Post Occupancy Evaluation of Decentralised Energy Systems and District Heating

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REDEVELOP RECREATE RETHINK
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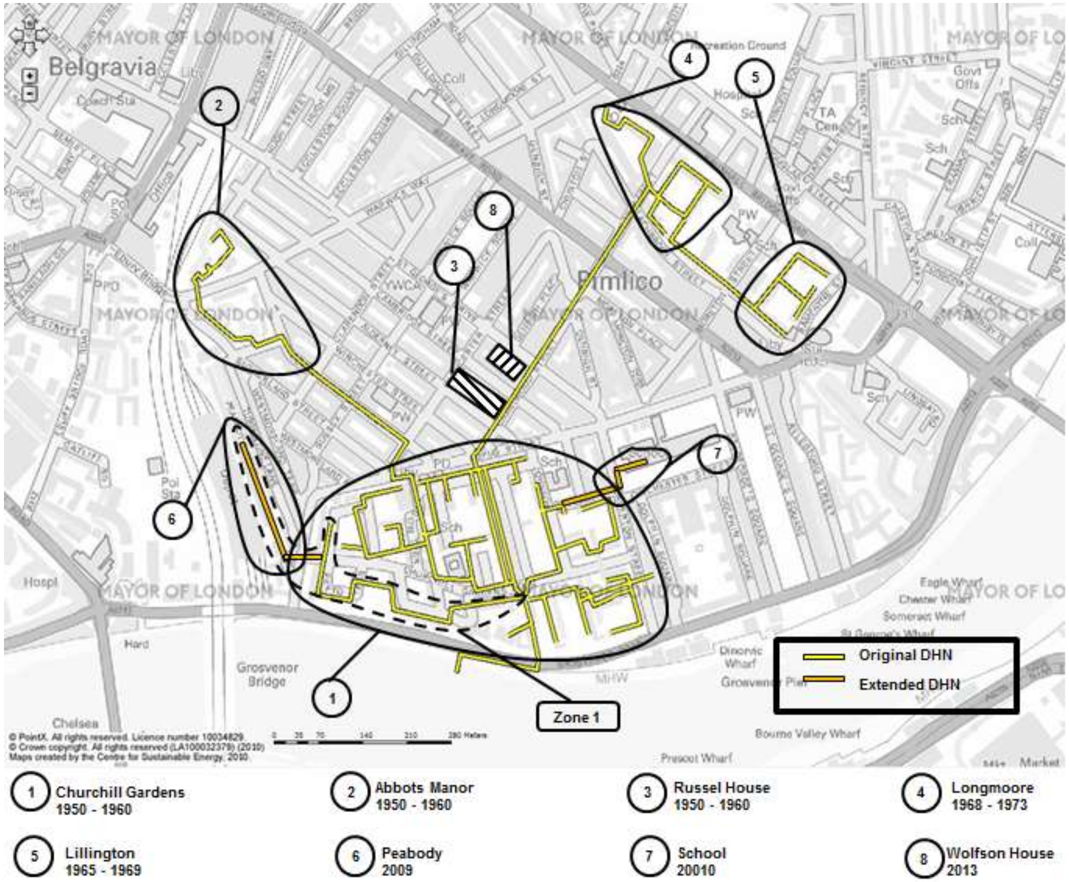
Case study: Pimlico District Heating Undertaking

