# CONDENSING HEAT RECOVERY for Industrial Process Applications

**Capturing heat that would otherwise escape the process through the stack, waste heat recovery allows industrial thermal processing operations to recover and reuse process heating.**

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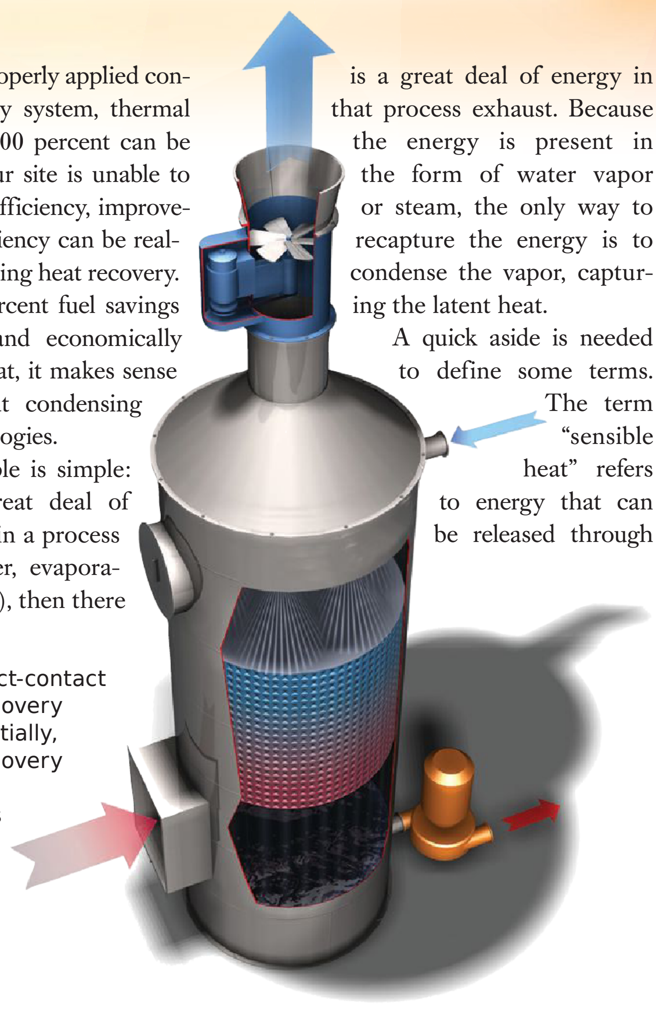
Consider the conditions found at a food and beverage facility outside of Memphis, Tenn., not long ago. With an outside air temperature of 100°F (38°C), the boiler plant exhaust was 90°F (32°C). That is right – on that hot summer day, you could cool off by standing above the short stainless steel boiler exhaust. Condensing heat recovery technologies made it possible.

Condensing heat recovery technologies are not the only means of recovering waste heat used in industrial processes these days. Many simple projects such as liquid-to-liquid heat recovery, boiler feedwater economizers and the use of high-grade heat to generate steam or hot air from exhaust gas streams are effectively applied. In fact, they often are correctly implemented before condensing heat recovery is considered.

However, with a properly applied condensing heat recovery system, thermal efficiencies nearing 100 percent can be achieved. Even if your site is unable to achieve this level of efficiency, improvements in energy efficiency can be realized through condensing heat recovery. Typically, 5 to 20 percent fuel savings can be practically and economically realized. Given all that, it makes sense to learn more about condensing heat recovery technologies.

The basic principle is simple: when there is a great deal of water vapor (steam) in a process exhaust (boiler, dryer, evaporator, cooker, oven, etc.), then there is a great deal of energy in that process exhaust. Because the energy is present in the form of water vapor or steam, the only way to recapture the energy is to condense the vapor, capturing the latent heat.

A quick aside is needed to define some terms. The term "sensible heat" refers to energy that can be released through



A cut-away of a direct-contact condensing heat recovery unit is shown. Essentially, condensing heat recovery equipment is a heat exchanger that uses the hot exhaust stream to heat a cold medium.

## Tips to Avoid Derailing a Heat Recovery Project for Industrial Process Applications

Sometimes during the selection process, the decision-making process is derailed by one or more common pitfalls. Here are some tips to keep your heat recovery project on track.

