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Engineering and Physical Sciences Research Council

LoT-NET

Benefits of including thermal energy stores in district heating networks

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04-07-2023

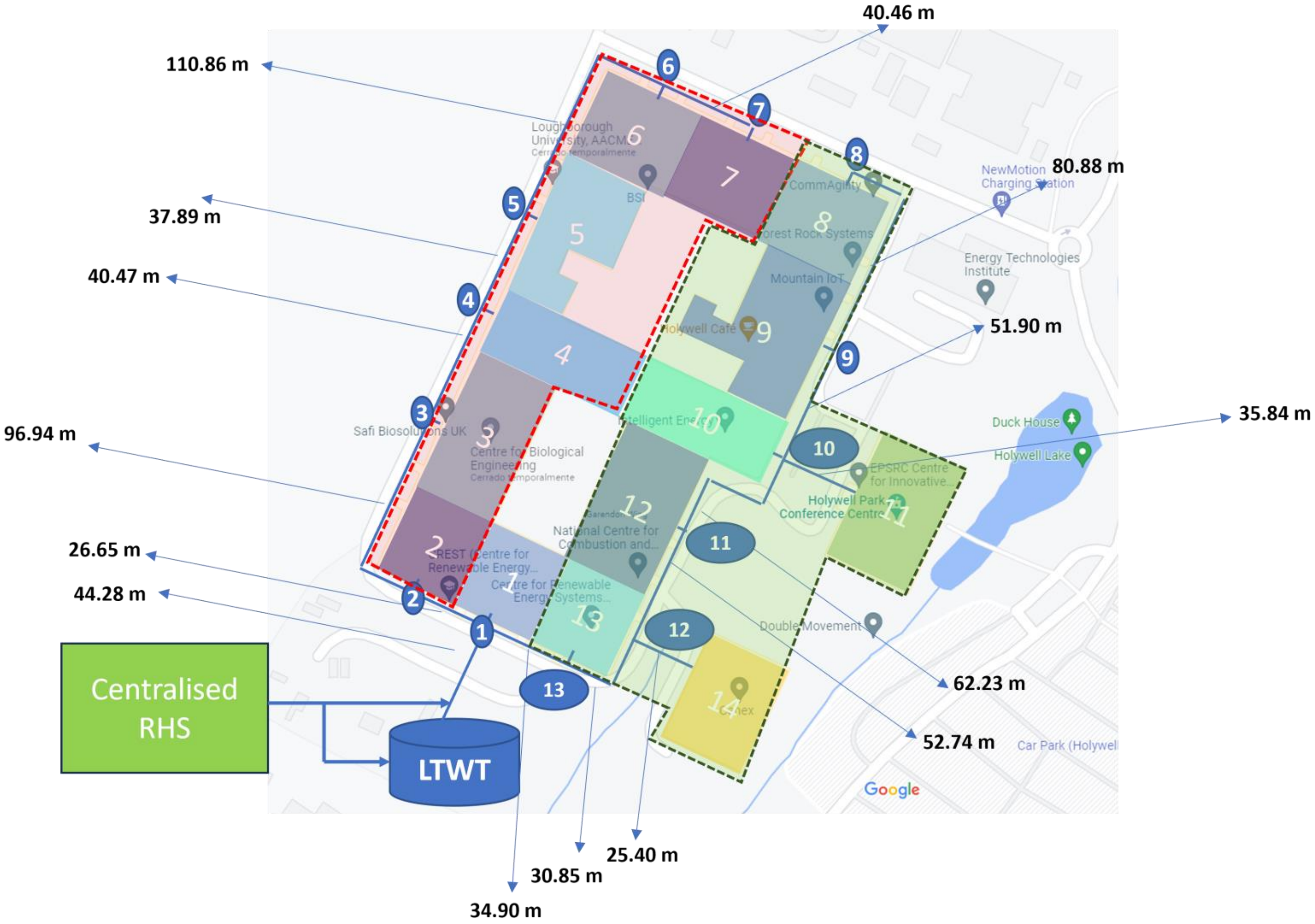
Summary and objectives

i. **A previously-developed novel model was used to simulate a hypothetical DH network located in the Holywell Campus in Loughborough University, Loughborough, UK for the year 2021. The simulation assumes the use of HPs and ETSTCs to both provide heat for dwellings and charge a centralised TES system;**

ii. **The model uses both i) real historic half-hourly CO_2 emissions per kWh of electricity produced in UK in the year 2021 and ii) real historic half-hourly heat demands in the Holywell campus in the year 2021;**

