First Batch of Domestic TOP TENs List

U.S. BAT List

BAT1:Flue gas heat recovery system (feedwater economizers and/or combustion air preheaters) for boilers

1.Technology description

A flue gas heat recovery system can make boilers more efficient by capturing and re-using heat energy that would otherwise have escaped out of your flue or chimney. All boilers which burn fuel to produce heat create exhaust gases,and these need to be expelled outside. However,as these gases are hot (about 200°C),as much as 35% of the heat being produced by the boiler can be wasted when they are expelled.

This technology recovers available heat from exhaust gases and transfers it back into the system by preheating feedwater or combustion air[1]。

2.Level of Energy Savings

In most steam systems,this technology can improve the energy efficiency of the system 4% ~7% depending on the baseline efficiency of the system.

3.Market prospect

At the country level,most industrial steam systems,especially in the developing countries,have low to medium efficiency level. This indicates a significant

Notes：

[1]U.S. Department of Energy,Advanced Manufacturing Office (U.S. DOE/AMO). 2012. Improving Steam System Performance: A Sourcebook for Industry-Second Edition.

market prospect for this technology in the industry sector in various countries. The recent study by UNIDO and LBNL[2]on industrial steam systems showed that in steam systems with low efficiency level,often no flue gas heat recovery equipment is installed on the boiler resulting in elevated flue gas temperature and in steam systems with medium efficiency level,often the final flue gas temperature is elevated and a significant energy recovery potential remains. The flue gas heat recovery technology can improve the steam system efficiency by around 7% if the system has low system efficiency and by around 4% if the system has medium system efficiency.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology will vary depending on the size of the steam system and the country it is installed and other factors. The recent study by UNIDO and LBNL show that for installation in China this technology will cost in the range of 72 – 1,160 thousand US dollars for system size ranging from <4 t steam/h to >94 t steam/h.

6.Social Characteristics and co-benefits

• Reduced energy-related CO_2 emissions

• Reduced other air pollutants emissions resulted from fossil fuel use.

BAT2:Flash-steam recovery technology

1.Technology description

Flash steam is released from hot condensate when its pressure is reduced. The steam released by the flashing process is as useful as steam released from a steam boiler[3] .

In any steam system seeking to maximize efficiency,flash steam will be separated from the condensate,and used to supplement any low pressure heating application. Every kilogram of flash steam used in this way is a kilogram of steam that does not need to be supplied by the boiler. It is also a kilogram of steam not vented to atmosphere,from where it would otherwise be lost.

2.Level of Energy Savings

In most steam systems,this technology can improve the energy efficiency of the system 2.5% ~4% depending on the baseline efficiency of the system.

3.Market prospect

At the country level,most industrial steam

Notes:

[2] Hasanbeigi,A. Harrell,G. Schreck,B. (2014). Energy Efficiency Potentials in Industrial Steam Systems in China: Development of the Steam Systems Energy Efficiency Cost Curve. United Nations Industrial Development Organization (UNIDO),Vienna,Austria.

[3] U.S. Department of Energy,Advanced Manufacturing Office (U.S. DOE/AMO). 2012. Improving Steam System Performance: A Sourcebook for Industry-Second Edition.

systems,especially in the developing countries,have low to medium efficiency level. This indicates a significant market prospect for this technology in the industry sector in various countries. The recent study by UNIDO and LBNL[4]on industrial steam systems showed that in steam systems with low efficiency level,flash-steam is not recovered and in steam systems with medium efficiency level,flash-steam is partially recovered. Flash steam recovery technology can improve the steam system efficiency by around 4% if the system has low system efficiency and by around 2.5% if the system has medium system efficiency.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology will vary depending on the size of the steam system and the country it is installed and other factors. The recent study by UNIDO and LBNL show that for installation in China this technology will cost in the range of 38 – 674 thousand US dollars for system size ranging from <4 t steam/h to >94 t steam/h.

6.Social Characteristics and co-benefits

• Reduced energy-related CO_2 emissions

• Reduced other air pollutants emissions resulted from fossil fuel use.