1. **Avoid Paralysis by Analysis.** Too often, facilities get lost in finding the perfect project. A process environment is forever changing. Often, people suggest this change as a reason to delay action because a better project may exist after a change occurs. But then, more change is imminent and the cycle of delay continues. If a good and robust project is identified, act on it.

2. **Where Loads Are Intermittent, Consider Storage.** Hot water storage can be a waste of energy, and so many are moving to instantaneous heating. But, when the energy is free (recovered waste energy) and an issue is that the heat source profile does not match the heat sink profile, a buffer such as a hot water tank can be used to create the capacity for an intermittent heat sink such as wash water at a food and beverage facility.

3. **Apply the Heat to Your Coldest Point.** Suppose a site has a warm water tank that is heated by steam. If the tank is being fed by both hot water recovered from the process and cold makeup water, then add the heat to the cold makeup water rather than the blended warm water. This may allow you to recover more heat by cooling the exhaust down to a lower temperature.

4. **Consider Heating Process Water or Fluid Directly or Indirectly.** If water quality in the heat recovery system is a concern, the heat recovery system can generate a simple recirculating heating loop. Then, the process fluid can be heated indirectly through a heat exchanger. This is common in food-grade applications so the quality of the water in the heat recovery system is not an issue.

5. **Integrate Process and Utilities.** Too often, sites consider the boiler plant/utilities to be separate from the process. For proper assessment of heat recovery opportunities, the boiler plant and the process must be considered together.

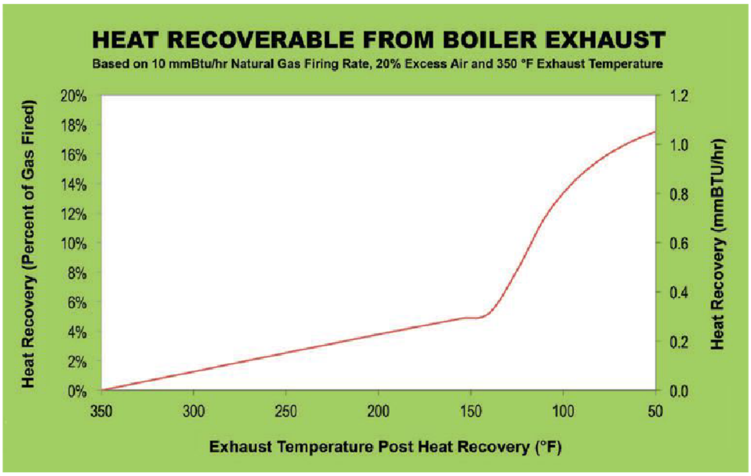
6. **It Is Not Necessary to Hit Setpoint with Recovered Heat.** Many sites worry that the recovered heat cannot bring their heat users to setpoint, but they do not need to. Recovered heat can be used to preheat any process stream — from process water to dryer makeup air — and then existing heating systems can be used to bring the process stream the rest of the way.

7. **Do Not Remove Existing Heating Infrastructure.** Heat recovery should be used as first-stage heating even if it can reach setpoint. Then, existing heating systems and top-ups or backups can be used so that your process does not become dependent on the proposed heat recovery system. These are noncritical redundant systems. Approaching it as such improves the likelihood of acceptance from production engineering and management.

8. **Engage Management Early.** If management criteria around capital costs and payback are not understood, significant effort can be wasted.

9. **Include Validation.** Ensure that instrumentation required for savings validation is included.

a temperature change. Heating water from 32 to 212°F (0 to 100°C) is a change in sensible heat. By contrast, the term "latent heat" refers to energy stored or released in a phase change. An example is the heating that is done when steam changes from vapor to water without any temperature change. As it happens, the energy released when a pound of steam turns into a pound of water – all happening at 212°F with no temperature change, so this is latent heat – is some five times the energy released when that same pound of water is cooled from 212 to 32°F (100 to 0°C). All this is to say there is a lot of energy released in the phase change from water vapor to liquid water.