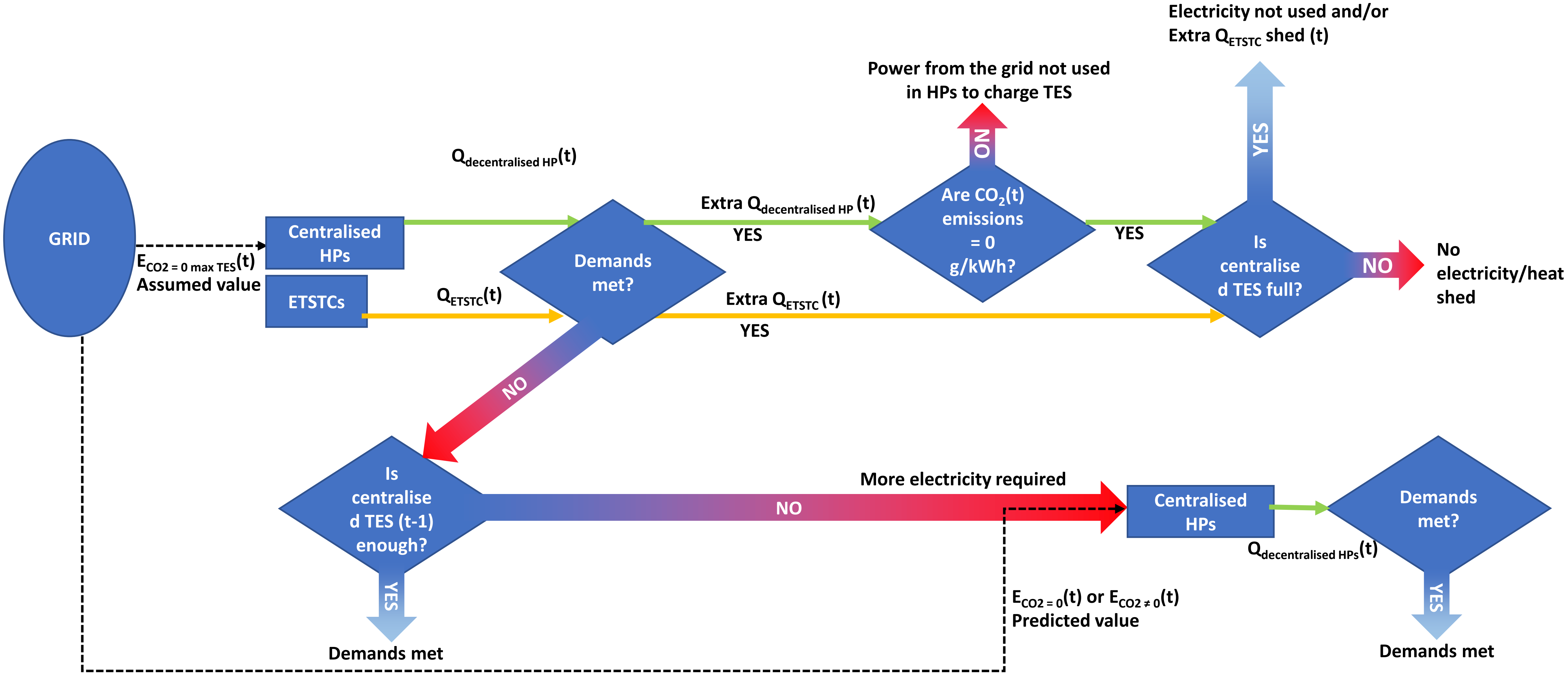
iii. **The model assumes that HPs can be only used to charge TES at those times when the CO_2 emissions generated from the electricity production are 0;**

iv. **The objective is to study the effect of the 1) the volume of the centralised TES system and 2) the heat capacity assumed for an individual HP on b) the annual CO_2 emissions, c) the DH system energy efficiency, d) the investment costs and e) the annual electricity cost per dwelling.**

