The Real Merits of Large CHP-DH

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Summary

Why Combined Heat and Power ?

Electric Heat Pumps

Large CHP-District Heating

The Importance of CHP Unit Size

Large CHP-DH is best for near-zero-carbon heat

Why CHP ?

A Combined Heat and Power plant provides ‘Thermodynamic’ heat.

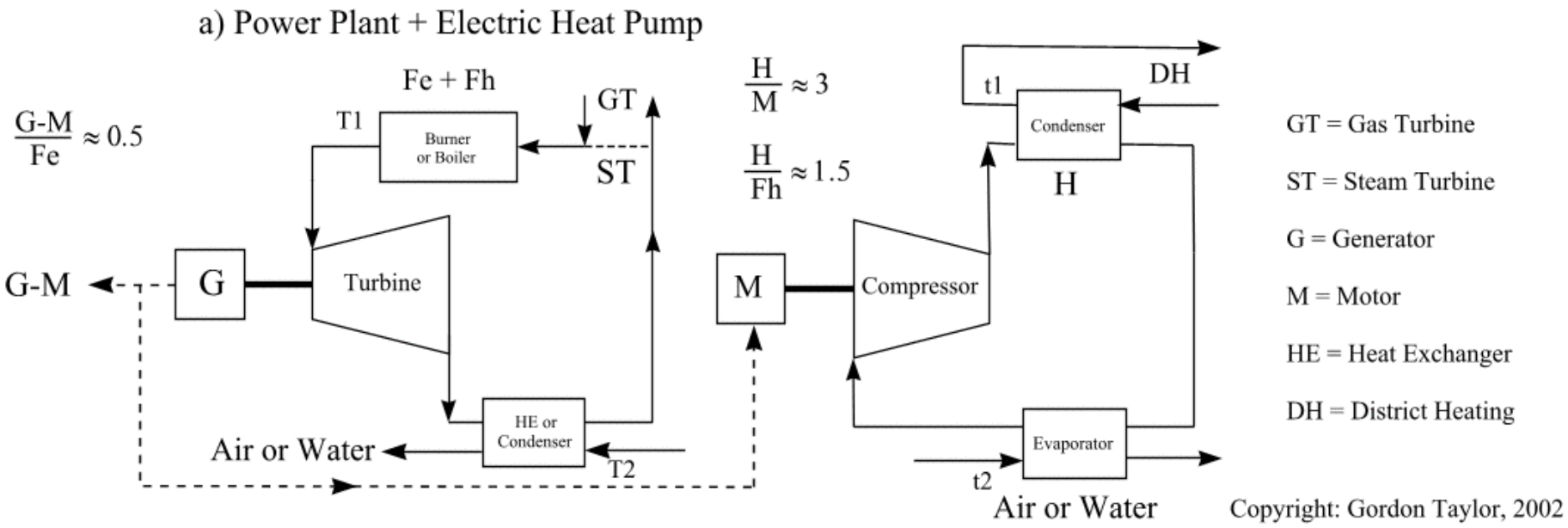
It uses a ‘Virtual’ Heat Pump, with no separate hardware or working fluid.

A CHP plant replaces a Power-Only plant and Cooling Towers with a District Heating network.

So it makes use of Power Plant reject heat, which is otherwise wasted.

In the UK, this is about 15% of all Primary Energy consumption.

Power Plant + Electric Heat Pump - 1



Power Plant Effy 50% x HP COP 300% = Thermodynamic Heating Effy 150%

Power Plant + Electric Heat Pump - 2

The Thermodynamic Heating Efficiency = Heat Out / Incremental Fuel.
This is the reciprocal of the 'Primary Energy Factor' used on the Continent.