BAT3:Loss on ignition (LOI) optimization technology for coal-fired boilers

1.Technology description

Coal fired boilers have various sources of thermal energy loss. The main sources are the dry gas loss as well as the loss-on-ignition (LOI) of the ash leaving the boiler. The vast majority of the combustible portion of the ash that accounts for the energy loss is simply unburned carbon. The common approach in the past has been to keep the carbon as low as possible to minimize the combustible losses in the ash. However,the most efficient way to operate a boiler is to minimize the energy losses due to the fly ash LOI and the stack gases at the same time. LOI optimization technology which may have several features such as on line measurement of unburned carbon,ash reinjection,etc. can improve the energy efficiency of coal-fired steam systems significantly.

2.Level of Energy Savings

In most steam systems,this technology can improve the

Notes:

[4] [Hasanbeigi,A. Harrell,G. Schreck,B. (2014). Energy Efficiency Potentials in Industrial Steam Systems in China: Development of the Steam Systems Energy Efficiency Cost Curve. United Nations Industrial Development Organization (UNIDO),Vienna,Austria.

energy efficiency of the system 3% - 5% depending on the baseline efficiency of the system.

3.Market prospect

At the country level,most industrial steam systems,especially in the developing countries,have low to medium efficiency level. This indicates a significant market prospect for this technology in the industry sector in various countries. The recent study by UNIDO and LBNL[5]on industrial steam systems showed that in steam systems with low efficiency level,Loss On Ignition (LOI)) is not monitored regularly and is managed poorly and in steam systems with medium efficiency level,LOI is monitored regularly but timing is infrequent and significant corrective actions are not clearly applied to reduce the LOI. Loss on ignition (LOI) optimization technology for coal-fired boilers can improve the steam system efficiency by around 5% if the system has low system efficiency and by around 3% if the system has medium system efficiency.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology will vary depending on the size of the steam system and the country it is installed and other factors. The recent study by UNIDO and LBNL show that for installation in China this technology will cost in the range of 72 – 507 thousand US dollars for system size ranging from <4 t steam/h to >94 t steam/h.

6.Social Characteristics and co-benefits

- Reduced energy-related CO_2 emissions
- Reduced other air pollutants emissions resulted from fossil fuel use
- LOI optimization can also improve the fly ash quality. Fly ash becomes an even more attractive product if it is of consistent quality.

BAT4:Variable frequency drives (VFDs)

1.Technology description

An adjustable speed drive (ASD) is a device that controls the rotational speed of motor-driven equipment. Variable frequency drives (VFDs),the most common type of ASDs,efficiently meet varying process requirements by adjusting the frequency and voltage of the power supplied to an AC motor to enable it to operate over a wide speed range. External sensors monitor flow,liquid levels,or pressure and then transmit a signal to a controller that adjusts the frequency and speed to match process requirements.

Notes：

[5][Hasanbeigi,A. Harrell,G. Schreck,B. (2014). Energy Efficiency Potentials in Industrial Steam Systems in China: Development of the Steam Systems Energy Efficiency Cost Curve. United Nations Industrial Development Organization (UNIDO),Vienna,Austria.]

2.Level of Energy Savings

In most cases,this technology can improve the energy efficiency of the system 15%~25% for pumping and compressed air systems and 20%~35% in fan systems depending on the baseline efficiency of the system.

3.Market prospect

A recent study by UNIDO and LBNL[6]on industrial motor systems showed that at the country level,most industrial motor systems have low to medium efficiency level. This indicates a significant market prospect for VFDs in the industry sector in various countries. The same study indicates that in motor systems with low efficiency level VFDs are not commonly used and in systems with medium efficiency level VFDs are only sometimes used as a solution for flow control. VFDs can improve the system efficiency by 15% - 25% for pumping and compressed air systems and 20% - 35% in fan systems,depending on the baseline system efficiency.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology will vary depending on the type and size of the system and the country it is installed and other factors. The UNIDO and LBNL study shows that for installation in the US,VFD technology will cost in the range of 4 – 65 thousand US dollars for pumping systems,12 – 100 thousand US dollars for compressed air systems,and 8 – 150 thousand US dollars for fan systems with size ranging from <50 hp to 1000hp.