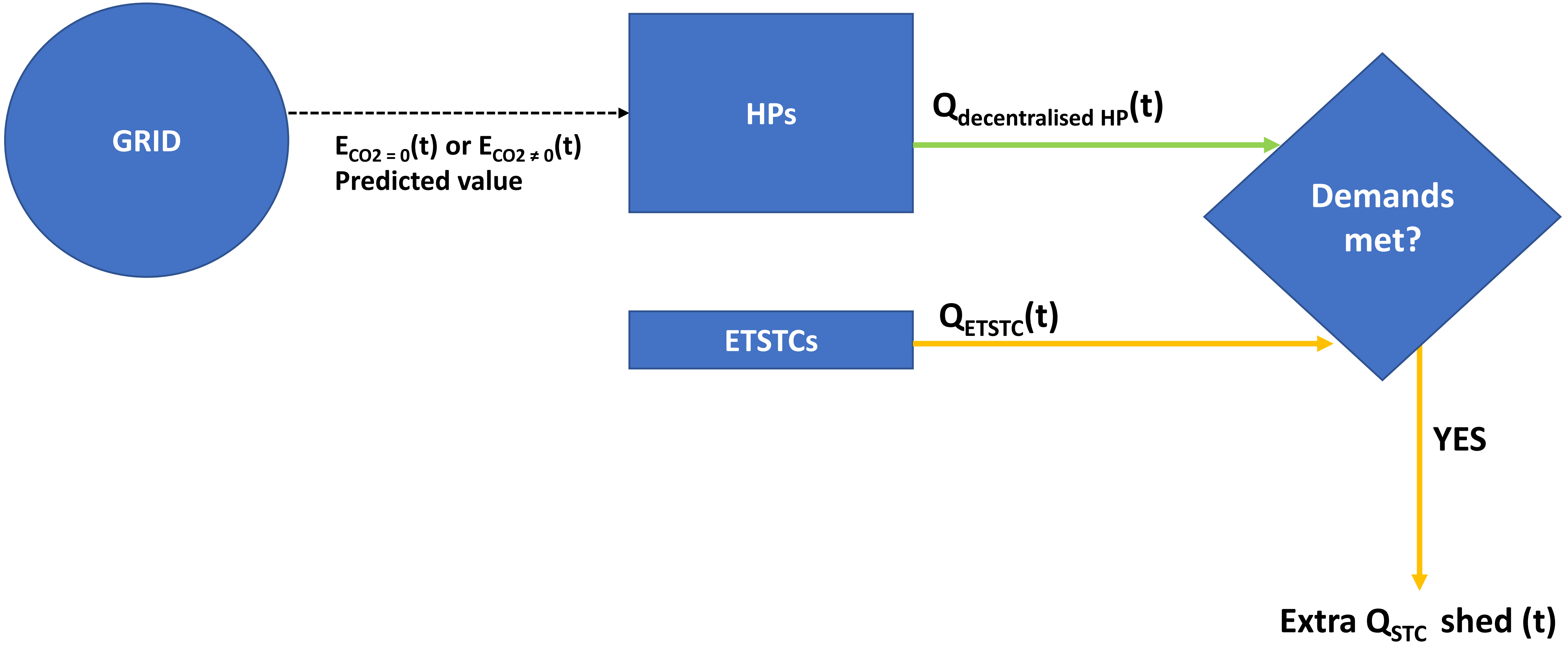


Total length of the DH network (m)	812
Total area (m2)	57714

Methodology: Flow diagram of the process followed when using TES (Scenario 1)