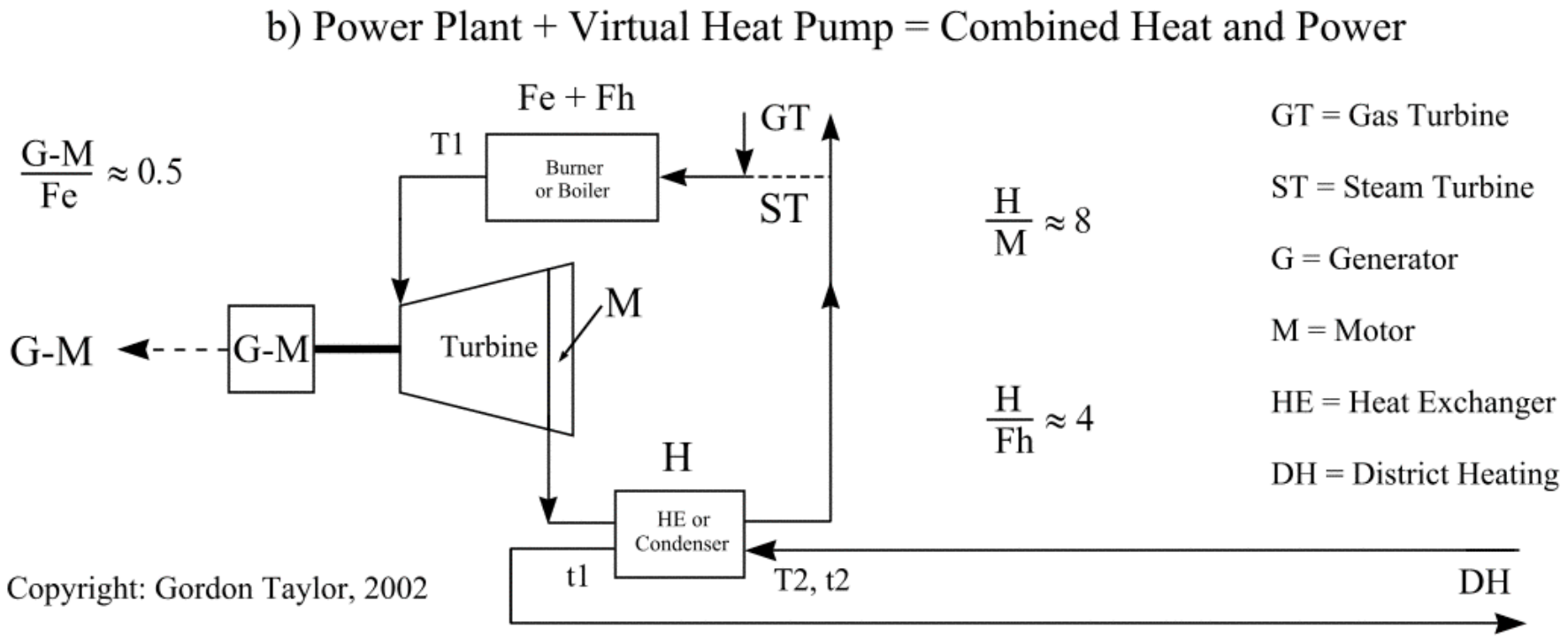
Thermal power plants and individual electric heat pumps have a Thermodynamic Heating Efficiency of less than 150%.

Compared with individual condensing gas boilers with efficiency of 96%, the fuel and CO2 saving is less than 30%.

Building heat loads are uncertain and vary with occupant number and behaviour. So the heat pump may be oversized and run inefficiently, or undersized and require more use of the backup heater. Thus the fuel and CO2 saving is often less, as shown by field trials.

Widespread use of electric heat pumps would require very costly upgrading of electricity generation, transmission and distribution.

Large CHP-DH - 1



Power Plant Effy 50% x Virtual HP COP 800% = Thermodynamic Heating Effy 400%

Large CHP-DH - 2

The Thermodynamic Heating Efficiency = Heat Out / Incremental Fuel.
This is the reciprocal of the 'Primary Energy Factor' used on the Continent.

Large gas-fired CHP plants have a THE at the plant gate of about 400%.
Some heat is from Heat-Only Boilers and the DH network has heat losses.
So the Thermodynamic Heating Efficiency of Large CHP-DH is about 330%.