6.Social Characteristics and co-benefits

- Reduced energy-related CO_2 emissions
- Reduced other air pollutants emissions resulted from fossil fuel use.
- Improved system reliability in some application

BAT5:Low-grade waste heat to power absorption chillers

1.Technology description

Absorption chillers use heat/waste heat,instead of mechanical energy,to provide cooling. The mechanical vapor compressor is replaced by a thermal compressor that consists of an absorber,a generator,a pump,and a throttling device.

Compared to mechanical chillers,absorption chillers have a low coefficient of performance (COP = chiller load/ heat input). Nonetheless,they can substantially reduce operating costs if they are energized by low-grade waste

Notes:

[6] [McKane,A. and Hasanbeigi,A. (2010). Motor System Efficiency Supply Curves. United Nations Industrial Development Organization (UNIDO).]

heat,while vapor compression chillers must be motor or engine driven.

2.Level of Energy Savings

Energy saving achieved by implementation of this technology varies by industry,process,application,technology provider,etc.

Example:

In a plant where low-pressure steam is currently being exhausted to the atmosphere,a mechanical chiller with a COP of 4.0 is used 4,000 hours per year (hr/yr) to produce an average of 300 tons of refrigeration. An absorption unit requiring 5,400 pounds per hour of 15-psig steam could replace the mechanical chiller,providing annual electricity savings of 1,055 MWh.[7]

3.Market prospect

The current adoption rate of this technology varies in different industries and countries,but in general the current adoption rate is low in most countries. Therefore,there is a significant market potential for this technology.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

Below are some estimated ranges in capital costs for select absorption chillers.[8]

Tons	Single-Effect Hot Water or Steam ($/ton)	Double-Effect Hot Wateror Steam ($/ton)
100-400	$1,110	$1,970
400-800	$820	$1,470
800-1,200	$730	$1,300
1,200-1,600	$680	$1,220

6.Social Characteristics and co-benefits

• Reduced energy-related CO_2 emissions

• Reduced other air pollutants emissions resulted from fossil fuel use

• Avoids the use of any ozone-depleting fluorocarbons for cooling

BAT6: Industrial combined heat and power (CHP)

1.Technology description

Combined heat and power (CHP),also known as cogeneration,is the concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy. Instead of purchasing electricity from the grid and burning fuel in an on-site furnace or boiler to produce thermal energy,CHP provides both energy services to a facility in one energy-efficient step.

For smaller industrial plants,commercial microturbines,with outputs ranging from 30–600 kW,are also available.

Notes：

[7] [US DOE. 2006. Use Low-Grade Waste Steam to Power Absorption Chillers,Energy Tips-Steam. Washington,DC.]

[8]Antares Group Inc.2012 how to decide if an absorption chiller hight for you

2.Level of Energy Savings

It is reasonable to expect CHP applications to operate at 65-75% efficiency,a large improvement over the national average of 35%~45% for these services when separately provided.

3.Market prospect

In the United States,the Obama Administration has a goal to achieve 40 GW of new,cost-effective CHP by 2020. Achieving this goal would:

•Increase total CHP capacity in the United States by 50% in less than a decade

•Save energy users $10 billion per year compared to current energy use

•Save 1 quadrillion Btu (Quad) of energy — the equivalent of 1% of all energy use in the United States

•Reduce emissions by 150 million metric tons of carbon dioxide (CO_2) annually — equivalent to the emissions from over 25 million cars

•Result in $40-$80 billion in new capital investment in manufacturing and other U.S. facilities over the next decade.[9]

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology varies by industry,process,application,size,technology provider,etc.

The investment costs of a gas-turbine CHP plant ranges from $900/kW to $1500/kW,with a typical cost figure of $1000/kW (US$2008). The annual operation and maintenance (O&M) costs are approximately $40/kW. The investment costs of a combined-cycle (CCGT) CHP plant range from $1100/kW to $1800/kW and more,with a typical cost figure of $1300/kW. The annual O&M costs are approximately $50/kW. The investment costs of a fluidized-bed combustion (FBC) CHP plant based on coal ranges from $3000/kW to $4000/kW and more,with a typical cost figure of $3250/kW and annual O&M costs of approximately $100/kW. The investment costs of a gas-engine CHP plant are in the range of $850–1950/kW,with a typical cost figure of $1,150/kW. Its annual O&M costs are about $250/kW[10].

