and energy consumption needed for that process.

Power Supply without extra Fuel

The ORC-Technology allows the use of waste heat independent from the way of the production of this heat. Any process utilizing waste heat in a certain amount and temperature can drive an Organic Rankine Cycle.

Typical industries with waste heat appropriate for the ORC-Technology are
- Chemical Industry
- Glass, Cement and Ceramic Industry
- Food and Beverage Industry
- Rubber and Plastic Industry
- Metal and Mining
- Pulp and Paper
- Coke Industry

Benefits of the Siemens ORC-Modules:

- Efficient:
  - Highly efficient ORC Turbine based on proven Siemens Steam Turbine SST-060
  - Good part load efficiency

- Reliable:
  - No blade erosion due to superheated turbine exhaust vapor (dry ORC fluid used)
  - ORC turbine development based on proven SST-060 (more than 850 installations)

- Flexible:
  - Wide operating range possible (10% to 100% load)

- Low investment cost:
  - Simple and compact plant design
  - Lower temperatures and pressures compared to conventional steam applications

- Low operating cost:
  - No make-up water treatment necessary
  - Unattended operation possible
  - Low demand on repair and maintenance
The ORC-Components

Siemens delivers pre-fabricated functional units to the site. Here experienced work teams implement the components and bring them into service. For each component, Siemens guarantees the highest quality and best service.

The ORC- Turbine

The SST-060 is a well proven Siemens Turbine and has been installed more than 850 times all over the world. Its rugged design and renowned reliability means it can operate under the most severe conditions. The SST-060 is ideal for saturated steam conditions. Its suitability for use as condensation or back-pressure turbine in combination with various integral gear modules opens up a broad application range. Based on this proven turbine the ORC-Turbine was developed.

The Recuperator

Siemens delivers a recuperative ORC-Technology. Here, a recuperator is used employing the turbine outlet vapor to heat up the liquid working fluid going via the pre-heater to the evaporator. The recuperator reduces the heat load in the evaporator and increases the thermal efficiency to produce more power.

The Working Fluid

The working medium indicates optimal characteristics for a working fluid. It is a silicon oil, which is a chlorine free, non-toxic substance with a zero ozone depletion potential.

Main characteristics of the working medium:
- Low freezing point and high temperature stability
- High heat of vaporization and density
- Low environmental impact
  - Ozone depletion potential (ODP) ≤ 0
  - No global warming potential
- Safety
  - The fluid is non-corrosive, and non-toxic
- Good availability and low cost

Proven Components:

The Siemens ORC-Module

The Siemens ORC-Module consists of well proven and long established components. Heat is converted into electricity and at the heart of this conversion process is the turbine. For well over 100 years, steam turbines have been manufactured within the Siemens network.

The ORC-Module essentially comprises the turbine (with generator), recuperator with condenser combined in a functional unit, feed pump, pre-heater(s), evaporator and the interconnecting piping. The vapor produced in the evaporator is supplied to the ORC-turbine which drives the generator.

After leaving the turbine the vapor enters the recuperator to transfer the energy from the superheated exhaust vapor to the liquid side of the process. Afterwards it is condensed in the condenser. Cooling water supplied by the customer is used for the condensing process.

The condensate collected in the condenser hotwell is discharged by the feed pump back to the evaporator via the pre-heater(s). The speed of the feed pump is controlled via a frequency converter to maintain the level in the condenser hotwell. For start-up and (emergency) shutdown purposes a bypass system is included.

Arrangement Concept Example

In below shown example, the base frame connects the evaporator and pre-heaters to one functional unit, whereas the turbine and the generator are on a separate turbine base frame as an extra functional unit. The recuperator is directly placed on the foundation and the feed pump is located in a separate room or cellar below the ORC-Module. This construction is necessary due to the requirements of the feed pump. Small modules below approx. 700 kW are completely placed on one common base frame.*

*Other Siemens ORC-Modules may have other arrangements.
Siemens Solutions: ORC-Module Overview for Combined Heat and Power Applications

<table>
<thead>
<tr>
<th>Module</th>
<th>ORC-Module 1</th>
<th>ORC-Module 2</th>
<th>ORC-Module 3</th>
<th>ORC-Module 4</th>
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<tbody>
<tr>
<td><strong>Performance</strong></td>
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<td>300 / 240</td>
<td>300 / 240</td>
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<td>Low temperature (LT) circuit (kWh)</td>
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<td><strong>Condenser Output</strong></td>
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<td>Heat transfer to heating network (kWh)</td>
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**Diagram**

- **Vapor**
- **Main condensate**
- **Auxiliary condensate**
- **High temperature (HT) circuit**
- **Low temperature (LT) circuit**
- **heating network water**

**Legend**

1. Turbine
2. Generator
3. Recuperator
4. Condenser
5. Feed Pump
6. Partial flow pre-heater
7. Main flow pre-heater
8. Evaporator
9. Bypass valve

**Optional**

- Terminal Point Siemens
- Customer

- 60 / 80
- 60 / 80
- 60 / 80
- 60 / 80