Stanford ENERGY SYSTEM INNOVATIONS

Efficiency and Environmental Comparisons

Separate Heat & Power (SHP)

Combined Heat & Power (CHP)

Combined Heating & Cooling (CHC)

Introduction

The enclosed information is provided to explain and illustrate some of the differences between Cogeneration and Trigeneration; Combined Heat & Power (CHP) and Separate Heat & Power (SHP); and to introduce Combined Heat & Cooling (CHC) as a (re)emerging technology for providing heat, power, and cooling in district energy systems. For these illustrations it is necessary to select a common fuel type for calculation and comparison of overall system efficiencies. Whereas natural gas is the fossil fuel of choice for many new base load grid power plants as well as distributed cogeneration plants it is the fuel selected for the comparisons herein.

The figures enclosed are for Stanford University energy loads, and compare relative natural gas use for both a 100% gas fuel scenario as well as the actual scenario in which Stanford employs 65% renewable electricity instead of 100% fossil based power. Studies of energy loads at other universities across the United States indicate that at least 50% of the annual heating and hot water loads in district energy systems which include cooling could be met with heat recovery with a system such as SESI. Ground or water source heat exchange offers additional opportunity for enhancement of such systems to achieve further GHG reductions and water savings. Although electrification of district energy heating and cooling processes opens the path to major GHG reduction via the use of renewable electricity, even on a 100% natural gas basis the heat recovery option may use less total natural gas than the CHP option as shown on the following examples.

For complimentary assistance in evaluating the potential for heat recovery in your system please contact:

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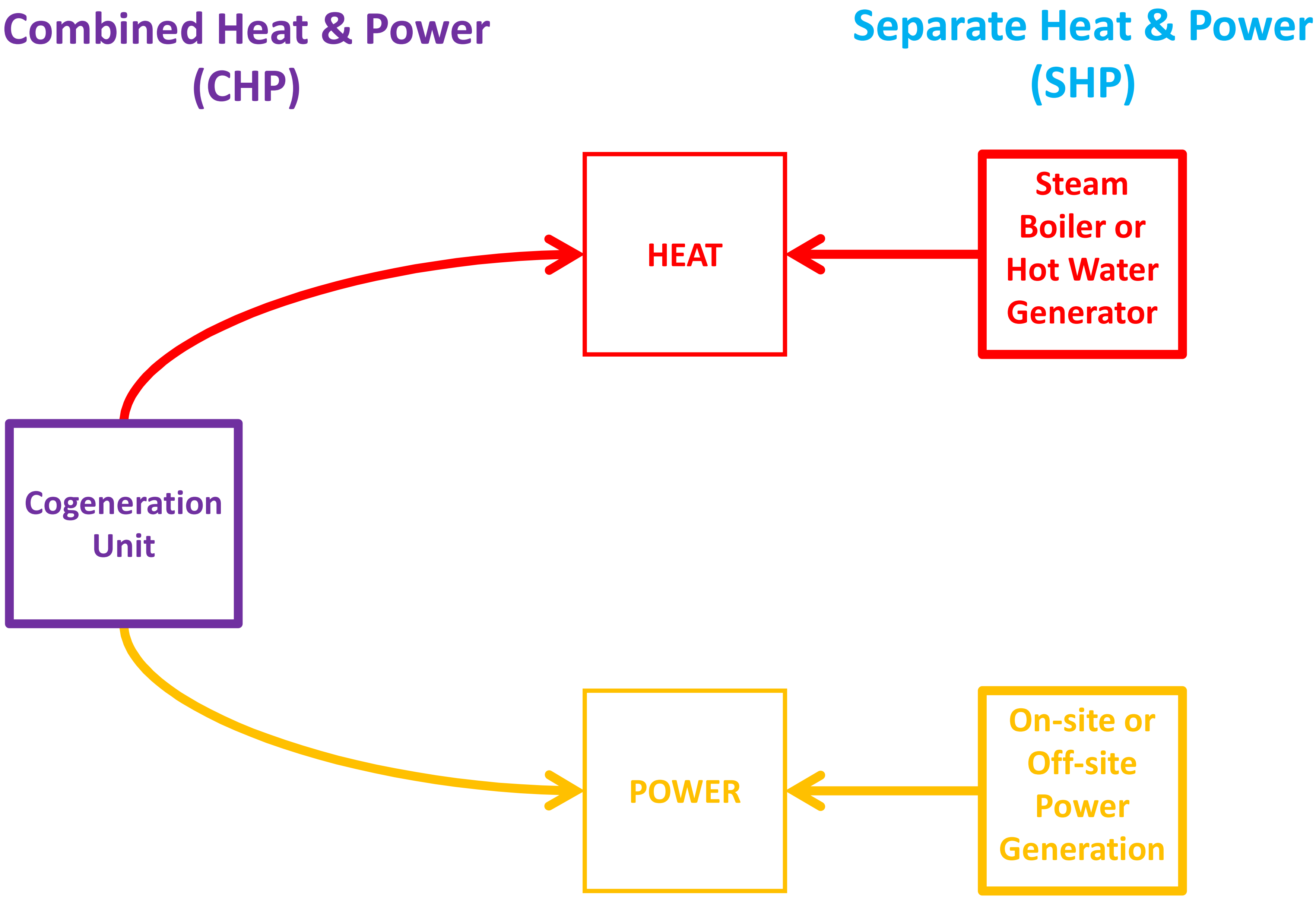
More information on SESI may be found at: https://sustainable.stanford.edu/campus-action/stanford-energy-system-innovations-sesi