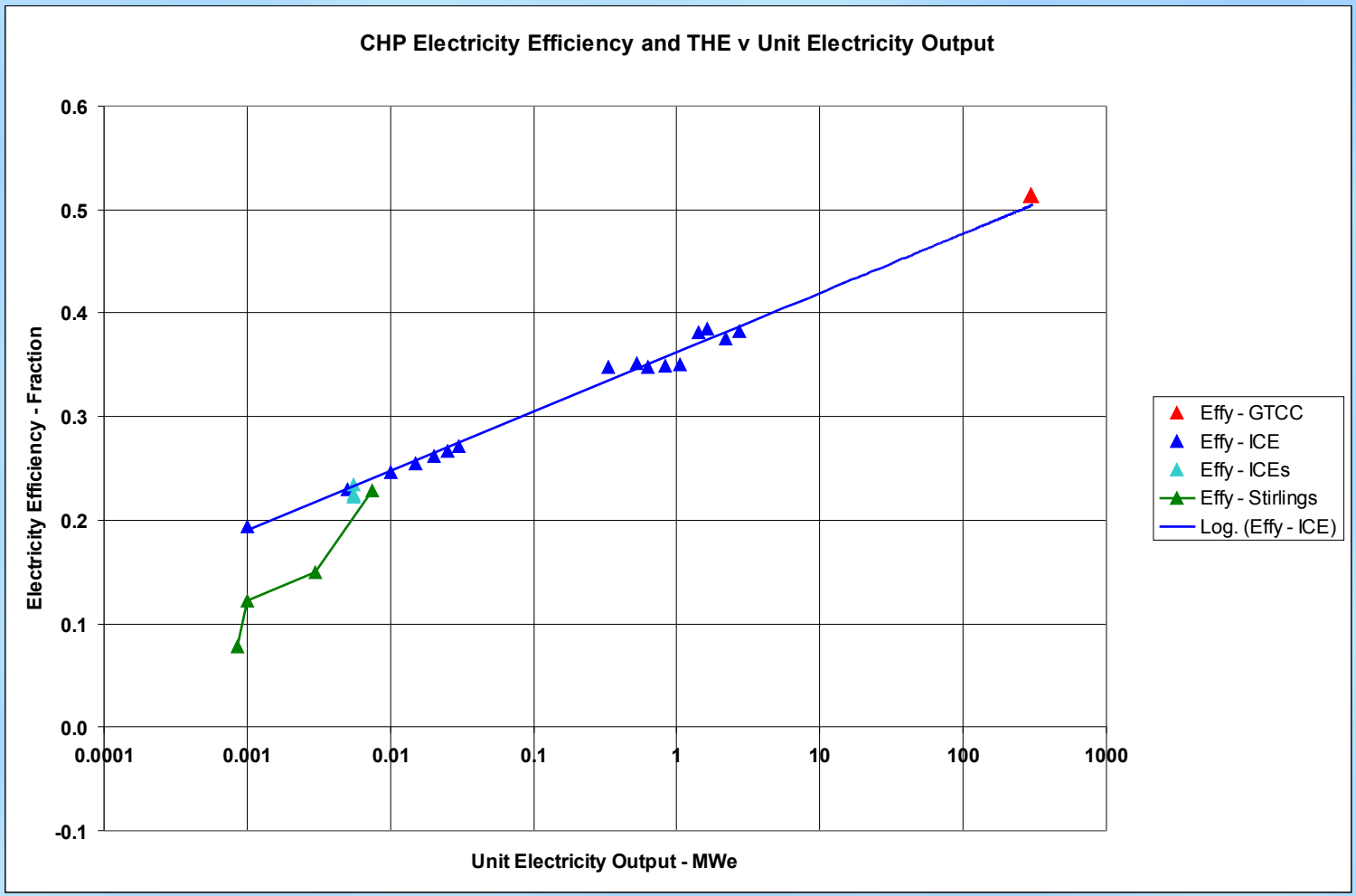
Compared with individual existing gas boilers with an annual average efficiency of 65%, the fuel and CO2 saving is about 80%.

Building heat loads are uncertain and vary with occupant number and behaviour.
But these are averaged, so have little effect on the THE and CO2 saving.

Modern DH systems vary the flow temperature over the year, so reducing losses and providing primary 'outside compensation' control. They also include individual water flow or heat meters, so avoiding waste.

