A review of methodologies analyzing electricity and heat production from Combined Heat and Power, CHP, and their signals to heat and electricity sectors. Cross subsidy of electricity sector by heat sector.

William R H Orchard MA (Oxon) MBA CEng FIMechE MCIBSE MIET FEI
Orchard Partners London Ltd
9 Lansdowne Close
London SW20 8AS
William@orchardpartners.co.uk

(1) Overview

Our EU funded Ecostiler project evaluates a low temperature low CO2 heat network option to decarbonize UK urban dwellings. We evaluate common modeling assumptions and methods for analyzing the joint heat and power products from Combined Heat and Power "CHP". We show how EUETS, the EU Cogeneration Directive, DUKES, CHPQA, and the EU "Carnot method for renewable CHP, all signal reductions in fuel and primary energy for incremental electricity generation, contravening the second law of thermodynamics which requires heat rejection as part of the thermal generation process. This reject heat exceeds UK domestic gas supply.

CHP a "Virtual heat pump" ref [i] ref [ii] , can in practice decarbonize dwellings heated by gas when retrofitted to the coal fired CHP district heat in Odense. Ten units of waste heat are upgraded using one unit of electricity. A coefficient performance "COP" of ten in electric heat pump terms.

We suggest CHP can be modeled simply, using this "COP" or Z factor to generate fuel use, CO2 overhead and marginal cost of heat to optimize CHP and heat networks in models such as Markal/Times. Sofia Simeos at JRC Petten simplified this concept by suggesting waste heat be treated as a potential low grade energy source in models. We also explore Exergy methods for CHP.

We further propose Modular Energy Hubs incorporating 500 kW-2000kW CHP, heat pumps, fuel and heat stores, with battery storage and exchange for Electric Vehicles. The Hubs, optimize intermittent renewable electricity from wind and solar PV minimizing electrical infrastructure investment for 2050. Large scale solar thermal feeds the 75C flow 30C return heat networks.

(2) Methods

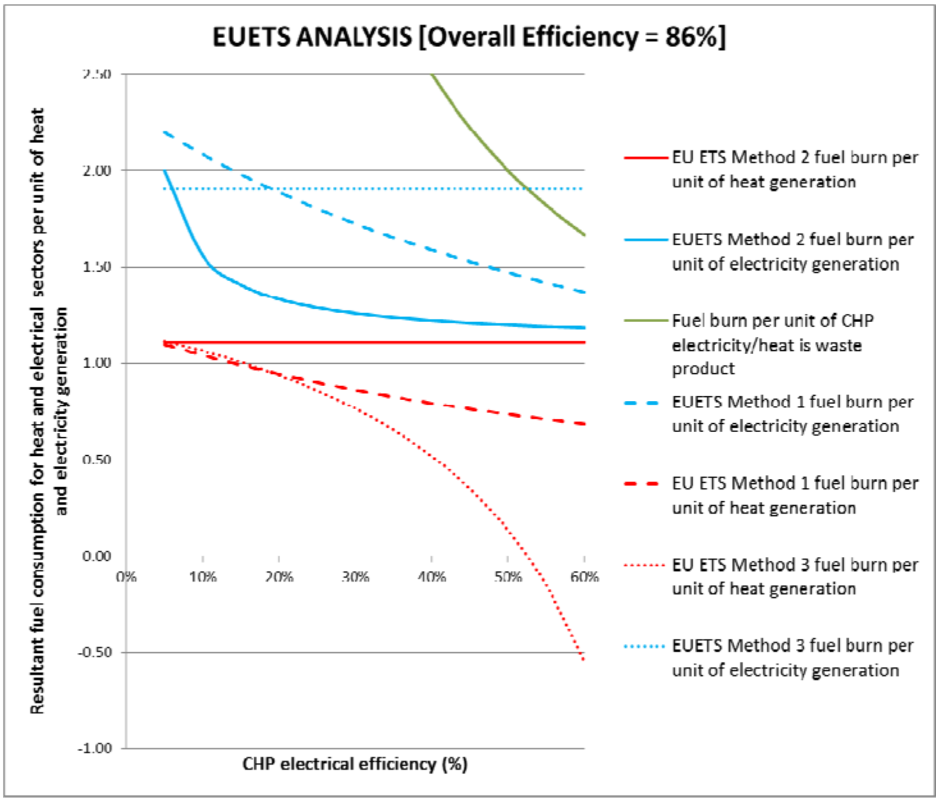
Analysis carried out with spreadsheets and graphs to explore effects of differing formulas and assumptions on policy and incentives. Thermodynamic analysis of power plants heat networks and retrofitting options for UK domestic housing stock for connection to heat networks.

(3) Results

Fig. 1: Illustrates a sample result for European Emissions Trading EUETS Ref [iii] when we analysed that reports three methods the effect on heat and electricity consumer's emissions.

Method 2 is the method currently adopted for EUETS. For heat consumers it signals fuel burn in a boiler as their emissions, reflected by the solid horizontal red line. For the electricity consumers it signals significant reductions in fuel use per unit of electricity shown by the difference between the green line, the actual fuel burn per unit of electricity, and the solid blue line the EUETS allocation. This result is inconsistent with an economic analysis of joint products under conditions where there is marginal increase in electricity demand with no change in heat demand. This always follows the green line.

The research sets out reasons why method three more closely reflects a “perfect market condition” ref [iv] where CHPs compete against each other, as well as electric heat pumps to meet changes in demand and summer domestic hot water loads.



(4) Conclusions

1) Modification of EUETS to signal heat as a low CO2 product, so that CO2 trading over heat networks develops. 2) CHP to be defined as “Renewable” as electric heat pumps in practice can generate higher CO2 emissions than fossil CHP, where electricity for the heat pump is fossil. 3) 2004 EU directive ref v requires a 10% saving for electricity combined with heat. Given CHP only delivers heat sector savings, revise to a 10% heat sector saving. 4) The EU renewable CHP “Carnot method” disadvantages Danish low temperature district heat. Revise arbitrary 150C assumption for CHP for district heat to use actual temperatures. 5) Integrate EUETS, EU CHP Directive and Carnot method into single consistent method. 6) Review Hub concept to increase security of supply of heat gas and electricity infrastructures, and its emergency liquid fuel stores.

Discussion. Is there a case for “Exergy Economists” to reflect the second law of thermodynamics?

References.

[i] Professor Robert Lowe, UCL Energy Institute, London, WC1H 0NN Combined heat and power considered as a virtual steam cycle heat pump. Energy Policy UK www.elsevier.com/locate/enpol 39 (2011) 5528–5534

[ii] WRH Orchard (2010) Why Heat from Combined Heat and Power (CHP), Vilnius Three, is as Renewable as Heat from Electric Heat Pumps. A Marginal Cost and Exergy Analysis for Fuel Allocations to Electricity and Heat (2010), Orchard Partners London Ltd

[iii] AEA report EU Emissions Trading System: Benchmarking as an allocation methodology for heat from 2013 (Final Report) (16 June 2010) Report to the Environment Agency and DECC

[iv] WRH Orchard Discussion of defects in current UK and proposed EU conventions for the allocation of fuel burn for power, and heat rejected in power generation. British Institute of Energy Economists BIEE 2003. “Orchard Convention methodology”

[v] Directive 2004/8/EC of the European Parliament and of the Council of 11th February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC (11 February 2004) Official Journal of the European Union