6.Social Characteristics and co-benefits

•Reduced energy-related CO_2 emissions

•Reduced other air pollutants emissions resulted from fossil fuel use

•Reduced exposure to grid power cut and grid power disruptions

BAT7: Recuperative or Regenerative Burners

1.Technology description

Notes：

[9] [US DOE. Benefits of combined heat and power. http://energy.gov/eere/amo/benefits-combined-heat-and-power]

[10] [IEA ETSAP. 2010. Combined heat and power. Paris,France.]

Application of recuperative or regenerative burners can substantially reduce energy consumption. A recuperator is a gas-to-gas heat exchanger placed on the stack of the furnace. There are numerous designs,but all rely on tubes or plates to transfer heat from the outgoing exhaust gas to the incoming combustion air,while keeping the two streams from mixing. Recuperative burners use the heat from the exhaust gas to preheat the combustion air.

Regenerators are basically rechargeable storage batteries for heat. During an operating cycle,process exhaust gases flow through the regenerator,heating a storage medium. After a while,the medium becomes fully heated (charged). The exhaust flow is shut off and cold combustion air extracts the heat from the storage medium,increasing in temperature before it enters the burners. For continuous operation,at least two regenerators and their associated burners are required.

2.Level of Energy Savings

• Recuperative burners can reduce fuel consumption by 10%~20% compared to furnaces without heat recovery.

• Regenerative burners can theoretically achieve savings of up to 35% compared to furnaces without heat recovery. The practical energy saving will be less than this depending on the plant-specific and process-specific condition.

As an example,in the steel industry,the use of this technology in hot mill reheating furnaces can typically save around 0.7 GJ/ton hot rolled finished steel[11].

3.Market prospect

The current adoption rate of this technology varies in different industries and countries. For the example given above on the use of recuperative or regenerative burners in hot mill reheating furnaces in the steel industry,in 2010,(based on the production capacity) only around 30% of steel plants in China and 40% of steel plants in India had installed this technology. Thus,there is significant potential for application of this technology in steel plants in those two countries (which account for over 50% of steel production in the world) and other countries.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology varies by industry,process,a pplication,technology provider,etc.

For the example given above on the use of recuperative or regenerative burners in hot mill reheating furnaces in the steel industry,the typical cost of the technology is around US$4.3 per ton hot rolled finished steel.[12]

Notes:

[11] [Worrell,E.,P. Blinde,M. Neelis,E. Blomen,E. Masanet. 2010. Energy Efficiency Improvement and Cost Saving Opportunities for the U.S. Iron and Steel Industry: An ENERGY STAR Guide for Energy and Plant Managers. US EPA. Washington,DC.]

[12] [Worrell,E.,P. Blinde,M. Neelis,E. Blomen,E. Masanet. 2010. Energy Efficiency Improvement and Cost Saving Opportunities for the U.S. Iron and Steel Industry: An ENERGY STAR Guide for Energy and Plant Managers. US EPA. Washington,DC.]

6.Social Characteristics and co-benefits

•Reduced energy-related CO_2 emissions.

•Reduced other air pollutants emissions resulted from fossil fuel use.

BAT8: Low temperature waste heat recovery for power generation in industry using Organic Rankine Cycles (ORC)

1.Technology description

Organic Rankine Cycles (ORC) uses an organic working fluid that has a lower boiling point,higher vapor pressure,higher molecular mass,and higher mass flow compared to water. Together,these features enable higher turbine efficiencies than in conventional Steam Rankine Cycle (SRC). The ORC systems can be utilized for waste heat sources as low as 150 degree Celsius,whereas steam systems are limited to heat sources greater than 260 degree Celsius. ORCs make it possible for economical power generation from low temperature industrial waste heat.