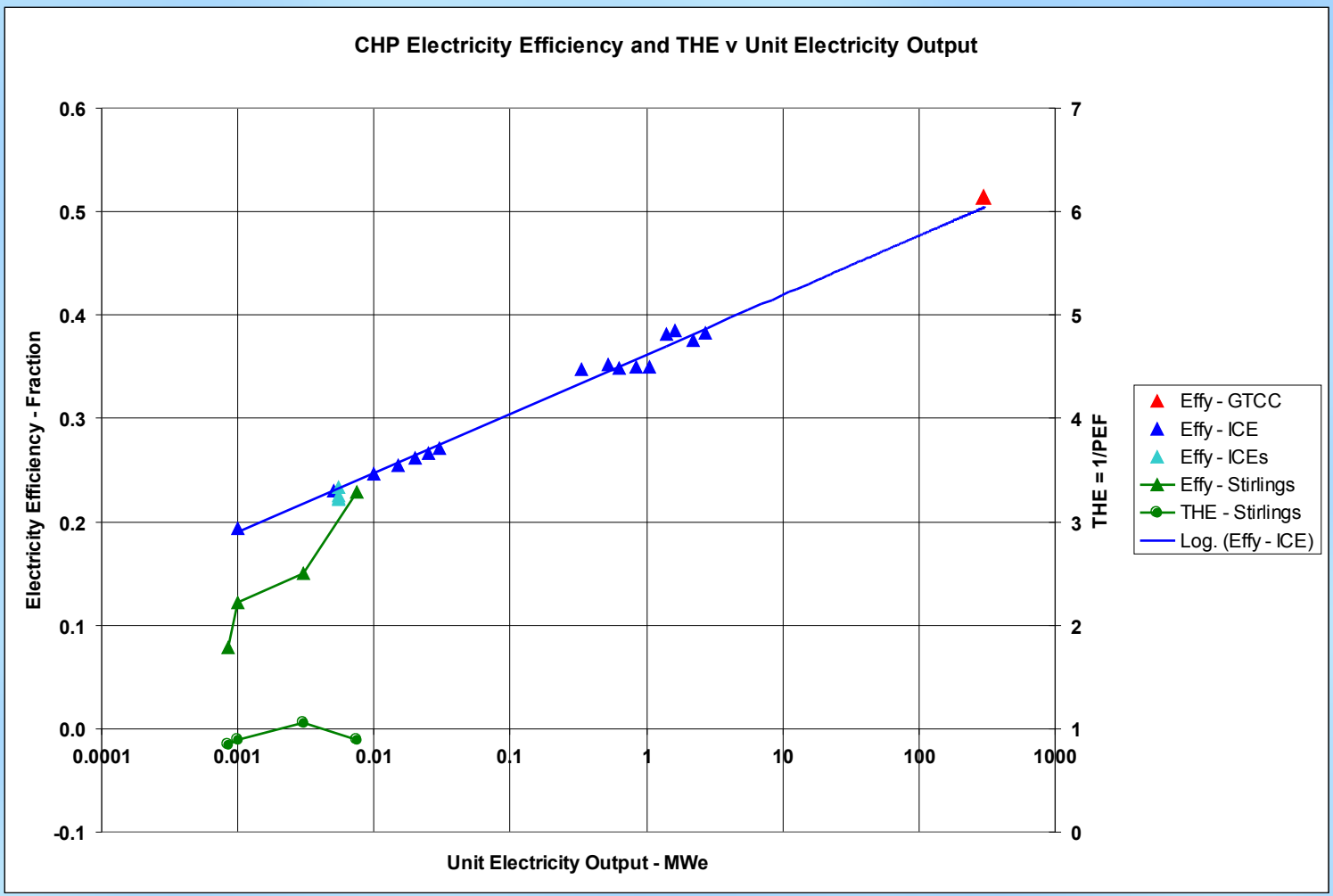
The Importance of CHP Unit Size - 1

Electricity Efficiency vs Unit Size – All CHP



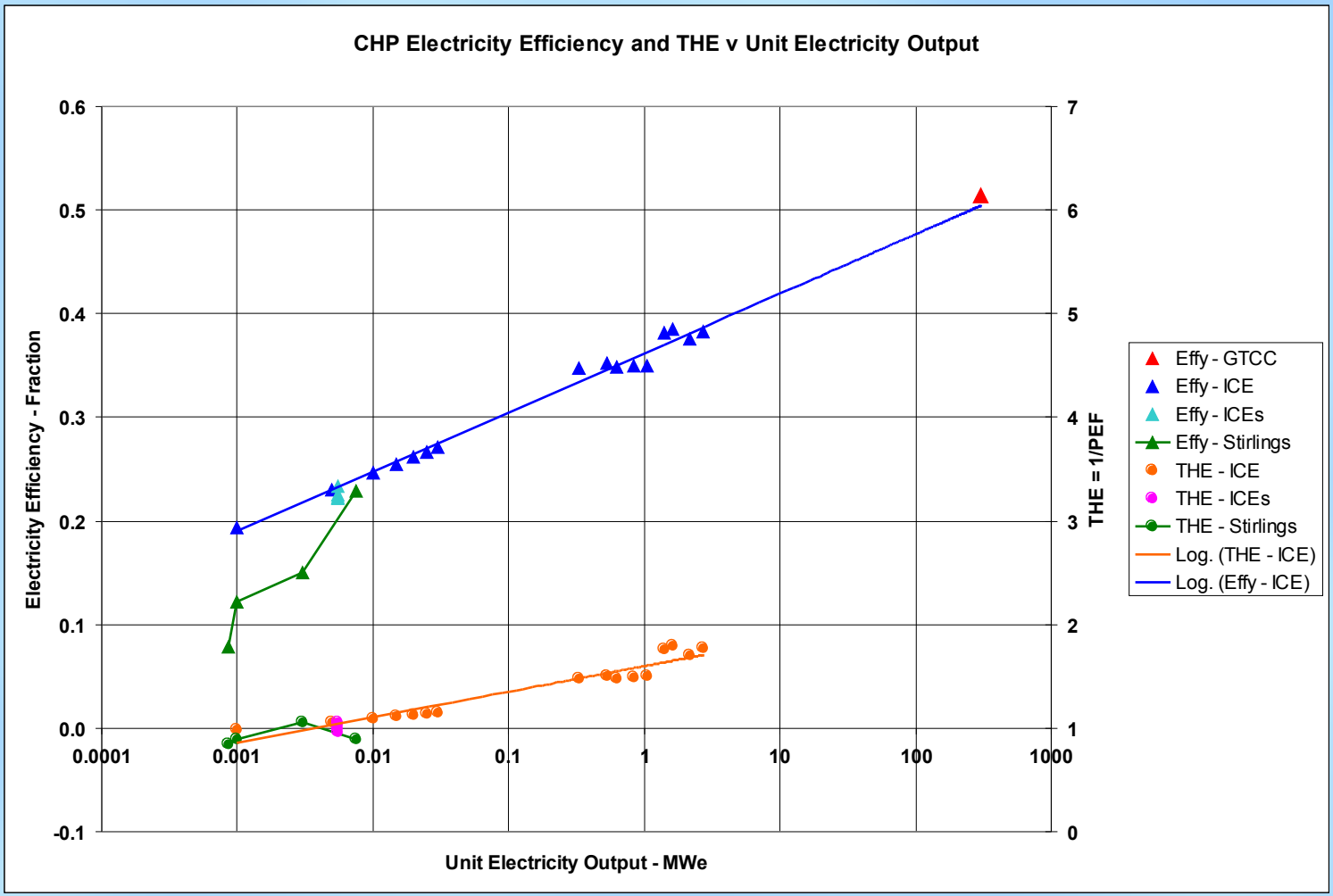
The Importance of CHP Unit Size - 2

Add Thermodynamic Heating Efficiency - Stirling micro-chp



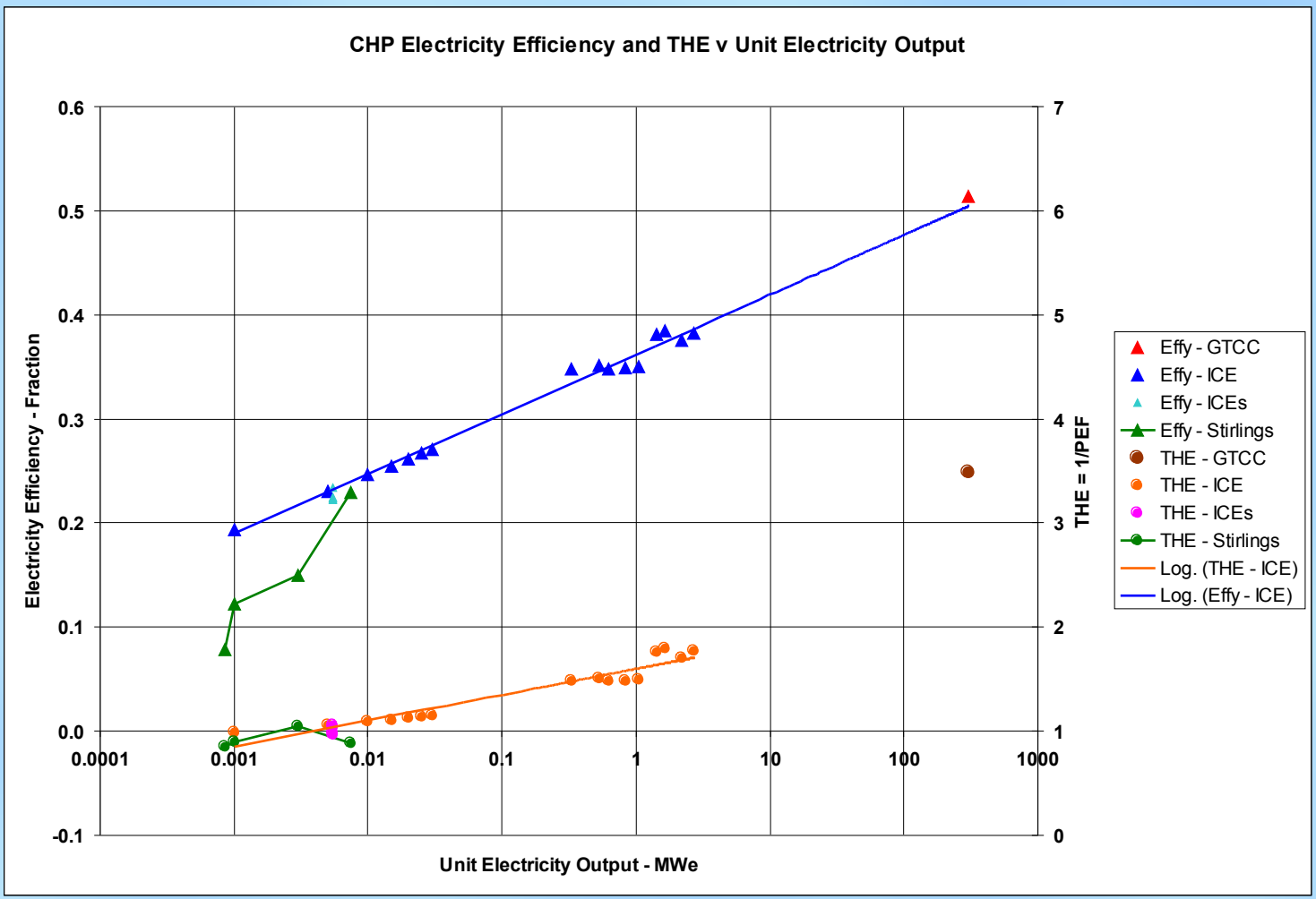