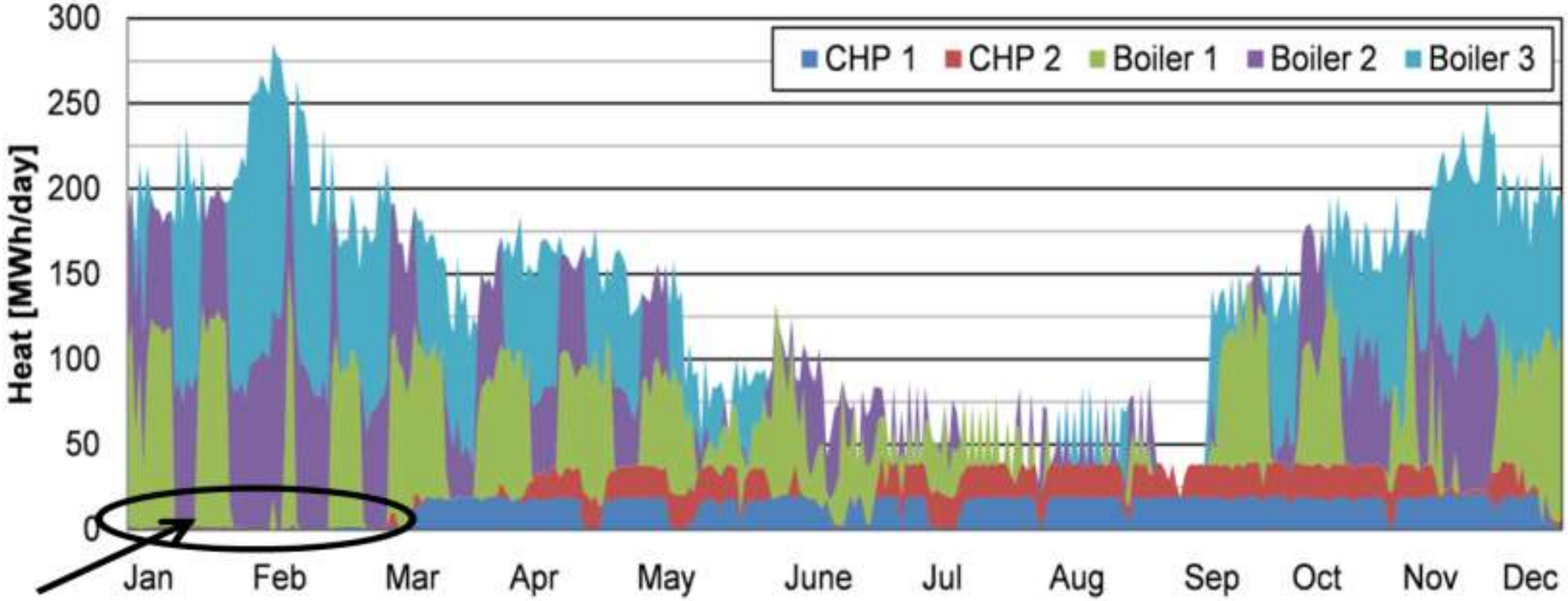


Through 7,900 metres of DHN, Pimlico supplies 50,000 MWh of heating load per year to:

- 3,256 residential units
- 55 commercial units

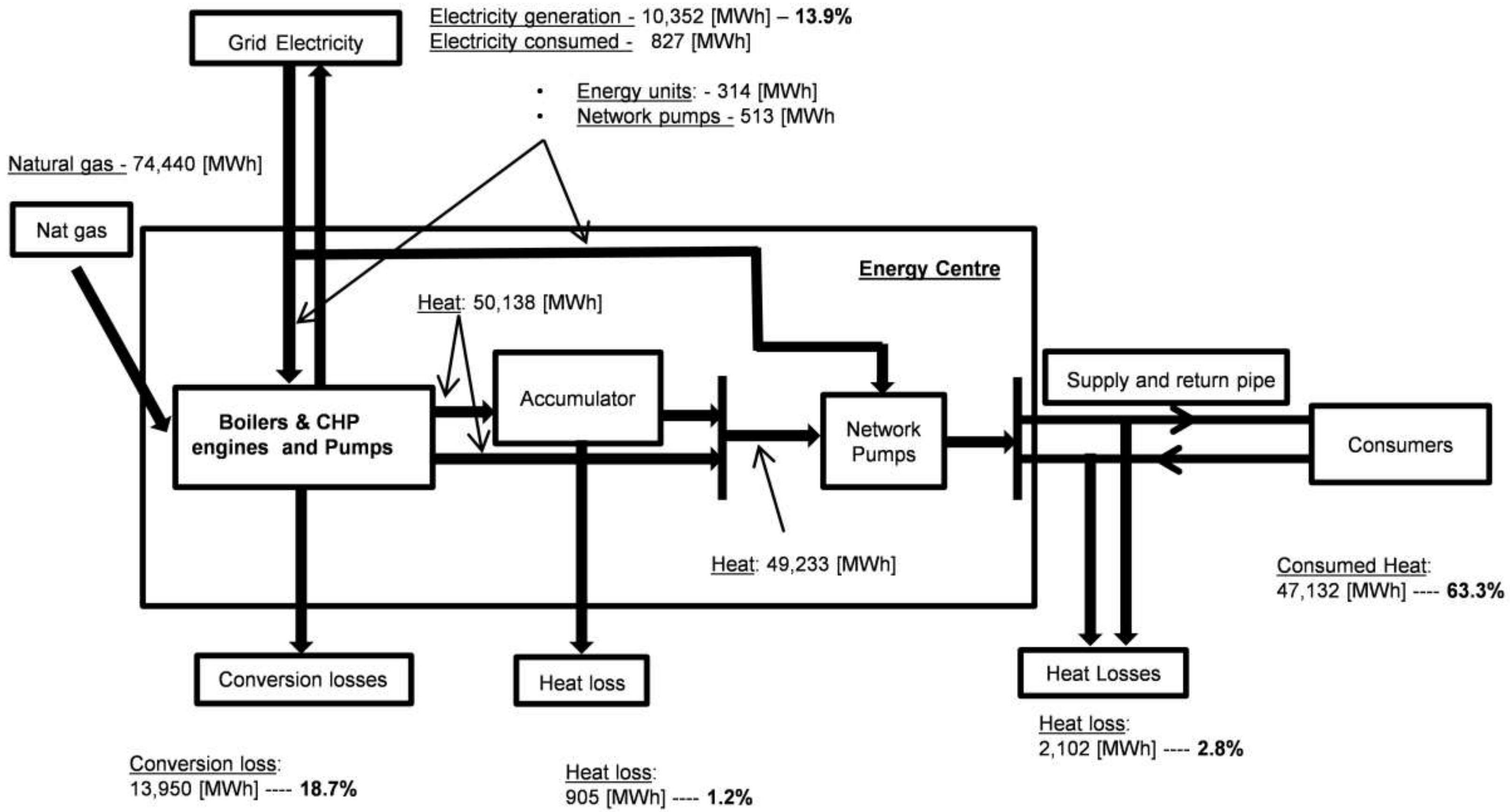
Pimlico District Heating Undertaking

Annual Daily Heat Generation

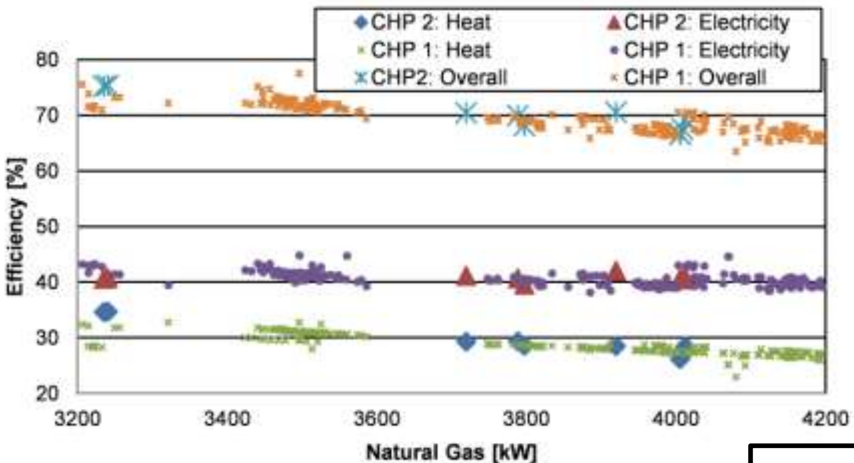


Due to no maintenance agreement contract at this time, the CHP engines were regularly broke down and not operating.