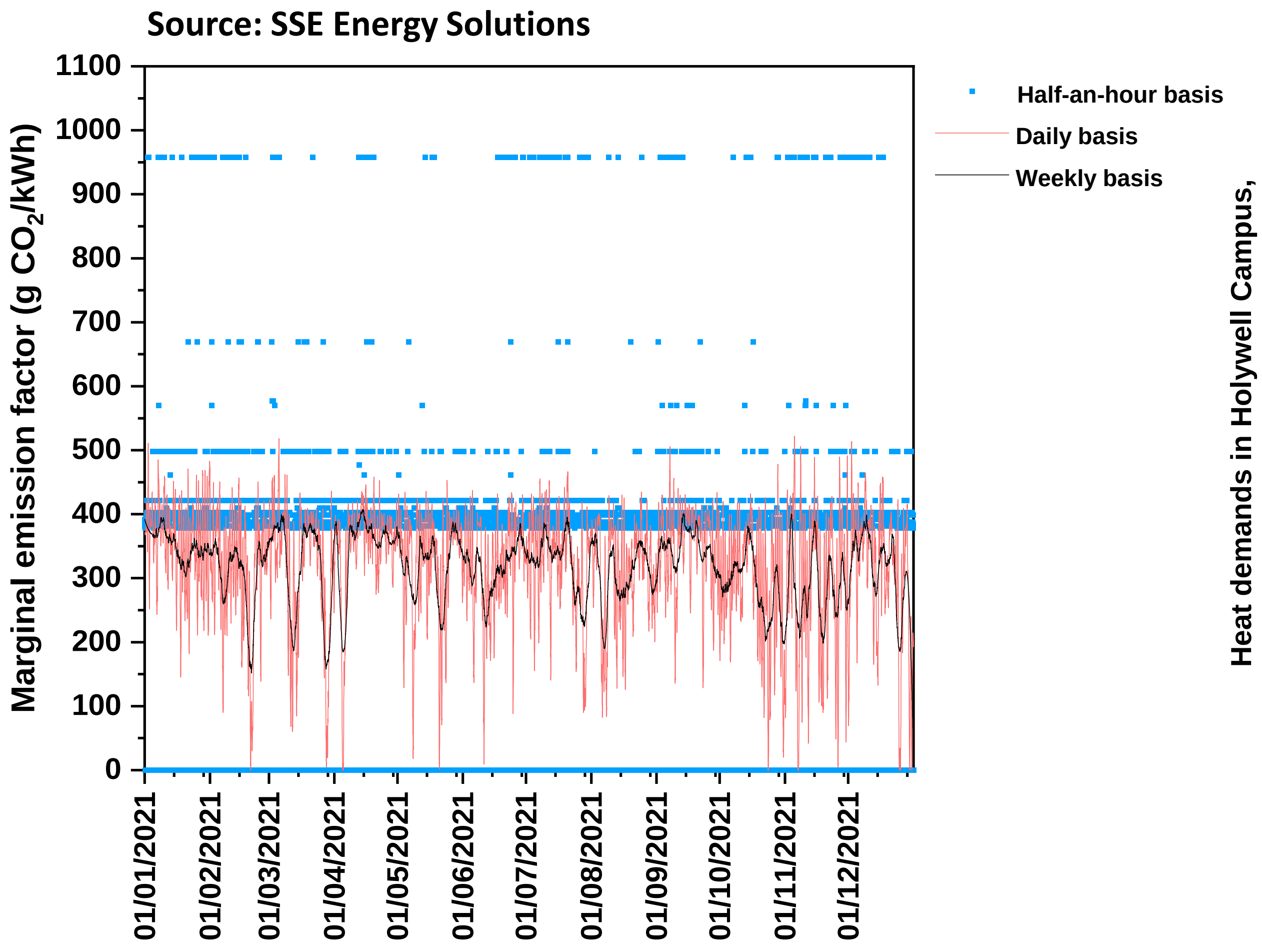
Methodology: Flow diagram of the process followed when NOT using TES (Baseline scenario, Scenario 2)