The Importance of CHP Unit Size - 3

Add Thermodynamic Heating Efficiency - micro-chp and mid-chp



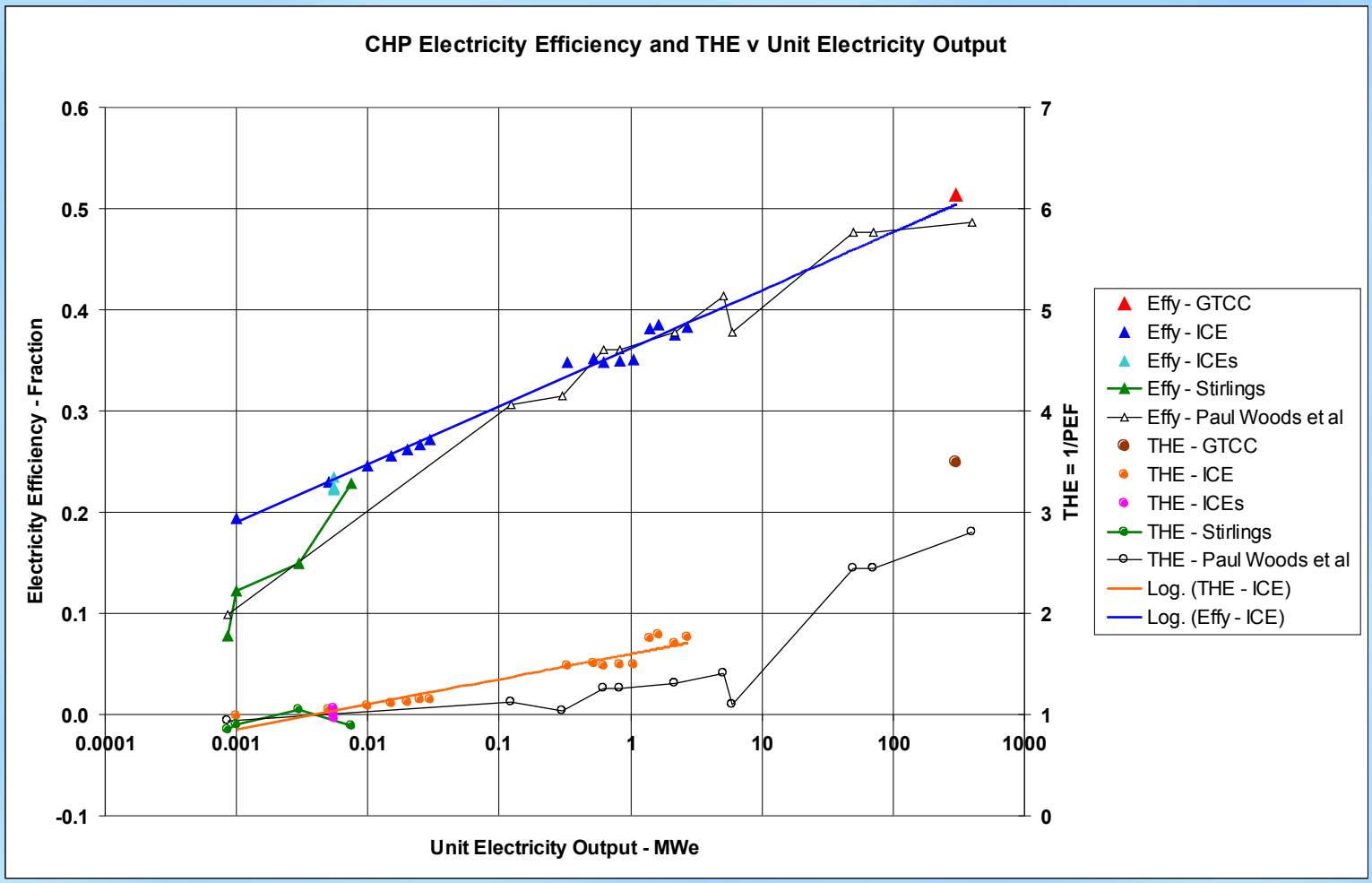
The Importance of CHP Unit Size - 4

Add Thermodynamic Heating Efficiency - GTCC



The Importance of CHP Unit Size - 4

Add data from Paul Woods et al, as amended



The Importance of CHP Unit Size - 6

GTCC CHP units of ~ 300 MWe have a Thermodynamic Heating Efficiency of about 400% (HCV). With ~ 5% of the heat from Heat Only Boilers, and ~ 7% for DH network heat losses, the THE of Large CHP-DH is about 330%.