Annual Energy Flow Diagram

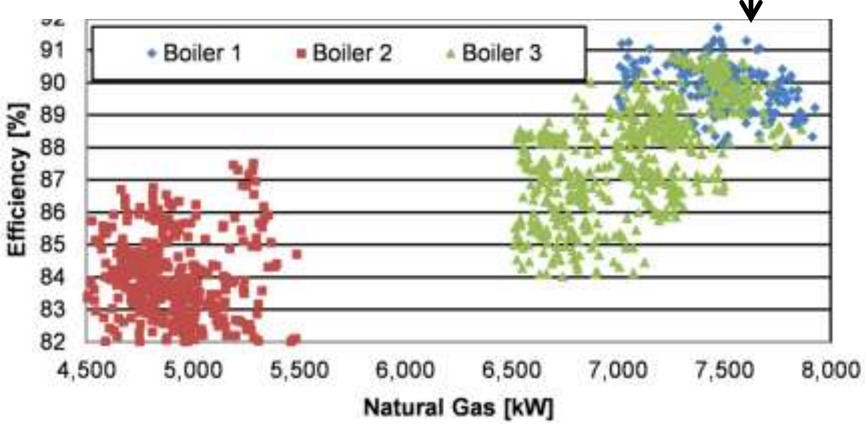


Boilers and CHP Engines Efficiencies and Operation

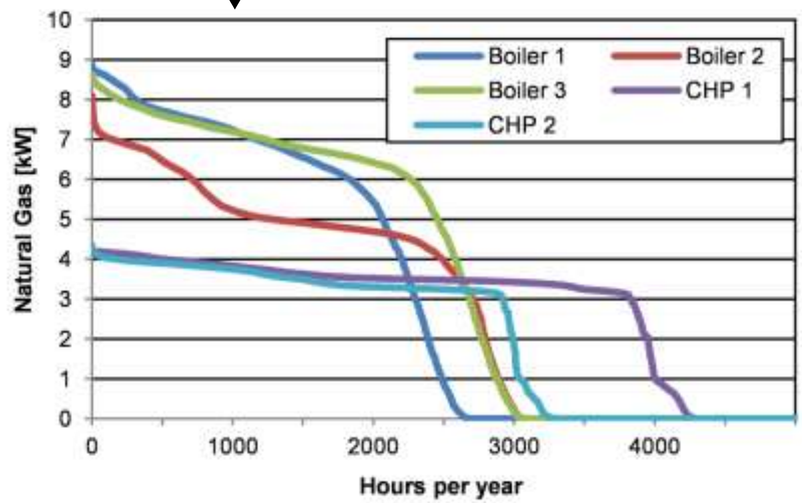


CHP engines steady- state operating efficiencies

Boilers steady-state operating efficiencies



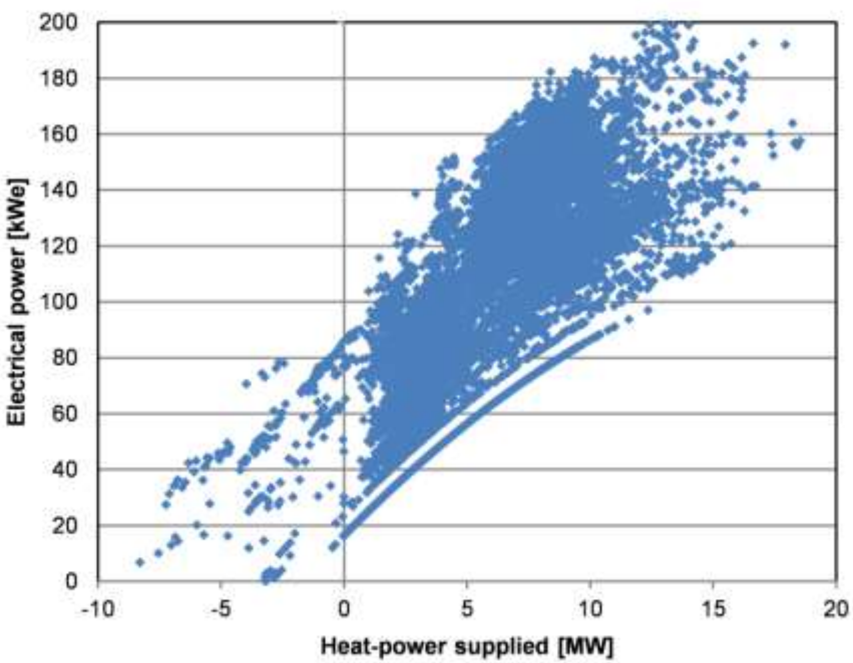
Duration curve



Electricity Consumption From The Energy Centre

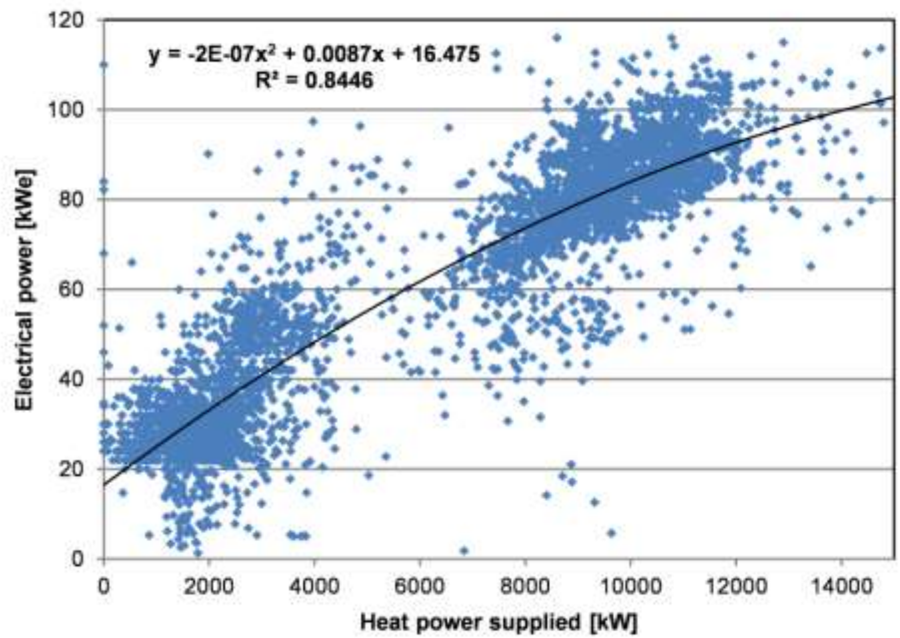
Total electricity consumption based on half-hourly data:

- 827 MWh/year



Total electricity consumption to pump the heat through the DHN:

- 513 MWh/year



Energy Analysis

	Pimlico (2012)
Natural gas consumption [MWh/annum]	74,440
Electricity consumed in the energy centre [MWh/annum]	827
Electricity generated [MWh/annum]	10,352
Heat generated [MWh/year]	50,138
Accumulator heat loss[%]	7%
DHN heat loss [%]	4.3%
Line heat density [MWh/(m ·yr)]	6.0
Heat loss per meter [kWh/m/yr]	0.27

Energy consumption

Generated energy

Heat loss

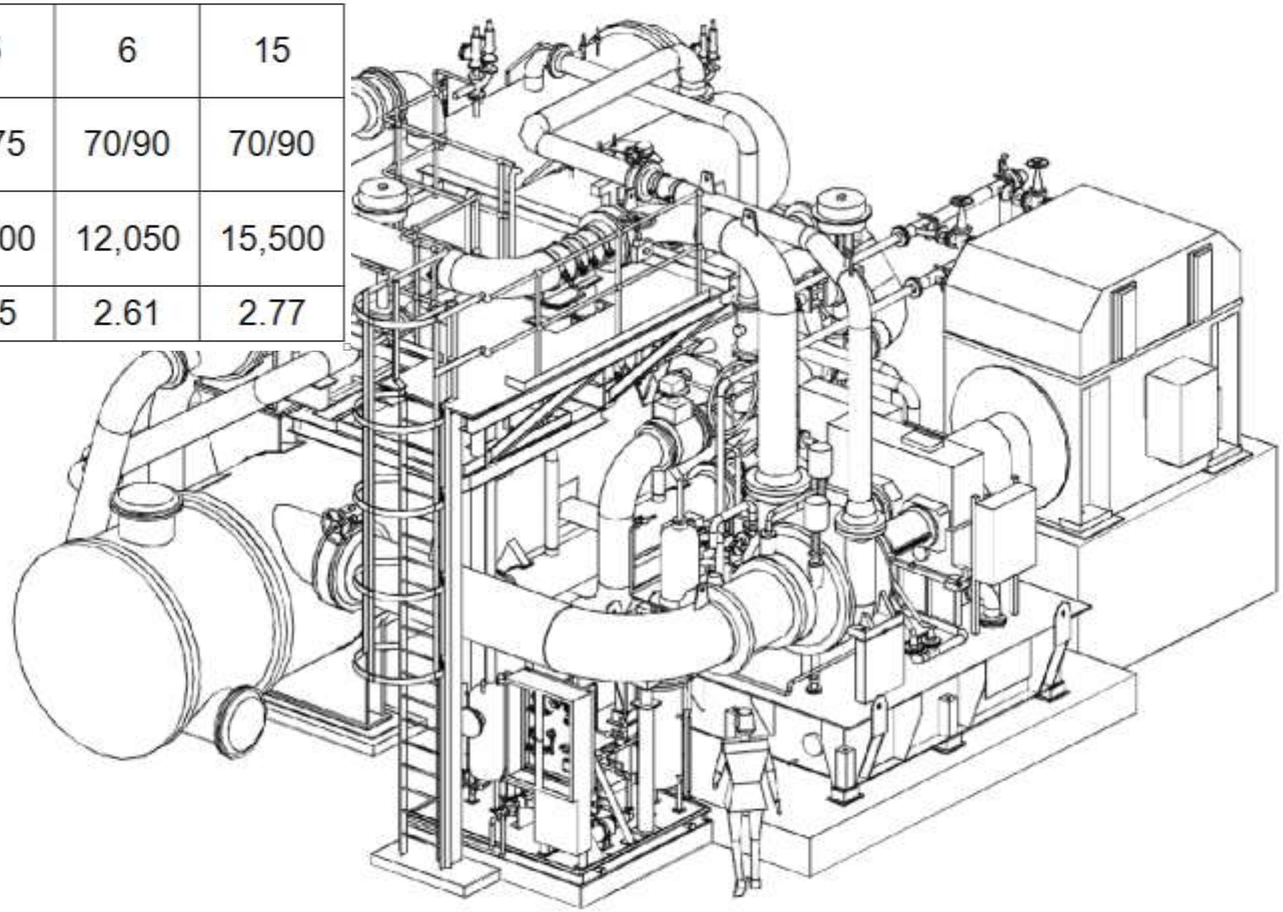
Comparing the Current Operation to 3 Alternative Scenarios