By cooling a process exhaust below its dewpoint – the temperature at which water starts to condense out of a given gas/vapor mix – this latent heat can be recovered and reused for process applications. So, hot and humid exhausts are prime candidates for condensing heat recovery. That makes streams such as

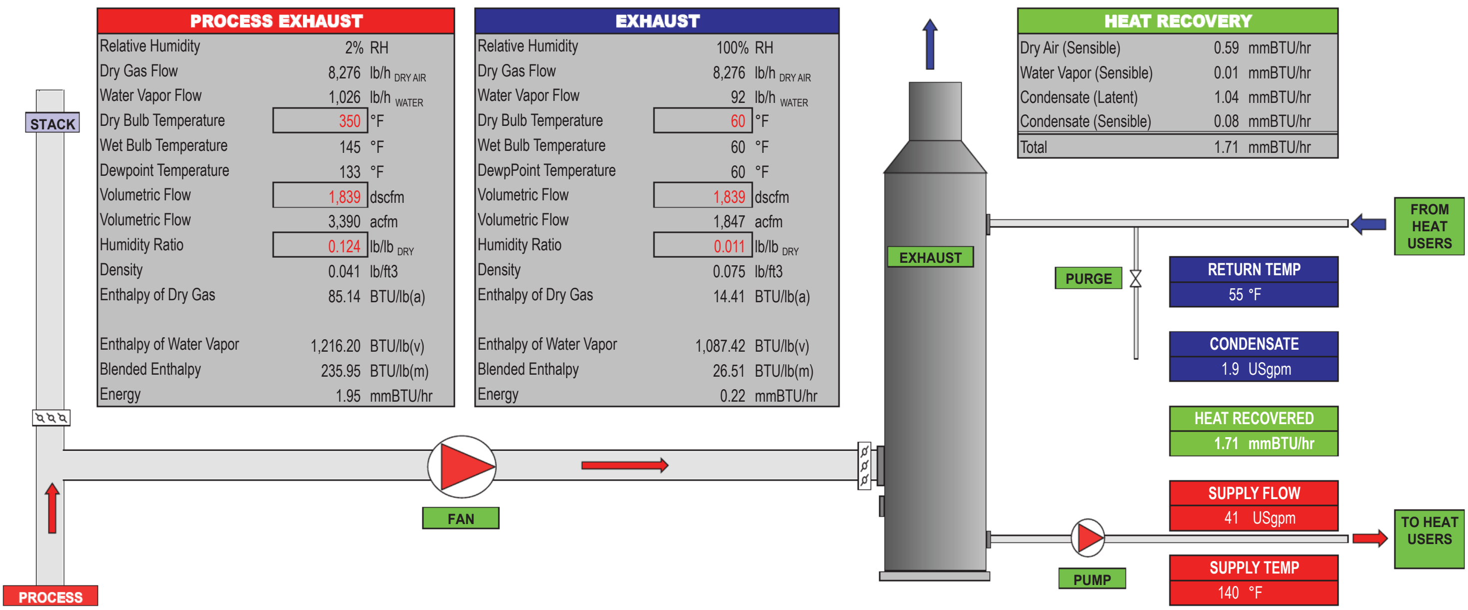



Figure 1. Using a boiler plant as an example, the figure shows the heat recoverable from a boiler exhaust versus the temperature to which the boiler exhaust is cooled. A 10 million BTU/hr boiler at 20 percent excess air and 350°F (176°C) exhaust temperature is used for the example.

boiler plant exhausts prime candidates because they are very humid. Combustion of any fossil fuel made up of carbon and hydrogen (natural gas, propane, oil, etc.) results in carbon dioxide ($CO_2$) and water vapor ($H_2O$) in the exhaust stream. Unless recovered, that water is steam going up your boiler stack.

Using the boiler plant as an example for a heat source because it is common to many production facilities, figure 1 shows the heat recoverable from a boiler exhaust versus the temperature to which the boiler exhaust is cooled. A 10 million BTU/hr boiler has been used for the example, easily allowing for conversion of recovered heat from million BTU/hr to percent. Figure 1 shows that at the dewpoint, the level of heat recovery per degree of cooling goes up exponentially. In fact, there is more heat available in the flue gas between the dewpoint of 150 and 130°F (65 and 54°C) than there is available in the cooling between 350 and 150°F (176 and 65°C). This again shows the large improvements that can be achieved through condensing heat recovery technologies, providing a 10 to 15 percent improvement. By contrast, a typical feedwater economizer might take some 100°F (55°C) of sensible heat out of the boiler exhaust, for an impact of roughly 3 percent.

