Energy consumption by the industrial sector worldwide is expected to grow, as economies accelerate and increasing affluence demands increasing amount of manufactured goods. World industrial energy demand is projected by the United States Energy Information Administration to grow by an average of 1.5% annually through 2035[1].

To pursue higher energy efficiency, energy intensive industries are keen to obtain the maximum gains on their energy resources. Combined heat and power (CHP) – the simultaneous production of electric power and useful thermal energy from a single fuel source – has found widespread adoption. For some applications though, higher gains can be obtained with a related technology: Combined cooling, heat and power.

**What is Combined Cooling Heat and Power?**

Combined cooling, heat and power, also known as trigeneration, is the simultaneous production of electric power, useful thermal energy and cooling from a single fuel source. This technology is essentially an integration of two major technologies: Combined heat and power technology and cooling technology through absorption system.

CHP systems consist of a power system which can be an internal combustion engine or turbine driven by a fossil fuel coupled to a generator which produces electricity. A heat recovery system recovers the thermal energy from the power system and exhaust gases for heating applications. By itself, a CHP system is capable of high efficiency, up to 80% at point of use, as opposed to 45% for electricity and heat produced separately[2].

In a trigeneration system, thermal energy produced by the internal combustion engine or turbine and not used for heating applications will be used to power a thermally driven absorption chiller system. With integration of the absorption chiller system, higher efficiency can be achieved – up to 90%[3].
Absorption chillers are a practical alternative to the usual compression chillers. Their main advantage is that they do not require any electrical power consumption, except for the pump moving the solutes. Instead, they rely on thermal energy to power their systems.

An absorption chiller works with a mixture of two fluids. The fluid with the lowest vapour pressure is the solvent, while the fluid with the highest vapour pressure is the solute. Usually the couple of fluids used can be water (solvent) and ammonia (solute), or lithium bromide (solvent) and water (solute).

An absorption chiller system comprises of four main parts: evaporator, absorber, generator, and condenser.

- **Evaporator**: The heat exchanger in which the refrigerant (the solute) absorbs heat from the surroundings at low temperature and becomes vapour. Considering the refrigerant is at low pressure, its boiling point is low and evaporates absorbing heat from the stream which needs to be cooled.

- **Absorber**: The device where the refrigerant, in the form of vapour, is absorbed by the liquid solvent. The absorption process takes place here because of the affinity between solute and solvent. As refrigerant vapour is absorbed by the solvent, the partial pressure in the evaporator reduces, allowing more refrigerant to vaporise.

- **Generator**: The solute-solvent mixture is heated by the heat source. In a trigeneration system, heat would be obtained from the combustion process of power generation. Application of heat causes the refrigerant to evaporate out and move to the condenser. The solvent is now directed back to the absorber.

- **Condenser**: The heat exchanger in which the refrigerant vapour, produced by the generator, condenses releasing heat to the environment. The refrigerant flows back to the evaporator, completing the cycle.
The absorption chiller system is capable of producing chilled water 7°C to 12°C when water is used as refrigerant. Temperatures lower than 0°C is possible, depending on the type of refrigerant used. Chilled water can then be used to cool buildings or other industrial applications.

**Benefits of Trigeneration**

The biggest draw of trigeneration is its ability to cut energy cost due to its higher overall cycle efficiency which reduces the amount of fuel used to produce one unit of usable energy. This is opposed to conventional methods of separately generating electricity, thermal energy using a boiler, and cooling, each with its associated efficiency losses.

Other benefits of trigeneration include:

- Lower greenhouse gases emissions
- Lower distribution losses
- Better power security
- Lower network demand

**Case study: Pfizer Asia Pacific**

Pfizer Asia Pacific operates a US$470 million multi-purpose Active Pharmaceutical Ingredient manufacturing facility occupying 40 acres at Tuas Biomedical Park, Singapore.

Prior to the adoption of trigeneration, the facility has an average utilities usage of about 6.5 megawatts (MW) of electricity, 8 tons per hour (T/hr) of steam, and 2,500 refrigeration tons per hour (RT/hr) of chilled water. This amount is expected to rise as production increases and the plant expands.
To increase energy efficiency, Pfizer Asia Pacific has made the decision to adopt a trigeneration system to provide its electrical, thermal and cooling needs. Based on the energy demand profile, the trigeneration plant design consists of a 5.0 MW rated gas turbine generator, a 14 T/hr waste heat boiler, and a two stage 1300 RT rated absorption chiller.

After the integration of its trigeneration system, Pfizer Asia Pacific managed to realise a reduction in its total energy cost by about US$587,000 per year. This is due to better fuel utilisation and improved plant energy efficiency, as well as reduced electricity consumption due to absorption chilling. All in all, the facility estimated an energy efficiency improvement of 14% with trigeneration, and a reduction in carbon dioxide emissions by 17%.

Trigeneration has proven to be a valuable addition to the industrial sector, by providing electrical, thermal and cooling resources in an efficient and reliable manner. While saving owners and operators a considerable amount of energy and money, it is also considered one of the most environmentally friendly ways to utilise fossil fuel. Widespread adoption of trigeneration in various industrial sectors worldwide will usher the way to a more sustainable model of production.

To find out more on trigeneration, please see:


To view the case study of the trigeneration project at Pfizer Asia Pacific, please visit:


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