These scenarios supply the similar heat demand:

- **Scenario 1:** Two CHP engines of 4.4 MWe and the three current boilers
- **Scenario 2:** A single open-loop heat pump with its capacity varying from 10 to 15 MW
- **Scenario 3:** The current CHP engines and the similar open-loop heat pump

Selected Heat Pump: UNITOP 50FY-91810U

Heat source temperature [°C]	6	15	6	15
Hþt water production [°C]	55/75	55/75	70/90	70/90
Heating capacity [kW]	11,150	15,800	12,050	15,500
COP	2.98	3.05	2.61	2.77



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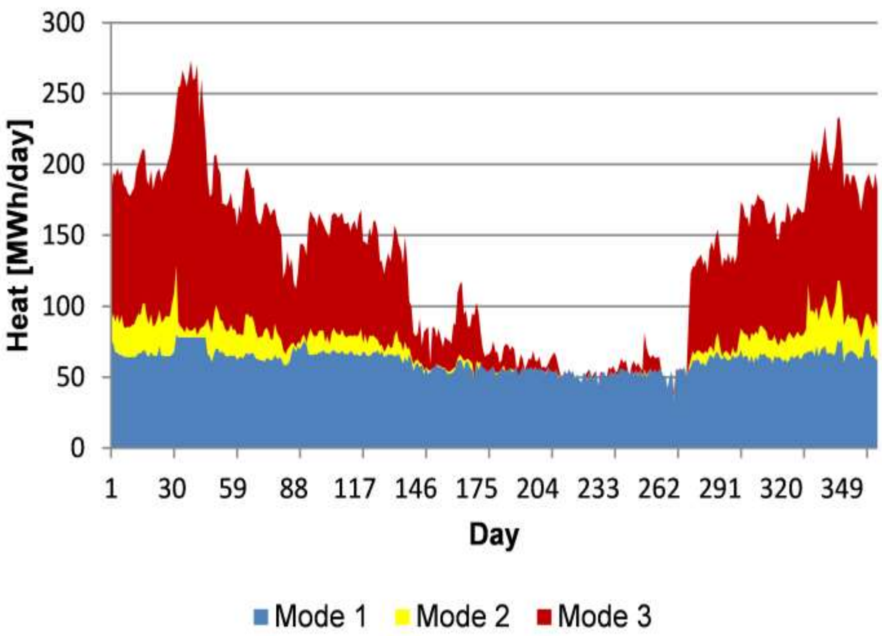
Heat Pump Operation

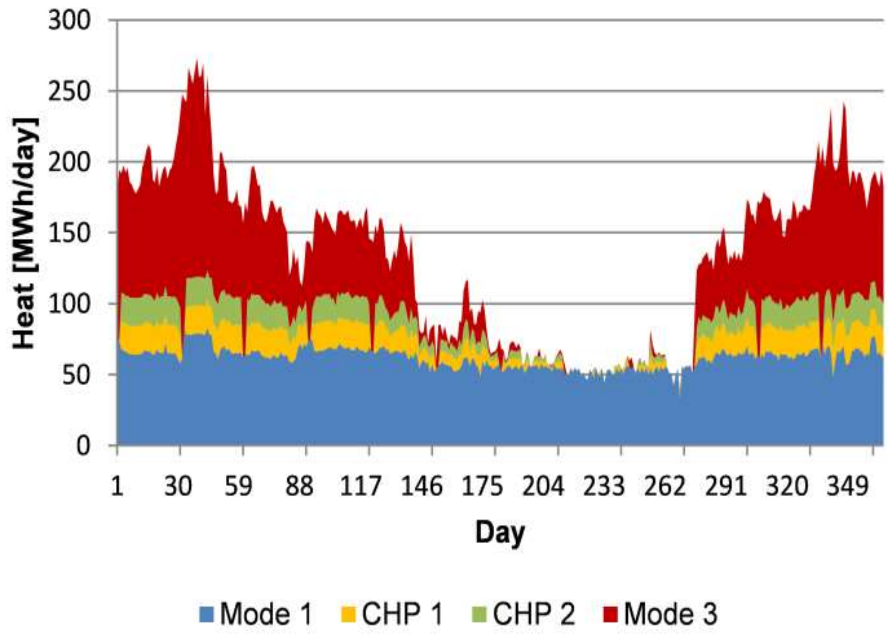
- **Mode 1**: It upgrades the DH water return temperature from 60°C to 75°C
- **Mode 2**: It upgrades the stored heat from 75°C to 90°C
- **Mode 3**: It upgrades the return DH water from 60°C to 90°C