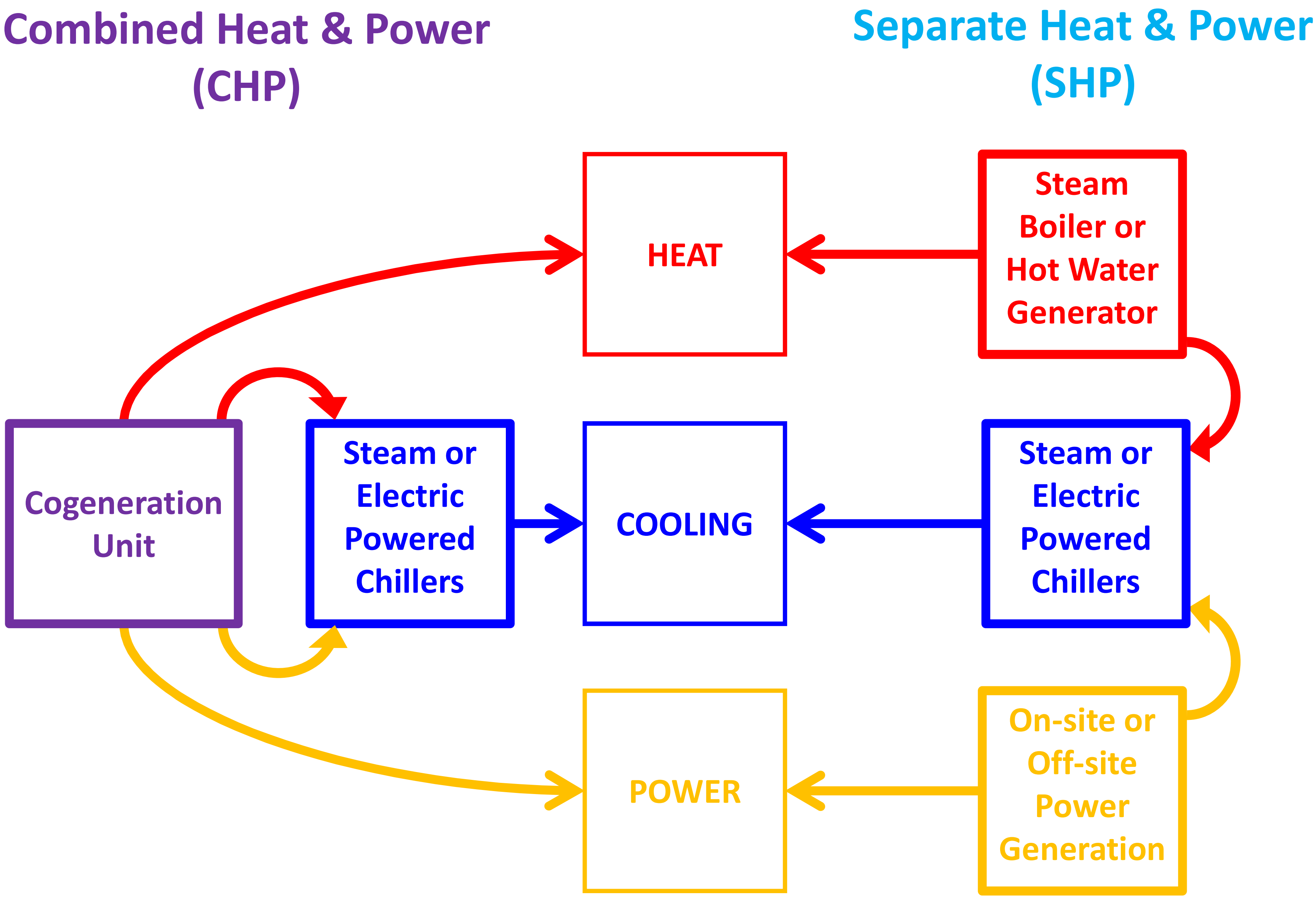
Definitions:

CHP vs. SHP vs. CHC

Cogeneration: Heat & Power



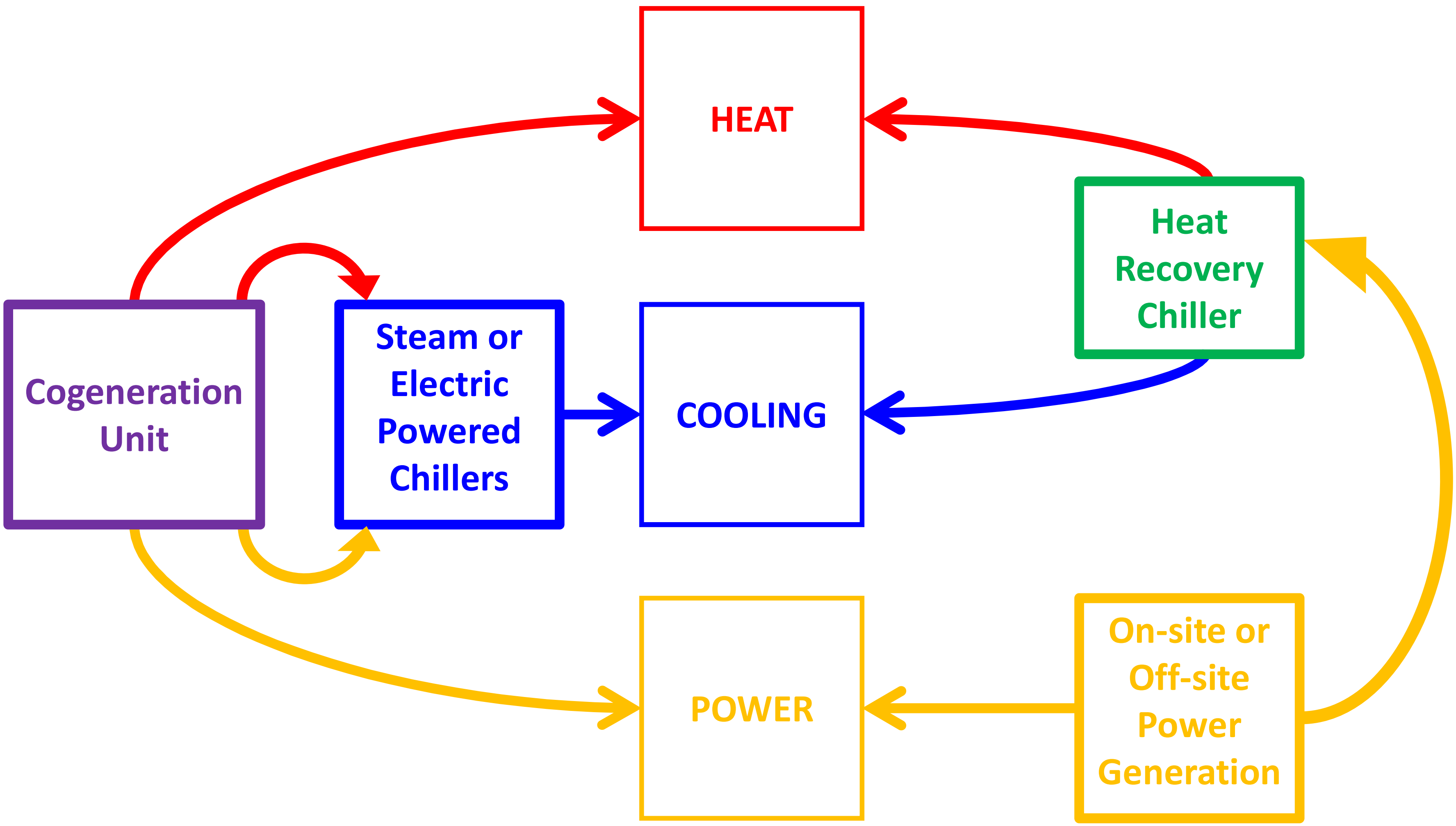
Trigeneration: Heat, Power, & Cooling