2.Level of Energy Savings

Energy saving achieved by implementation of this technology varies by industry,process,application,technology provider,etc.

As an example,this technology is used in hundreds of cement plants to recover waste heat from clinker making process to generate power. The electricity generated by this technology in a cement plant is in the range of 20kWh/ton~40 kWh/ton clinker.[13]

3.Market prospect

The current adoption rate of this technology varies in different countries. In 2010,(based on the production capacity) around 40% of cement plants in China and 30% of cement plants in India had installed this technology. Thus,there is significant potential for application of this technology in cement plants in those two countries (which account for over 50% of cement production in the world) and other countries.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology varies by industry,process,application,technology provider,etc.

For an example given above for WHR power generation in the cement industry,the technology costs around 800-1,250 US$/kW capacity.

6.Social Characteristics and co-benefits

•Reduced energy-related CO_2 emissions.

•Reduced other air pollutants emissions resulted from

Notes：

[13] [Worrell,E.,C. Galitsky,L. Price. 2008. Energy Efficiency Improvement Opportunities for the Cement Industry. Berkeley CA: Lawrence Berkeley National Laboratory Report LBNL-72E. Berkeley,CA.]

fossil fuel use.

• Reduced exposure to grid power cut and grid power disruptions.

BAT9:Wireless sensors for real time measurement and process monitoring

1.Technology description

An effective sampling and real-time control in manufacturing sensors and controls has been a long time issue in industry. In recent year with the advancement in ICT technology and smart manufacturing,some technology providers have tried to tackle these issue by developing wireless sensors and process control systems.

For example,Honeywell,GE,Emerson Process management,and other companies have commercialized technologies,which can send measurements wirelessly to a base radio connected to a control or data acquisition system.

2.Level of Energy Savings

Energy saving achieved by implementation of this technology can varies widely by industry,process,applicat ion,technology provider,etc.

For example,Emerson Process Management claims that its Rosemount 708 wireless acoustic transmitter for steam traps monitoring can reduce the plant’s fuel cost by 10%~20%.[14]

3.Market prospect

The current adoption rate of this technology varies in different industries and countries,but in general the current adoption rate is low in most countries. Therefore,there is a significant market potential for this technology.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology varies widely by industry,proc ess,application,technology provider,etc.

6.Social Characteristics and co-benefits

• Reduced energy-related CO_2 emissions.

• Reduced other air pollutants emissions resulted from fossil fuel use.

·Improve product quality

• Ensure high uptime

• Reduce O&M costs

• Enhance flexibility

BAT10:Plant or enterprise- level energy monitoring and management systems

1.Technology description

Energy is often lost through non-optimal process conditions or process management. Automated computer

Notes：

[14] Hand,A. 2011. Wireless Sensor Identifies Leaking Steam Traps.

control systems may help to optimize the processes and conditions' thereby save energy and reduce emissions. Improved process control may also help to improve the product quality,reduce downtime,and have other benefits. An example of such systems is GE's Power Management Control System (PMCS). PMCS is a customizable,fully integrated end-to-end energy management system. It can access GE's as well as third-party devices and systems in real-time for graphical representations of substation equipment status,energy trends,remote control of devices and automated responses to system conditions. By optimizing methods used to control both processes and equipment,energy efficiency is realized to utilize assets more effectively and efficiently.

2.Level of Energy Savings

Energy saving achieved by implementation of this technology can varies widely by industry,process,application,technology provider,etc.

3.Market prospect

The current adoption rate of this technology varies in different industries and countries,but in general the current adoption rate is low in most countries. Therefore,there is a significant market potential for this technology.

4.Reliability

Given that many installation of this technology is already working in different industries around the world,this technology has passed the reliability test. Although the quality and performance of the technology may vary by technology provider.

5.Economic Characteristics

The cost of this technology varies widely by industry, process,application,technology provider,etc.

6.Social Characteristics and co-benefits

• Reduced energy-related CO_2 emissions

• Reduced other air pollutants emissions resulted from fossil fuel use

• Improved predictive maintenance for less downtime

• Faster problem determination in the process

• Increased safety

• Higher productivity

• Improved power quality ■