## Condensing Heat Recovery Technology

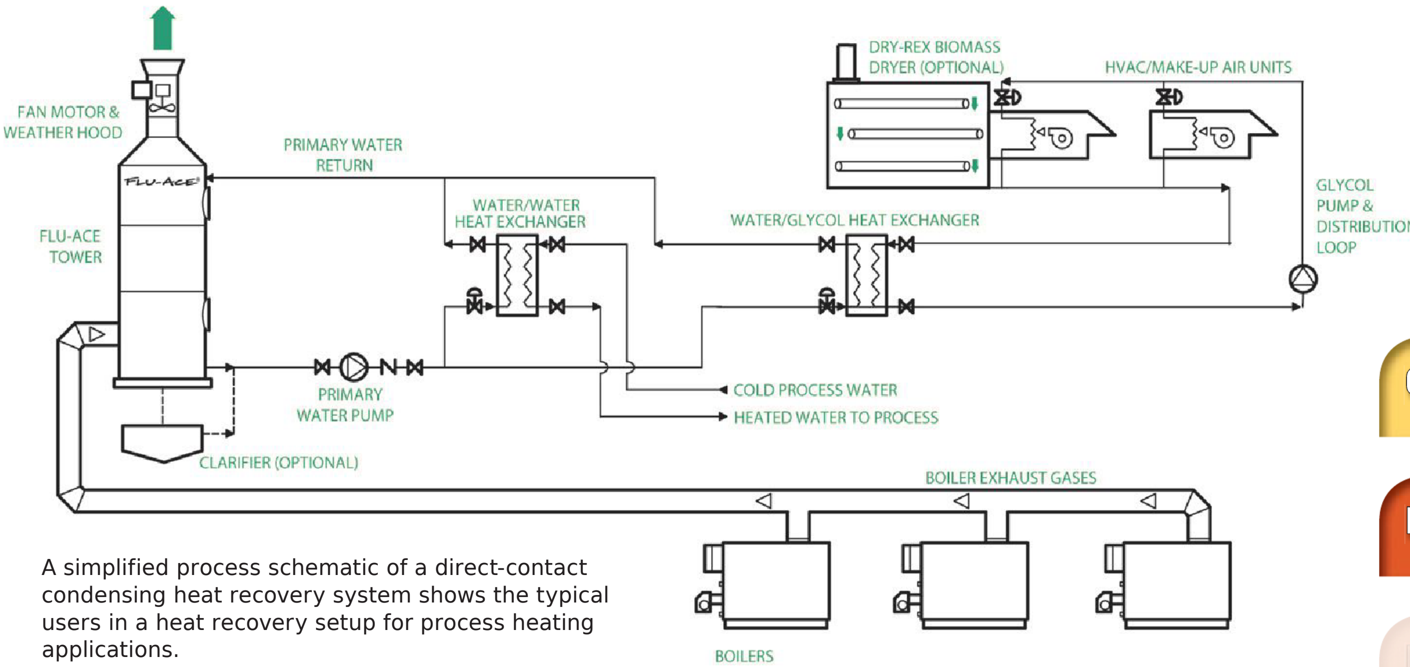
Condensing heat recovery can be applied in two ways: direct-contact and indirect-contact systems. Essentially, condensing heat recovery equipment is a heat exchanger that uses the hot exhaust stream to heat a cold medium (typically water although sometimes glycol is used).

An indirect-contact system is simply a standard heat exchanger: water passes through tubes and the hot exhaust passes outside the tubes. Sensible heat and latent heat are transferred through the tube walls from the hot side to the cold side. By contrast, direct contact systems bring the cold water medium in direct contact with the hot gas in an open spray tower or packed spray tower to recover the heat directly by heating the water.

Whether the heat is recovered via direct or indirect means, the cold medium that has been heated then is used directly in the process, or used to heat the process fluid (usually water or air) indirectly and recirculated. In addition, new fans typically are installed to overcome the additional pressure drop of the exhaust gas through the heat recovery system. The selection of direct contact versus indirect contact depends upon the specific process heating application.

The application of condensing heat recovery technology is not rocket science, but it does involve gathering good data, a proper analysis and some science and engineering. For large and complicated processes such as integrated paper mills, the analysis itself is a project. This is typically offered as a pinch analysis, which is a methodology for minimizing energy consumption of chemical processes by calculating thermodynamically feasible energy targets (or minimum energy consumption) and achieving them by optimizing heat recovery systems, energy supply methods and process operating conditions. A pinch analysis can cost tens of thousands of dollars, but the results narrow an unmanageable number of heat recovery and efficiency options to a few of the most promising projects with rough project metrics.