Scenario 2 and 3: Annual Heat Profile

Scenario 2

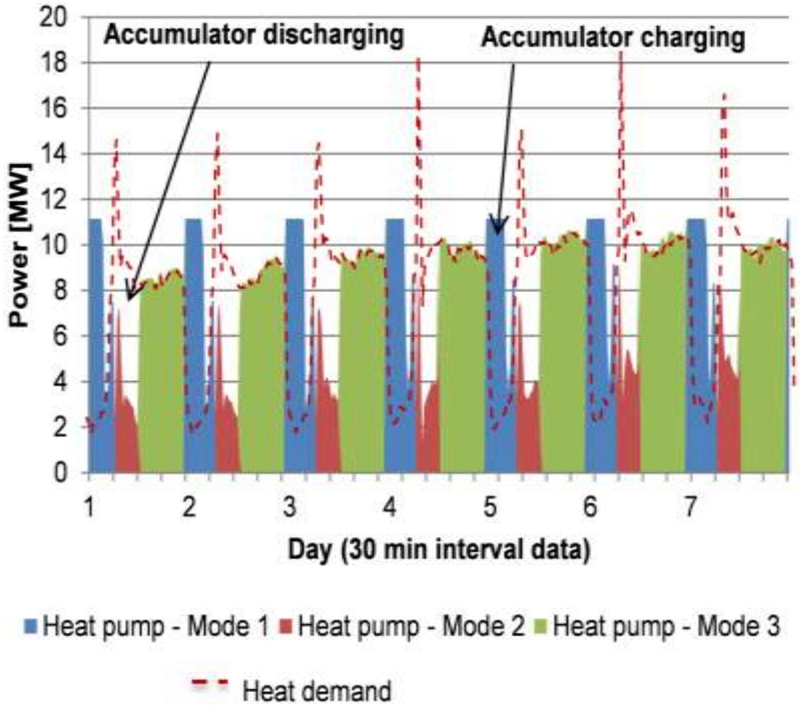


Scenario 3

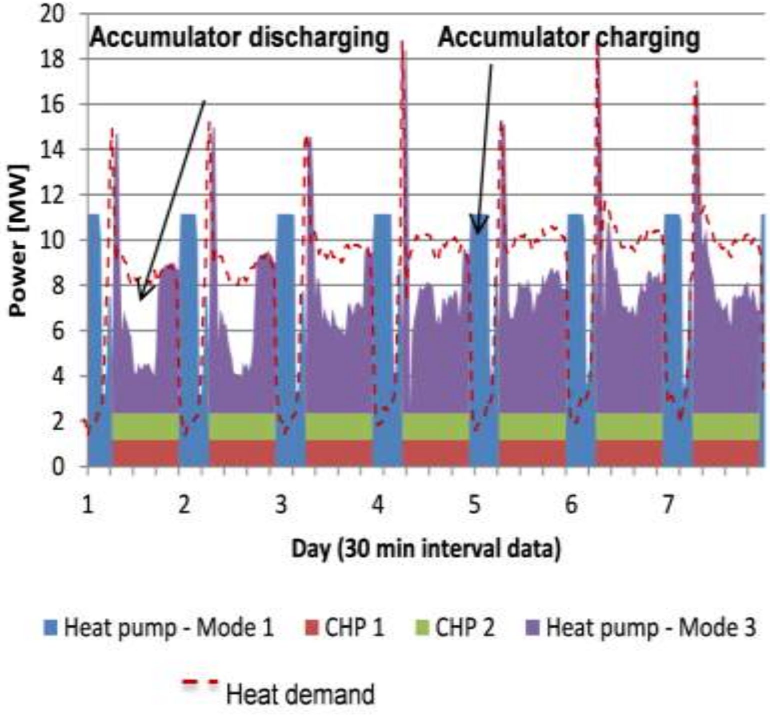


Scenario 2 and 3 - Heat generation and demand from 11-1-12

Scenario 2



Scenario 3



Financial Analysis

	Electricity or supplementary electricity consumption				Natural gas consumption	Maintenance cost		Heat cost	
	Heat pump	DHN	River pumping	CHP and boiler	CHP and boiler	CHP	Heat pump	Savings	Reduction
	£	£	£	£	£	£	£	£	%
Current operation	--	31,806	--	19,468	1,861,000	90,581	--	0	0
Scenario 1	--	31,806	--	30,814	2,946,760	336,000 to 373,000	--	82,000 to 120,000	6.0 to 8.8
Scenario 2	822,756	36,795	35,801	--	--	--	77,607	-348,562	-26%
Scenario 3	620,546	36,795	24,800	8,390	802,061	109,998	77,607	-260,156	-19%