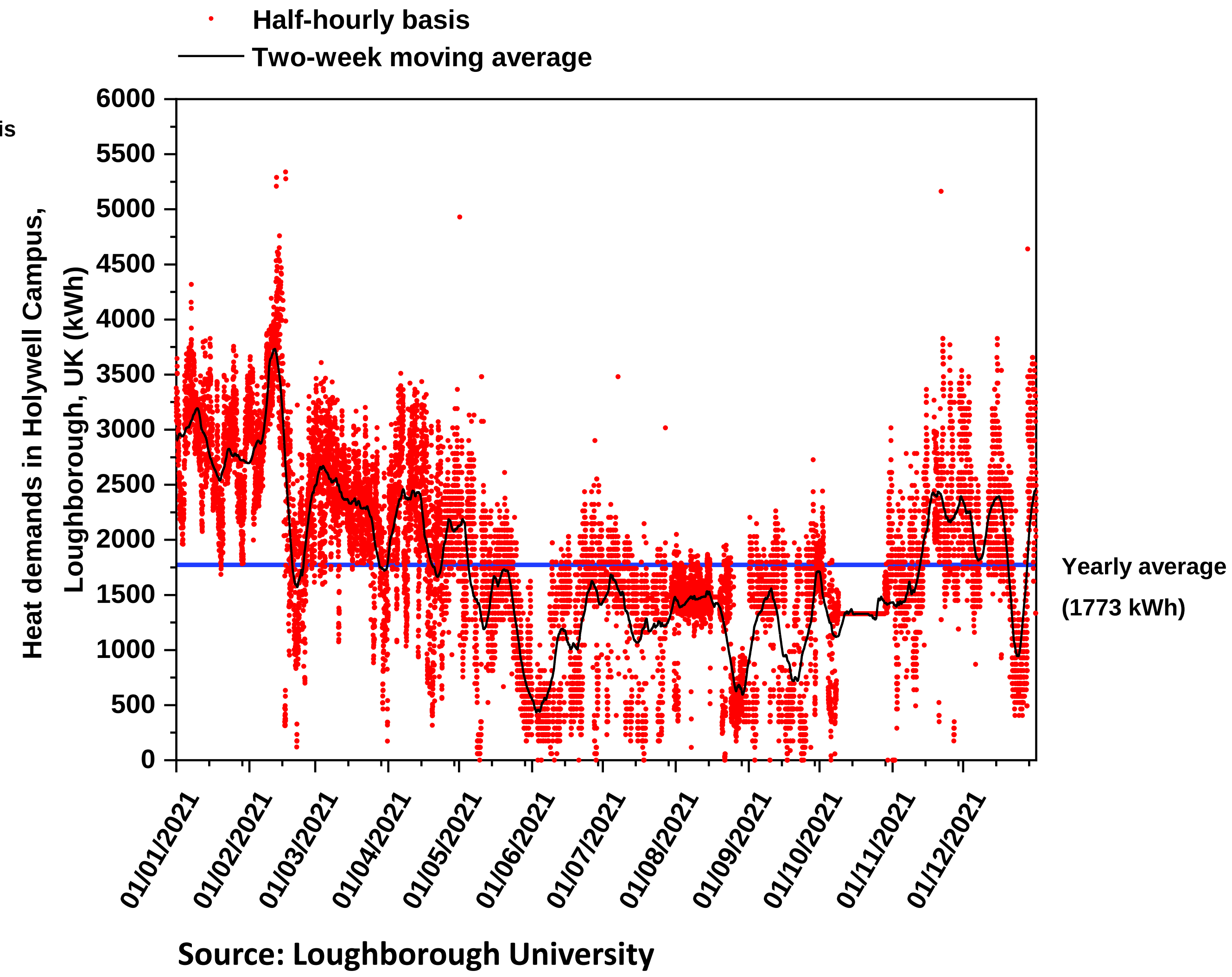


Main parameters specified for the simulation.