Trigeneration: Heat, Power, & Cooling

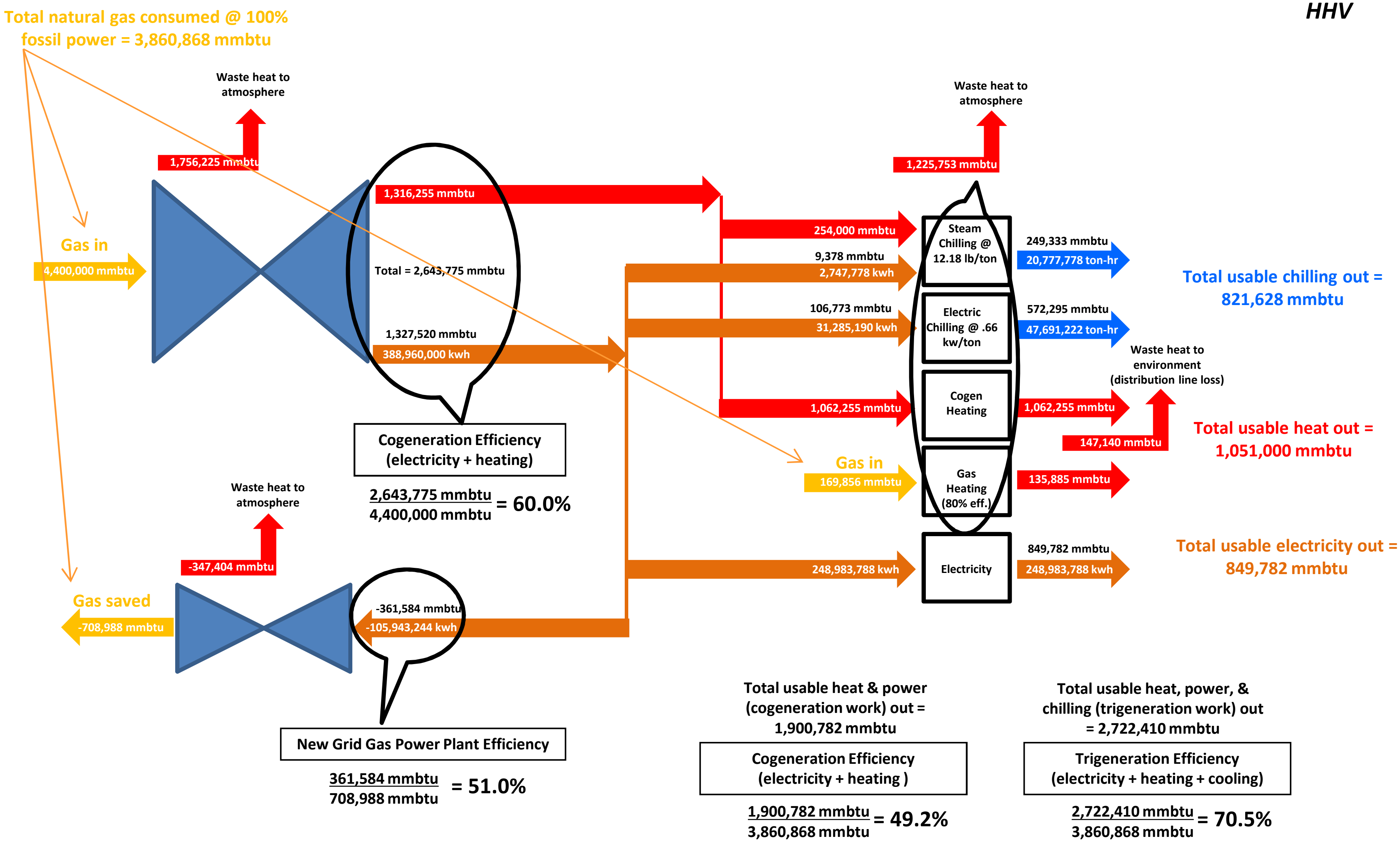
Combined Heat & Power (CHP)