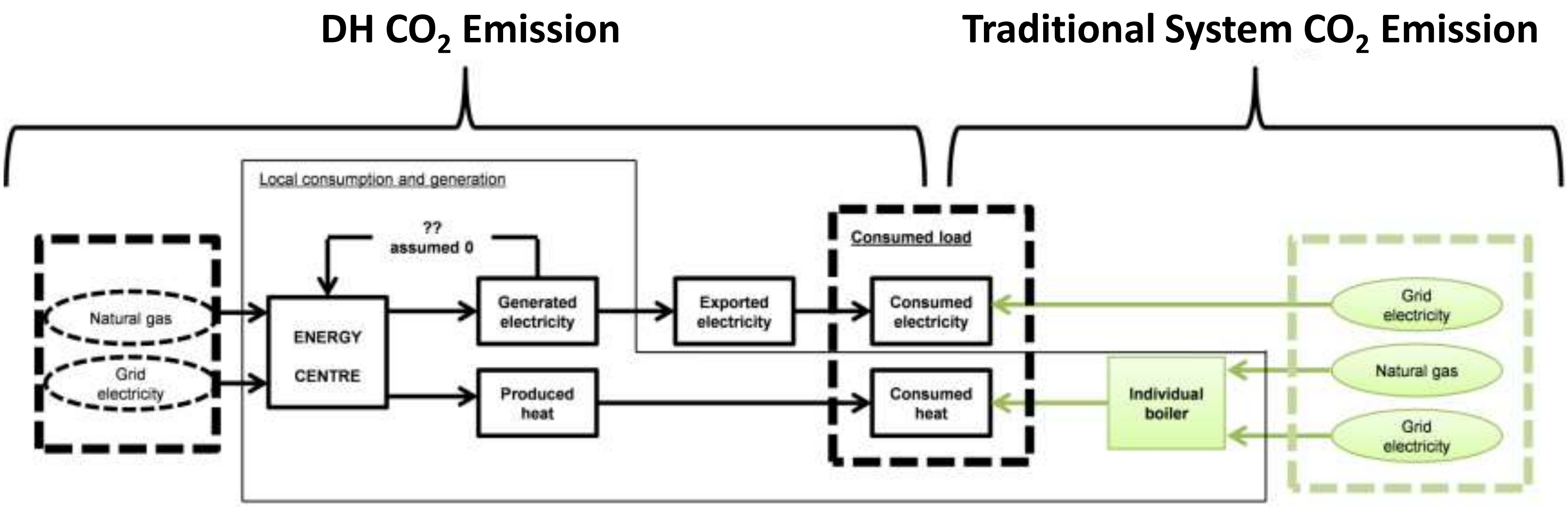
Installation cost:

- Two 4.4 MWe CHP engines: £3,700,000
- Heat pump: £5,200,000

Energy utility cost:

- Electricity day tariff: 0.062 £/kWh
- Electricity night tariff: 0.03 £/kWh
- Natural gas: 0.025 £/kWh

CO_2 Emission Analysis



CO_2 Emission Analysis

	Traditional system - Baseline			Site's operation			Equivalent CO_2 emission reduction
	Heating load	Electricity load	Equivalent CO_2 emission	CO2 emission	Consumed natural gas	Consumed electricity	
	MWh	MWh	Tonne CO_2	Tonne CO_2	Tonne CO_2	Tonne CO_2	%
Current operation	47,132	10,352	16,493	15,167	14,739	428	8 (1%)
Scenario 1	47,132	41,917	32,650	23,861	23,338	522	27 (15%)
Scenario 2	47,132	--	10,979	9,646	--	9,646	12 (32%)
Scenario 3	47,132	12,833	17,614	14,209	6,352	7,856	19 (23%)