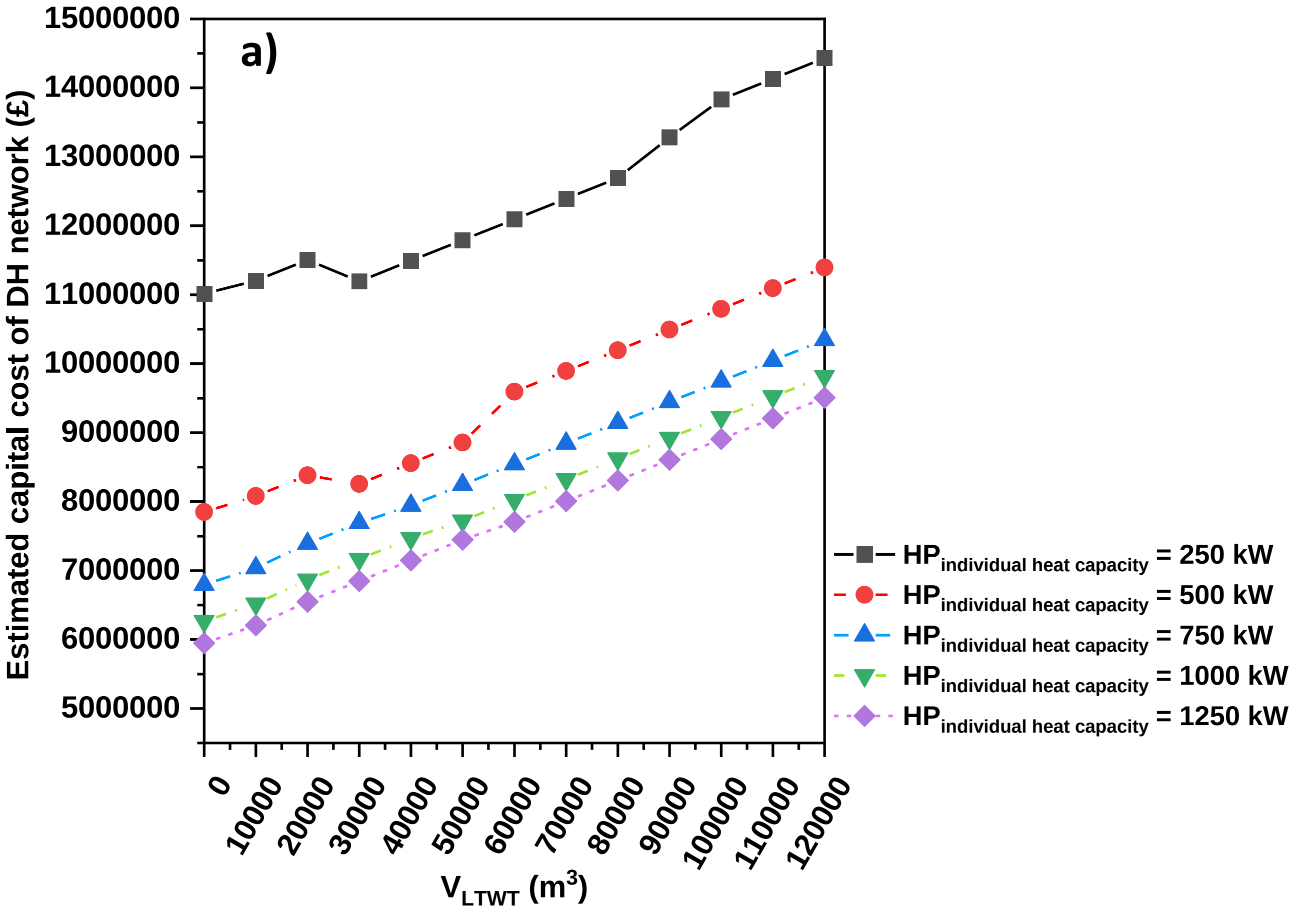
Area/town	Holywell campus, Loughborough University, Loughborough, (UK)
Time-period considered	From 01/01/2021 00:00 to 31/12/2021 23:30
Heat and electricity main parameters	
Maximum half-hourly electricity produced by renewables that can be used in HPs to charge TES ($E_{CO2 = 0 \ max \ TES}$, kW)	800
Half-hourly electricity produced by not zero-carbon sources used only in HPs to fully meet demands ($E_{CO2 \neq 0}$, kW)	Predicted
Assumed area of ETSTC per dwelling (m^2)	10000
HPs	
%ASHP	50%
%GSHP	50%
Heat Capacity per unit (kW)	variable
TES system main parameters	
$T_{charging \ LTWT}$ (°C)	60
$Volume_{LTWT}$ (m^3)	Variable
Initial assumed heat stored in LTWT (% of the maximum storage capacity)	50%