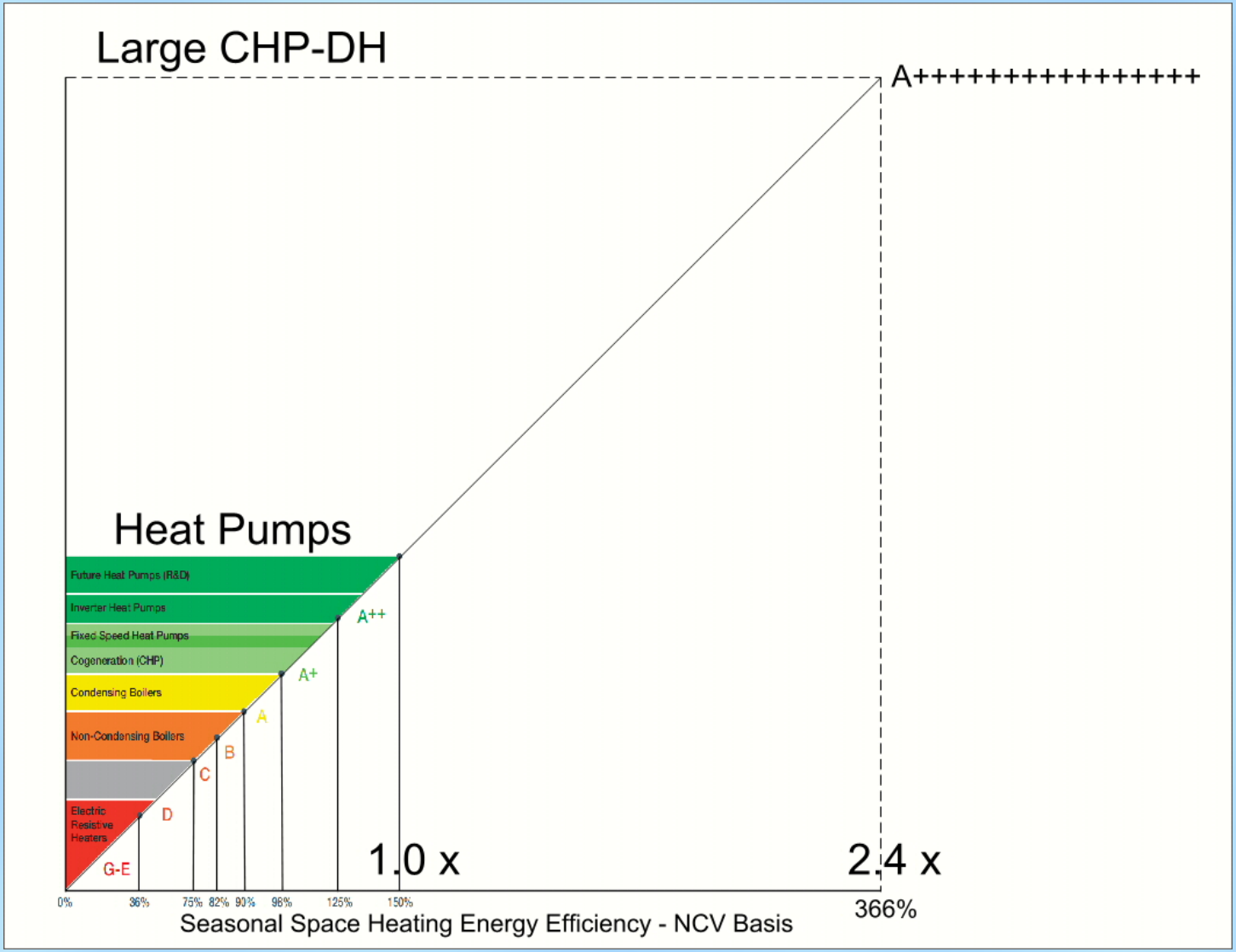
Compared with individual existing gas boilers with an efficiency of 65%, the fuel and CO2 saving is about 80%.

Micro-chp systems of ~ 1 kWe have a Thermodynamic Heating Efficiency of less than 100%.

