

Energy Efficiency and Waste Heat

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Introduction

According to Lawrence Livermore National Laboratory, the United States has a primary energy consumption of 97.5 quadrillion British Thermal Units (Btu) in 2015, accounts for approximately 19% of world total primary energy consumption. Generally, Americans used 0.8 quadrillion Btu less energy in 2015 than in 2014, and wasted 1 percent less energy in 2015, going down by 0.3 quadrillion Btu. These decreases indicate the improvement in both energy conservation and energy efficiency. Among all the alternative tactics, combined power and heat (CHP) technology can integrate energy conservation and efficiency. CHP is a valuable process to capture and reuse the waste heat in a single site, and its benefits include cost saving, emission reduction, higher fuel efficiency and energy resilience. With these technologies, the projected energy consumption would ramp further down in the mid-century.

Energy Conservation and Efficiency

Energy conservation is the efforts to reduce the total energy consumption to fulfill our demands (Dunlap, 2014). There are many approaches to achieve energy conservation, any reduction in energy usage, including less quantity, more services and behavioral change, would be feasible. While energy efficiency only means using less energy to perform the same task (Hamilton, 2015). Improving energy efficiency can be achieved by deployment of more efficiency technologies and production process (Diesendorf, 2007). Thus, the alternatives to increase energy conservation and improve energy efficiency are driven by the technological innovation over time.

The United States Department of Energy divides energy use in four major sectors: industrial, transportation, residential and commercial, accounting for 31%, 28%, 22%, and 19% of total primary national energy consumption, respectively (USEIA, 2016). The 2015 energy flow chart released by Lawrence Livermore National Laboratory (Figure 1) shows the sources of energy production, how Americans are using energy and how much waste exists. However, not all the energy consumption is put to use. The rejected energy, also refer to waste energy, still accounts for a large amount in the end use. Consequently, although the heat itself contributes little to global climate change, it still has some influence in urban area, such as heat island and urban boundary layer.

Thus, there remains a big challenge in the United States, or throughout the world, to increase energy conservation and improve energy efficiency in all these sectors. The strategies could vary from different sectors (Dunlap, 2014):

- Industrial: increasing efficiency in generation by adopting combined heat and power and waste heat and power (WHP) systems
- Transportation: adopting a series of policies, including 1975 CAFE (Corporate Average Fuel Economy) Standard, 1978 Gas Guzzler Tax and a preference on flex fuel and electric vehicles
• Residential: including 1987 National Appliance Energy Conservation Act, ENERGY STAR program and tax credits and subsidies for decreasing energy consumption
• Commercial: high standard for government building to reach zero net energy (ZNE)

**Waste Heat Recovery**

It is the intrinsic character of electricity production that excess heat will be involved, and its total quantity could be large. However, the excess heat is not the form of energy that desired, thus it could be neither removed or viewed as a source of thermal energy (Dunlap, 2014). Besides, in order to reduce the energy loss in distribution, the United States prefer to build energy generators near its consumers. With the transition of the nation’s energy system, more efficient energy technologies will be introduced. Consequently, the waste heat recovery technology would be a driver for a more efficient, cleaner, cheaper and more resilience energy system.

The combined heat and power (CHP) and waste heat to power (WHP) are two important waste heat recovery technologies. Combined heat and power (CHP), also refer to cogeneration, is an integrated method to solve the situation, which produce electricity and heat from a single fuel source (Figure 2). Compare to traditional electricity generation approaches, CHP system is 50% more efficient in delivering energy by integrating electricity production with thermal energy demands (Pew, 2016). Moreover, the on-site CHP system is compatible with any fuel generators, which is a huge advantage among other efficient energy solutions. WHP has similar converting process as CHP, but it recovers energy by capturing discharged heat from nearby facilities or working as primer remover to generate electricity (Figure 3).

The benefits of applying CHP and WHP including:

• Cost saving: the on-site power generation eliminates the cost of operating, transmission, distribution and additional cost in providing thermal energy
• Emission reduction: reduce air pollution (NOx, carbon monoxide, sulfur dioxide) and greenhouse gas (carbon dioxide, methane) emission from burning fossil fuel
• Productivity: achieve higher energy density, increase energy conservation and improve energy efficiency
• Energy reliability: makes energy supply independent during major grid disruptions

**Current situation and Future projections**

In 2008, the U.S. Department of Energy and the CHP association have made the target to improve CHP technical potential, reaching 241 GW by 2030. In July 2013, the U.S has 82.4 GW of installed CHP over 4200 facilities, covering 87% of capacity in industrial applications (Figure 4). The CHP systems help avoiding more than 1.8 quadrillion Btu of fuel consumption each year, and reduce 240 million metric tons of carbon dioxide as well (ICF International, 2013).

In 2016, the Solution Project has estimated the energy supply and demand in the United States through 2050 (Figure 5). The flow chart shows in the path of business as usual (BAU), the total power supply will be 2.621 TW in 2050. If all the energy conservation and efficiency technologies and policies would take into places, the total power consumption will reduce to 1.591 TW, about 40% more efficient.
Figure 1. Estimated U.S. Energy Consumption in 2015.

(Source: Lawrence Livermore National Laboratory)

Figure 2. Tradition Energy Efficiency vs. CHP system efficiency

(Source: Pew)

Figure 3. Waste Heat to Power Process

The waste heat to power process
Figure 4. CHP installation in 2013

(Source: ICF CHP Installation Database)

Figure 5. Projected Energy Supply and Demand in United States

(Source: Solution Project)
Reference