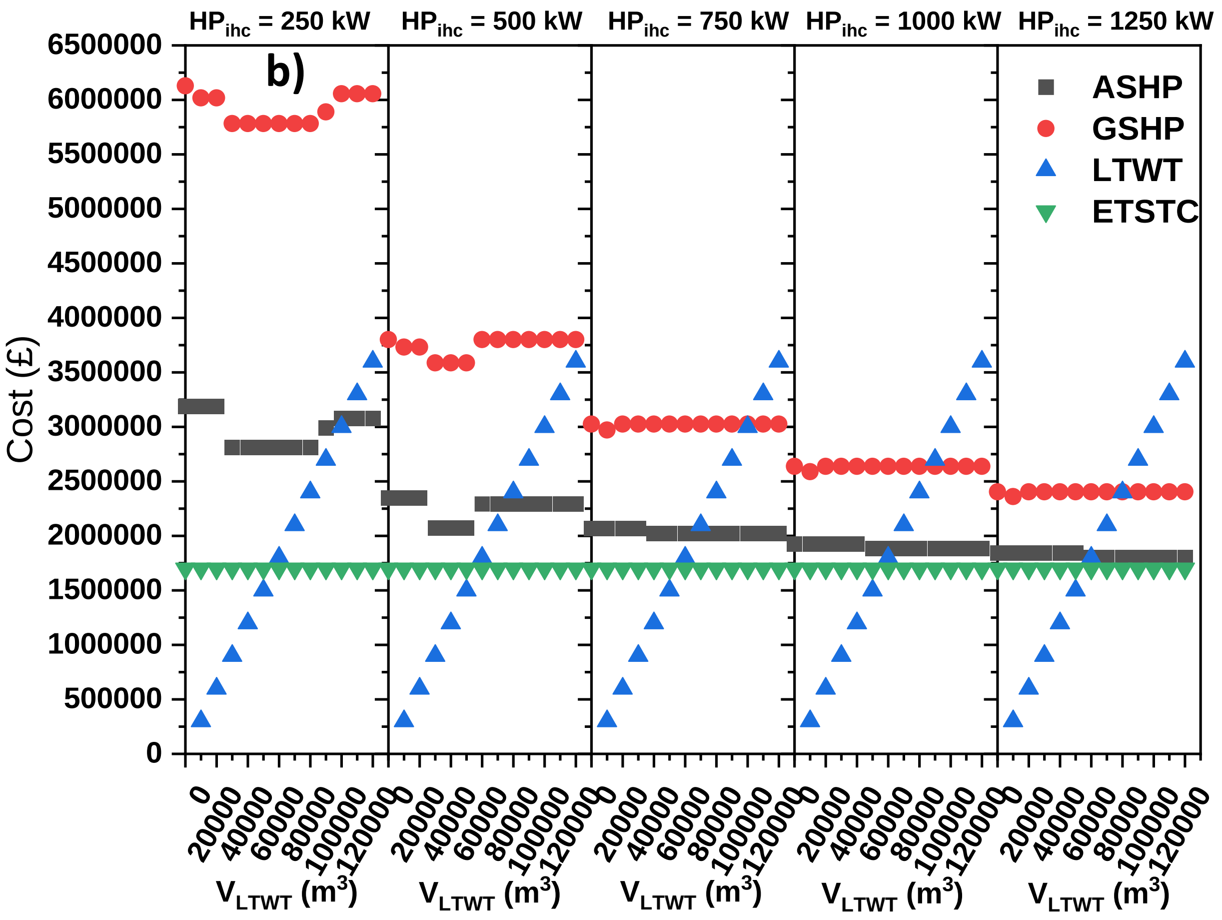
Real CO_2 emissions per kWh of electricity produced in the UK for the year 2021 (7% transmission and distribution loss included) and heat demands in Holywell campus, Loughborough University, Loughborough, UK.





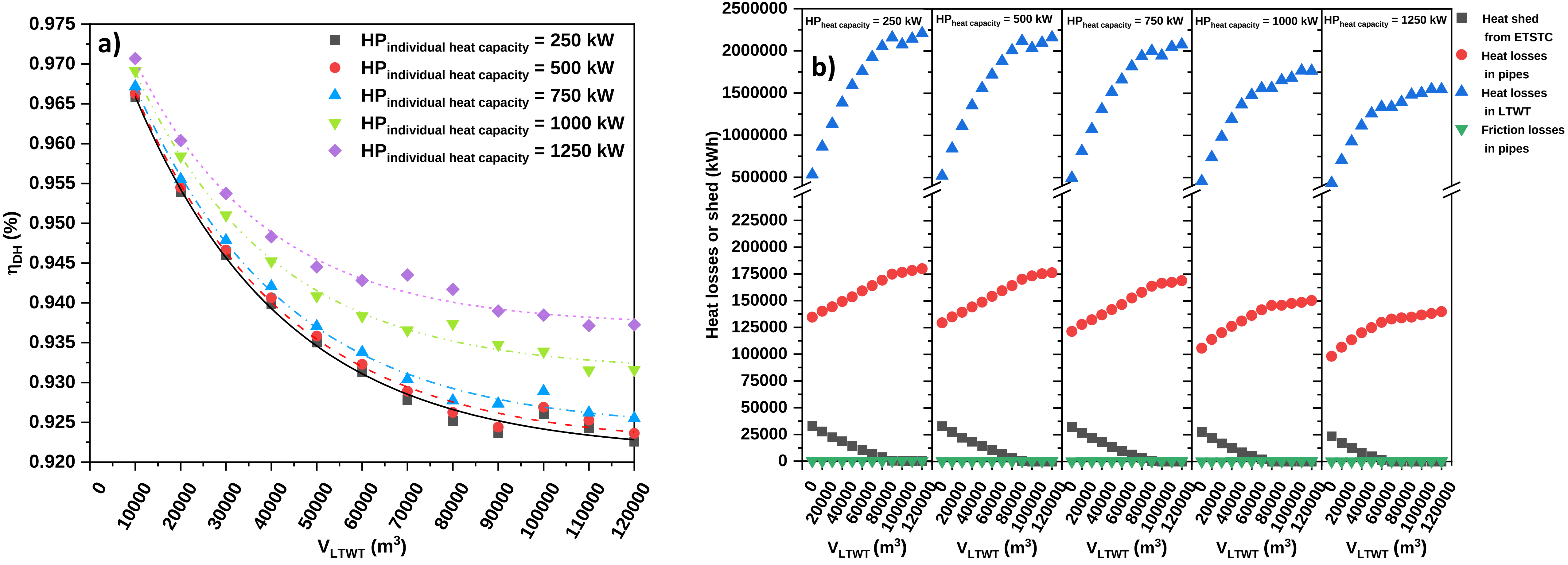
RESULTS: Effect of V_{LTWT} on a) the total capital cost of the DH system for different $HP_{individual\ heat\ capacity}$ values and on b) the cost of each part of the DH system.