Combined Heat & Cooling (CHC)



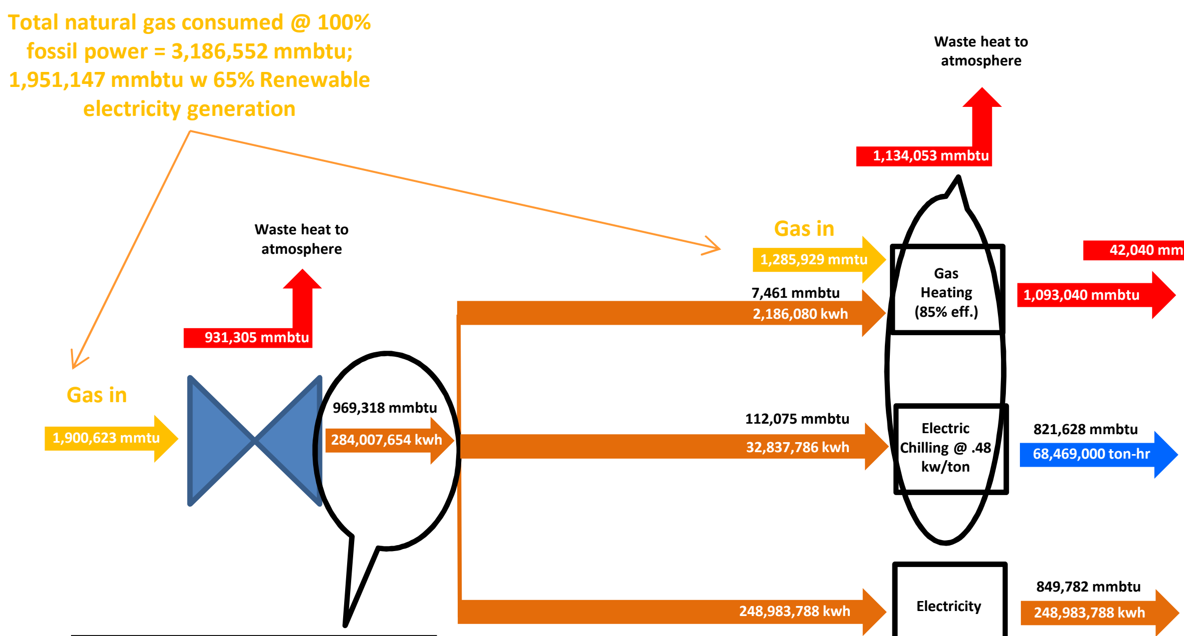
Cardinal Cogeneration (1987 – 2015)

All figures based on gas HHV



Separate Heat & Power with Hot Water

All figures based on gas HHV



Total usable heat out = 1,051,000 mmbtu

Total usable chilling out = 821,628 mmbtu

Total usable electricity out = 849,782 mmbtu

New Grid Gas Power Plant Efficiency

$$\frac{969{,}318 \text{ mmbtu}}{1{,}900{,}623 \text{ mmbtu}} = 51.0\%$$

Total usable heat & power (cogeneration work) out = 1,900,782 mmbtu

Cogeneration Efficiency (HW) (electricity + heating)

$$\frac{1{,}900{,}782 \text{ mmbtu}}{3{,}186{,}552 \text{ mmbtu}} = 59.7\%$$

'Relative' Gas Cogeneration Efficiency (HW) with 33% Renewable Electricity (electricity + heating)

$$\frac{1{,}900{,}782 \text{ mmbtu}}{1{,}951{,}147 \text{ mmbtu}} = 97.4\%$$

Total usable heat, power, & chilling (trigeneration work) out = 2,722,410 mmbtu

Trigeneration Efficiency (HW) (electricity + heating + cooling)