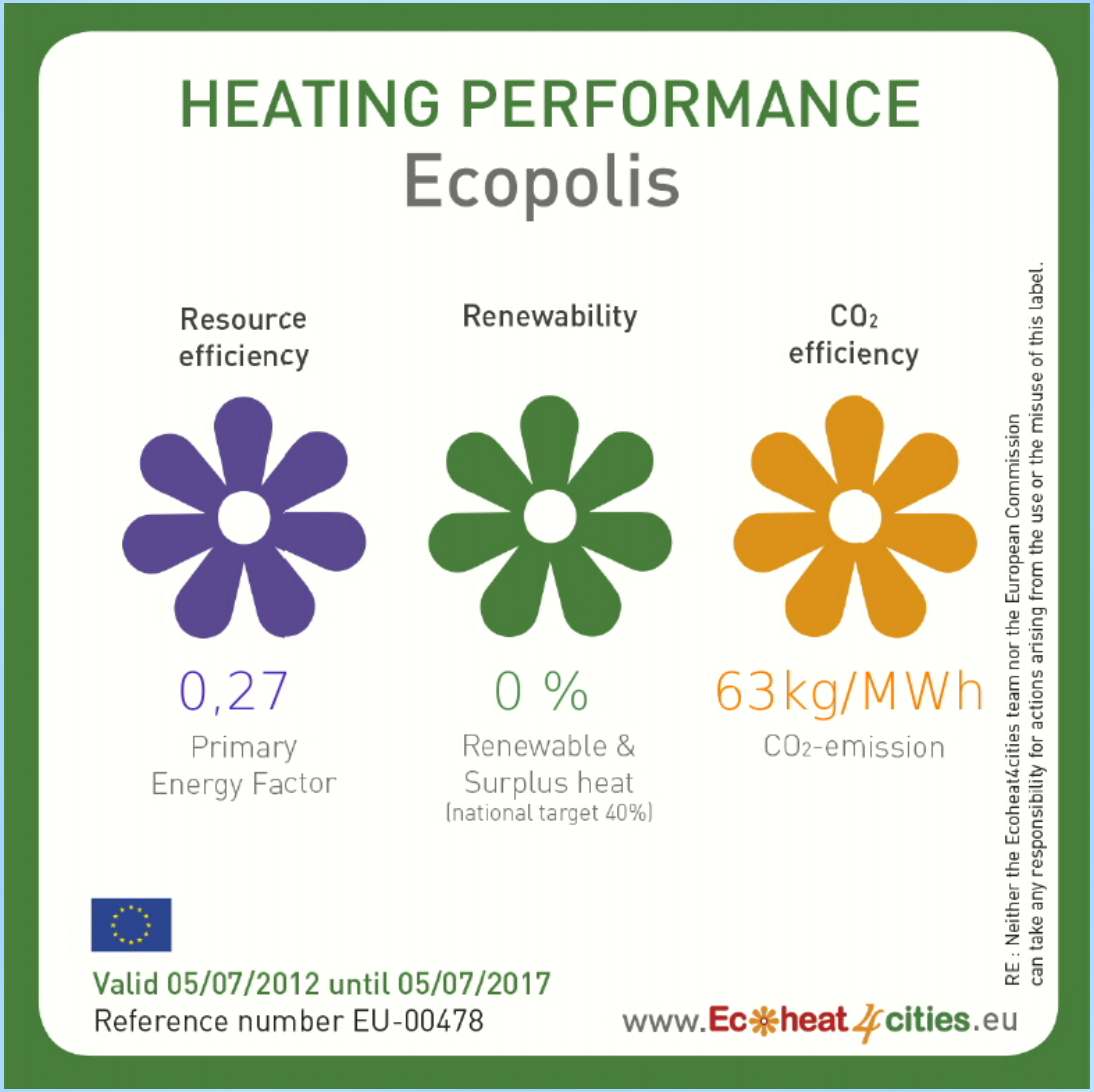
Compared with individual condensing gas boilers with an efficiency of 96%, the fuel and CO2 saving is less than 0% - I.e. negative.

For micro-chp systems the above values are for full load and full use of the electricity and heat. But the electricity load varies rapidly and widely and the heat load also requires a boiler. This reduces the electricity and heat efficiencies, and hence the fuel and CO2 savings, as shown by field trials.

Large CHP-DH compared as per ErPD



DH System Energy & Emissions Label



Further Merits of Large CHP-DH - 1

In large networks, the maximum load is ~ 0.6 times all the individual loads due to diversity, so the central plant is smaller and less costly.

Large CHP-DH can avoid the NOx emissions from individual gas boilers that contribute to poor air quality.

Large central plants are installed and run by professionals who look after reliable service, stack emissions, energy efficiency, water quality and maintenance, so have long lives.

But small distributed plants are often poorly installed, run by end-users, and poorly maintained, so have short lives.

Further Merits of Large CHP-DH - 2

Compared with electricity and gas, District Heating networks, at ~ 70 °C, give the best possible exergy match for space and water heating.

So they are future-proof and easy to finance over long periods.

DH networks can also use industrial reject heat and renewable heat.

This includes municipal waste, biomass, large solar heat arrays, excess wind electricity, and deep geothermal heat.

By such means, the CO2 saving for the buildings heated by the West Copenhagen CHP-DH system has reached nearly 90%.

Conclusions

Large CHP-DH gives much greater fuel and CO2 savings than individual electric heat pumps.

Micro-chp offers no fuel or CO2 saving over condensing boilers.

District Heating is the best means of harnessing industrial reject heat and low-carbon sources such as waste, biomass, solar heat, wind energy, and deep geothermal heat.

Large CHP-DH is the best means of near-zero-carbon heating of buildings in towns and cities where refurbishment to Passive House standards would be too costly or unacceptable, notably for heritage buildings.

The Real Merits of Large CHP-DH
'1000 Cities Cannot be Wrong'

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