Simpler sites and processes do not require a separate analysis or pinch project. For those, a small number of potential heat recovery applications and projects can be identified relatively rapidly and coarsely quantified in order to prioritize and select the heat recovery projects with the greatest economical and practical benefits.




A simplified process schematic of a direct-contact condensing heat recovery system shows the typical users in a heat recovery setup for process heating applications.

## 8 Steps to Adding Condensing Heat Recovery Technology

If you are considering adding heat recovery technology, here are eight steps to follow to help ensure the process is well planned. (Of course, keep in mind site-specific exceptions when planning any condensing heat recovery project.)

**1. Secure a Team in Place.** Be sure you have the internal and external resources in place that are required – from analysis to validation of potential savings, and project costs to implementation. Also ensure that management is involved, and that targets are set such that management expectations for payback and savings are understood. For example, if a project with a three-year payback and 10 percent fuel savings can be tabled, will management act on said project?

Traditionally, the team includes management, internal site engineers and support staff, equipment suppliers and consulting engineers. However, in North America today, many sites are short on the internal personnel required to develop such analyses and projects, so be ready to engage external vendors as required. Many projects die when the approach is piecemeal. For instance, a capital equipment cost could be provided, but internal engineering does not have the time to fully develop project impacts and costs, and management does not have the will to approve high-risk and considerable consulting costs required to fully flesh-out a project that may not meet investment criteria. In this case, some companies are willing to offer a no-risk development. If the outcome of the analysis reveals that the end-user's economic targets (e.g., payback or savings) do not meet the company's criteria, then the company does not pay for the analysis. This no-risk approach often facilitates moving forward.

**2. Gather Heat Source and Heat Sink Data.** At a preliminary level, this can be done internally although external help can accelerate the process. It simply involves gathering data on various process exhausts and effluents as well as flow rates and temperatures. Likewise for heat sinks, flowrates and initial/final temperatures are required.

**3. Complete Approximate Analysis.** This involves developing rough (±20 to 30 percent) estimates for cost, savings and payback for a number of potential project configurations. For a small facility, this can be relatively easy. For a large complicated process site, a full pinch analysis could be required. This step often is completed with the help of a consultant.

**4. Select Projects.** This step involves looking at the economics for each project option, determining which best suits the company's short-term goals and can be implemented practically by the company, and, ultimately, selecting a project or projects for a more detailed analysis.

**5. Perform Detailed Analysis.** For projects that meet management's investment criteria and engineering's technical criteria, firm costs and savings estimates should be created. With consultants, these will be estimated costs, and there can still be a significant risk element. If the project is approved and final costs end up much higher than the estimate, the liability of the cost overrun is with the end-user. Some companies can complete this stage with the end result being a firm price for turnkey implementation of the project. This transfers the risk to the supplier, and it typically provides more comfort for management when approving a project for implementation.

**6. Obtain Project Approval.** This step can take months or even years. Obtaining financing for a project is the largest hurdle. Consider a third-party financing approach if the company has energy reduction or sustainability goals to reach but capital is tied up in core process maintenance and optimization.

**7. Implement the Project.** Again, this can be done in two fashions: a three-party approach, where the end-user manages the project and purchases equipment, consultants design the project and a third-party subcontractor or subcontractors implement the project. This is the lower cost, higher risk approach. An alternative is to engage a turnkey provider that is responsible for engineering, implementation and delivering on the stated project cost and savings. This single-point liability approach will have a higher cost, but it largely eliminates risk to the end user. Also, it requires much less of the end-user's internal resources.

**8. Validate Results.** This is a requirement to satisfy management and to help spread the success of your project to other facilities within your corporation. In addition, if state or utility funding is applied to the project, this validation often is required to secure some or all of the committed funding from the agency.

Given the availability of proven technologies and the fact that these kinds of heat recovery projects have quantifiable and verifiable economic benefits, with the right team and committed management, these projects can be systematically developed and approved, resulting in a 5 to 15 percent reduction in site-wide fuel use at most North American production facilities.

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