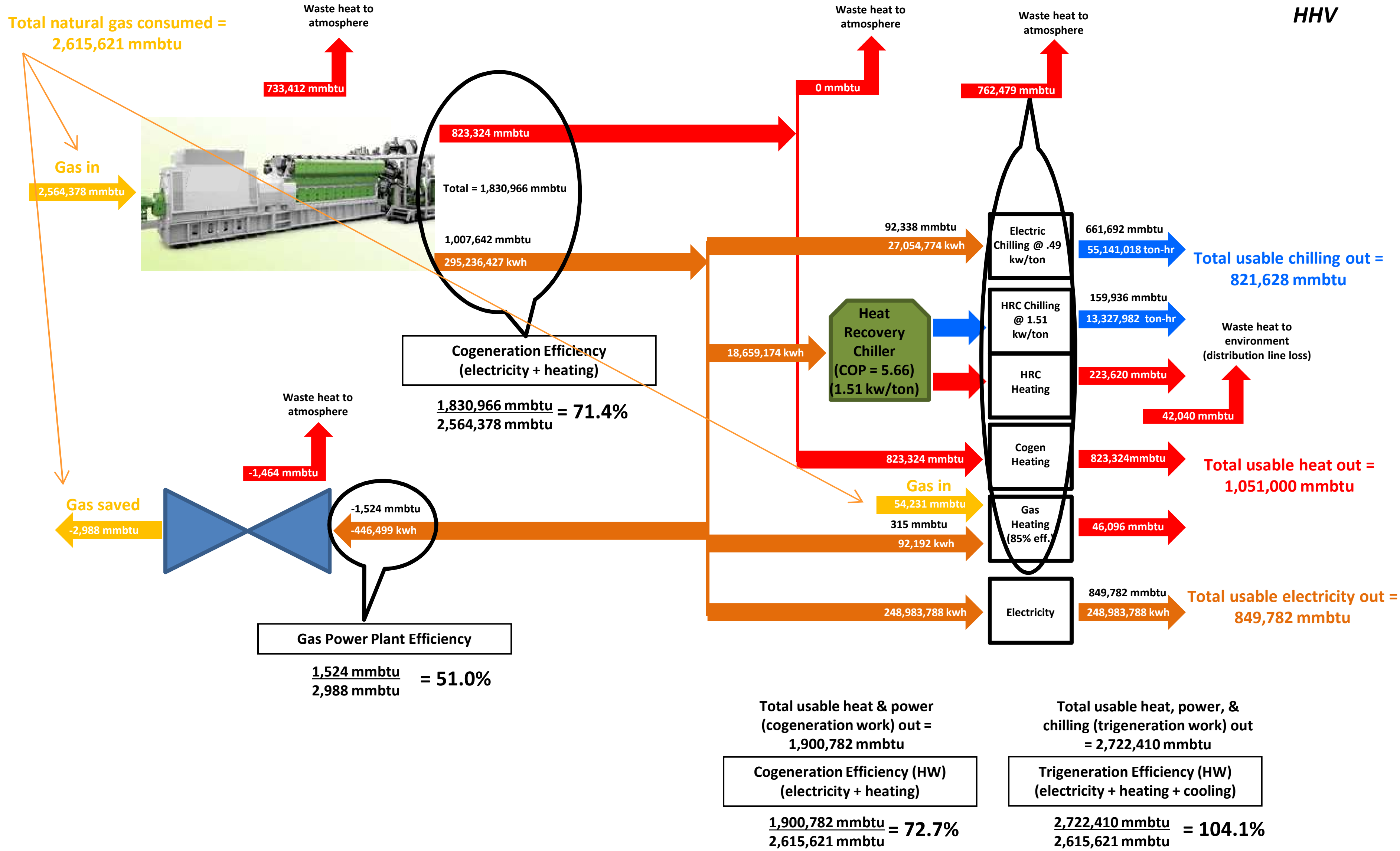
$$\frac{2{,}722{,}410 \text{ mmbtu}}{3{,}186{,}552 \text{ mmbtu}} = 85.4\%$$