- **Natural gas: 0.198 kg CO_2/kWh**
- **Electricity: 0.517 kg CO_2/kWh**

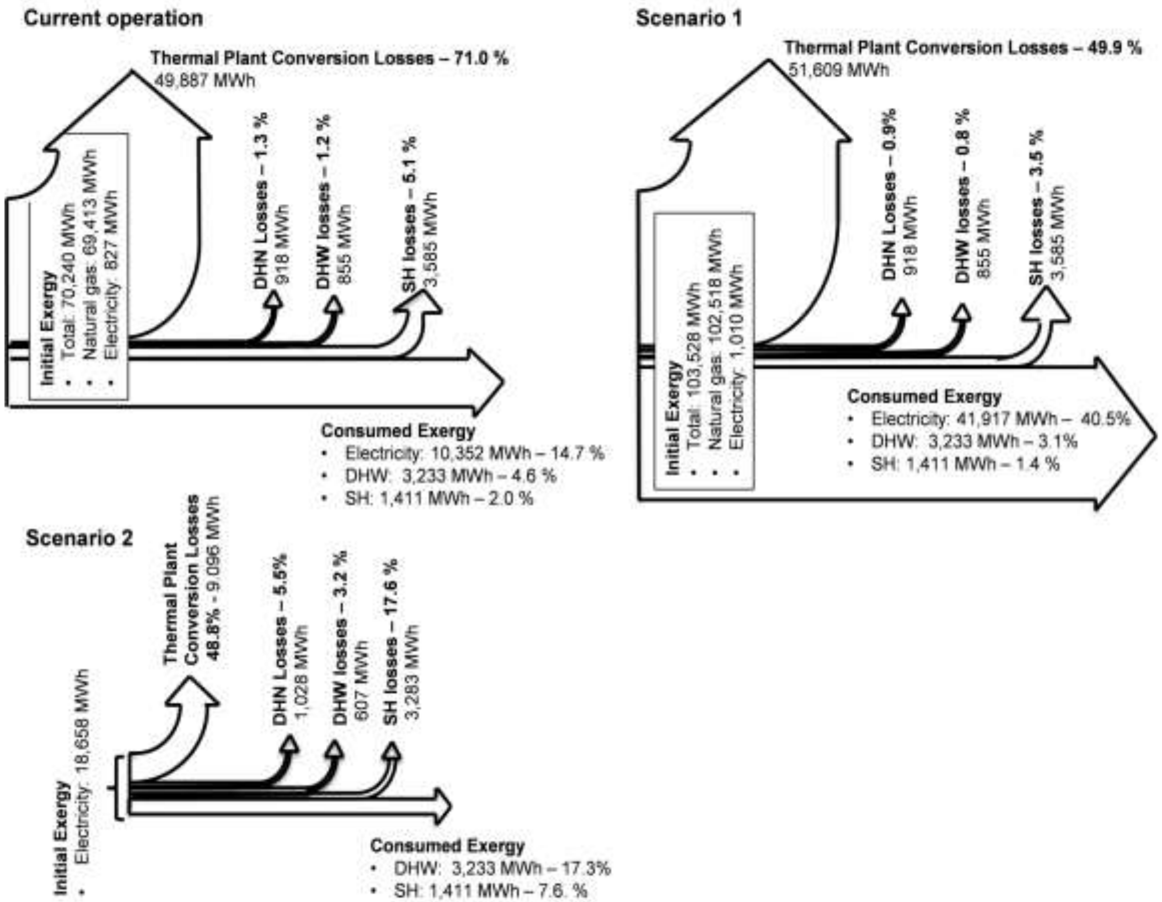
Electricity: 0.4 kg CO_2/kWh

Exergy Analysis

- Exergy is the potential of maximum work
- It allows to quantify the quantity and the quality of the different forms of energy considered
- the exergetic efficiencies are never bigger than 100%

$$\boldsymbol{\eta} = \frac{\sum \dot{E}^{-} + \sum \dot{E}_{q}^{-} + \sum \dot{E}_{y}^{-}}{\sum \dot{E}^{+} + \sum \dot{E}_{q}^{+} + \sum \dot{E}_{y}^{+}}$$

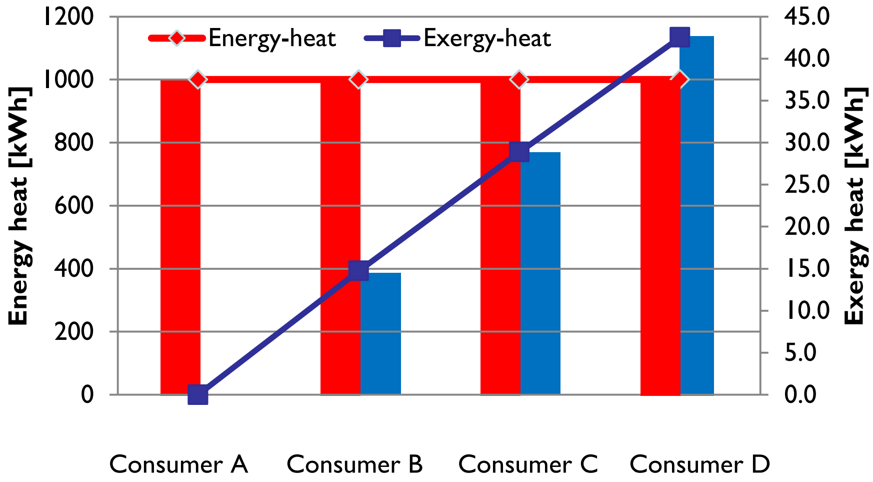
Grassmann Diagram



Selling Heat-Exergy

- To sell heat-exergy instead of heat-energy would give incentive to:
  - Consuming heat in off-tariff due to the lower supply temperature of the DH water
  - Reducing the DH water temperature further than the average current return DH water; this could also be done with the use of an additional heat pump installed at the consumer. The heat pump would evaporate its refrigerant by exchanging the heat from the return DH water.

Tariff Structure Based on Exergy



Every consumer consumes 1000 kWh of heat. The return DH water is at 60°C. The exergy is calculated relatively to the return DH water temperature and equals 0 when reducing the temperature below 60°C.

For a similar total revenue from Consumer A, B, C and D:

- Cost of heat: 0.06 £/kWh
- Cost of Exergy: 2.8 £/kWh

	Connection - Heat consumption	DH supply temperature [°C]	Consumed energy [kWh]	Consumed exergy [kWh]	Energy cost [£]	Exergy cost [£]
Consumer A	Return DH water	(60)*	1000	0	60	0
Consumer B	At night	70	1000	14.7	60	41
Consumer C	During the day	80	1000	28.9	60	80.5
Consumer D	On-peak	90	1000	42.5	60	118.5
Total		--			240	240

(60)*: New connection

Questions

- Any questions?

Acknowledgments

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