Article # 38

Which combination of heat and power saves the most of primary energy input

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Why do we like to have useful heat and useful power output together generated in one “machine”? The answer is we hope to save primary energy compared to generating heat and power separately in two different “machines”.

There is a simple equation which tells you the entire story.

$$PES = \left(1 - \frac{1}{\frac{CHP\,H\eta}{Ref\,H\eta} + \frac{CHP\,E\eta}{Ref\,E\eta}} \right) x\,100\%$$

Where:

PES is the primary energy savings in %.

CHP Hη is the heat efficiency of the cogeneration production defined as <u>annual useful heat output</u> divided by the fuel input used to produce the sum of useful heat and electricity from cogeneration.

Ref Hη is the efficiency reference value for separate heat production.

CHP Eη is the electrical efficiency of the cogeneration production defined as annual electricity from cogeneration divided by the fuel input used to produce the sum of <u>useful heat output and electricity</u> from cogeneration. Where a cogeneration unit generates mechanical energy, the annual electricity from cogeneration may be increased by an additional element representing the amount of electricity which is equivalent to that mechanical energy.

Ref Eη is the efficiency reference value for separate electricity production.

As an example take the case of generating process steam and electricity in a back pressure turbine. Take as a reference to generate separately electricity at 35% efficiency in a turbine and process steam at 85% in a boiler. Consequently the two reference values are Ref Hη = 85% and Ref Eη = 35%.

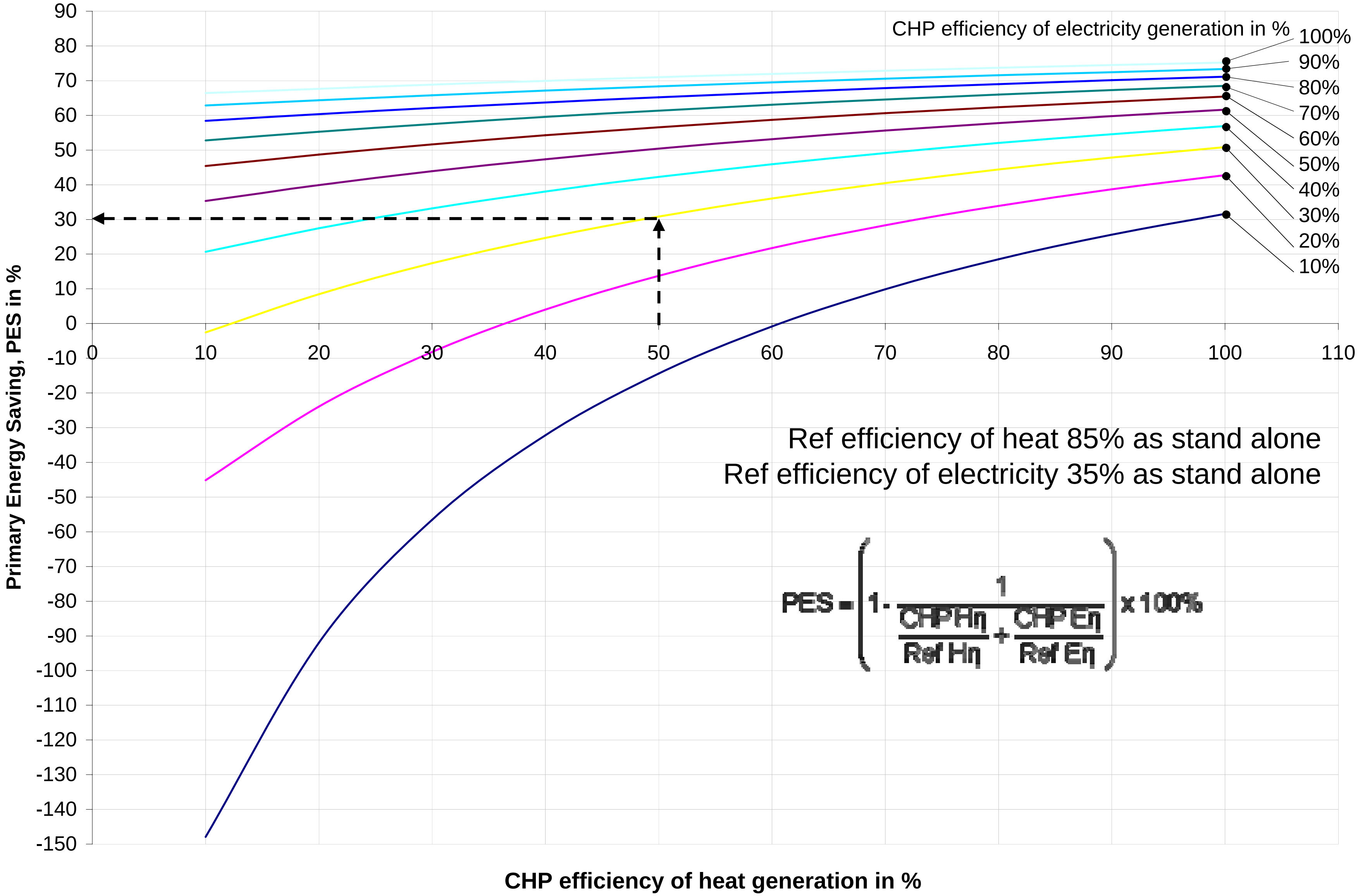
Next look at all theoretical and practical combinations of CHP Hη and CHP Eη from 10% to 100%. Generate the graphics below in an Excel spreadsheet independent whether the combination is technically feasible or saves primary energy. Remember some CHP systems, if not properly assessed and designed, may even increase primary energy consumption therefore PES should be at least larger 10%.

As an example assume CHP Hη of heat generation is 50% and CHP Eη of electricity generation is 30% efficient in the "one machine" setup. This combination would save 30% of primary energy based on the equation. Whether this pair (50, 30) of efficiencies can match a practical application is altogether a different issue.

Remember all CHP technologies have a so called power to heat ratio "C" constraint which correlates the amount of electricity E_{CHP} from cogeneration to the amount of useful heat H_{CHP} from cogeneration through the equation $E_{CHP} = C \times H_{CHP}$. This constraint "C" is given by the technology and may be anywhere from C = 0.40 for a steam backpressure turbine to C = 0.95 for a combined cycle gas turbine with heat recovery.

Consequently to maximize the primary energy savings it is always best to have an option to either export electricity or process heat from the CHP unit. It is common to observe and measure both energy streams to arrive at an annual average for C.

A national policy or regulation could set PES at any value between 10% and 30%. Which value is the best in terms of the national primary energy saving potential is determent by the product: "Market potential at PES x PES". Something the SERC's could think about.



CHP efficiency of electricity generation in %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
Ref efficiency of heat 85% as stand alone
Ref efficiency of electricity 35% as stand alone
PES = (1 - 1 / (CHP Hη / Ref Hη + CHP Eη / Ref Eη)) x 100%
Primary Energy Saving, PES in %
CHP efficiency of heat generation in %
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
0
10
20
30
40
50
60
70
80
90
100
110