'Relative' Gas Trigeneration Efficiency (HW) with 33% Renewable Electricity (electricity + heating + cooling)

$$\frac{2{,}722{,}410 \text{ mmbtu}}{1{,}951{,}147 \text{ mmbtu}} = 139.5\%$$

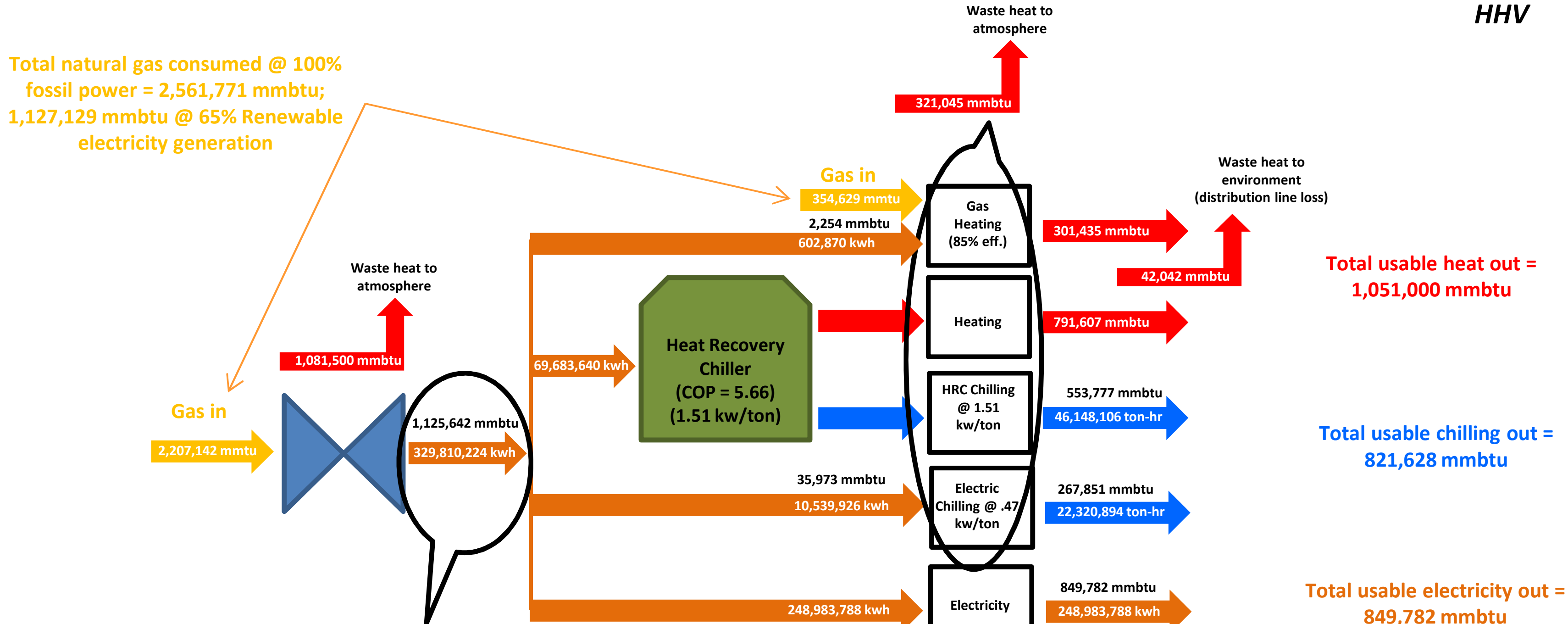
Hygeneration (IC) with Hot Water

All figures based on gas HHV



Combined Heat & Cooling (CHC) with Hot Water

All figures based on gas HHV



Gas Power Plant Efficiency

$$\frac{1{,}125{,}642 \text{ mmbtu}}{2{,}207{,}142 \text{ mmbtu}} = 51.0\%$$

Total usable heat & power (cogeneration work) out = 1,900,782 mmbtu

Cogeneration Efficiency (electricity + heating)

$$\frac{1{,}900{,}782 \text{ mmbtu}}{2{,}539{,}552 \text{ mmbtu}} = 74.8\%$$

Total usable heat, power, & chilling (trigeneration work) out = 2,722,410 mmbtu

Trigeneration Efficiency (electricity + heating + cooling)

$$\frac{2{,}722{,}410 \text{ mmbtu}}{2{,}539{,}552 \text{ mmbtu}} = 107.2\%$$

'Relative' Gas Cogeneration Efficiency with 65% Renewable Electricity (electricity + heating)

$$\frac{1{,}900{,}782 \text{ mmbtu}}{1{,}127{,}129 \text{ mmbtu}} = 168.6\%$$

'Relative' Gas Trigeneration Efficiency with 65% Renewable Electricity (electricity + heating + cooling)

$$\frac{2{,}722{,}410 \text{ mmbtu}}{1{,}127{,}129 \text{ mmbtu}} = 241.5\%$$