- ✓ Less $HP_{individual\ heat\ capacity}$ leads to a higher cost, due to the higher number of heat pumps needed.
- ✓ Cost increases with V_{LTWT} due to the higher cost of the LTWT (with the number of HPs needed being roughly constant for different V_{LTWT} values, due to the lack of heat stored in LTWT at the beginning of the year).

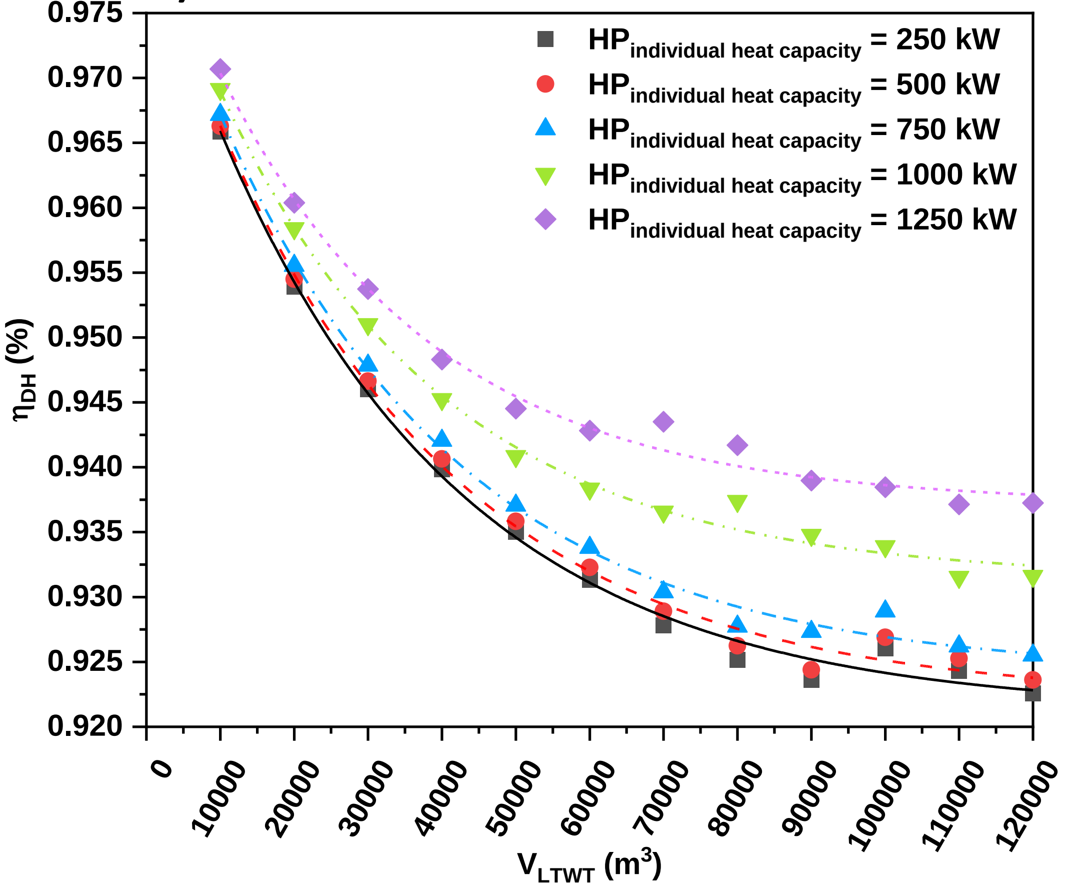
RESULTS: Effect of V_{LTWT} on a) the energy efficiency of the DH system (η_{DH}) and b) the total heat shed or lost from different parts of the DH system for different $HP_{individual\ heat\ capacity}$ values.



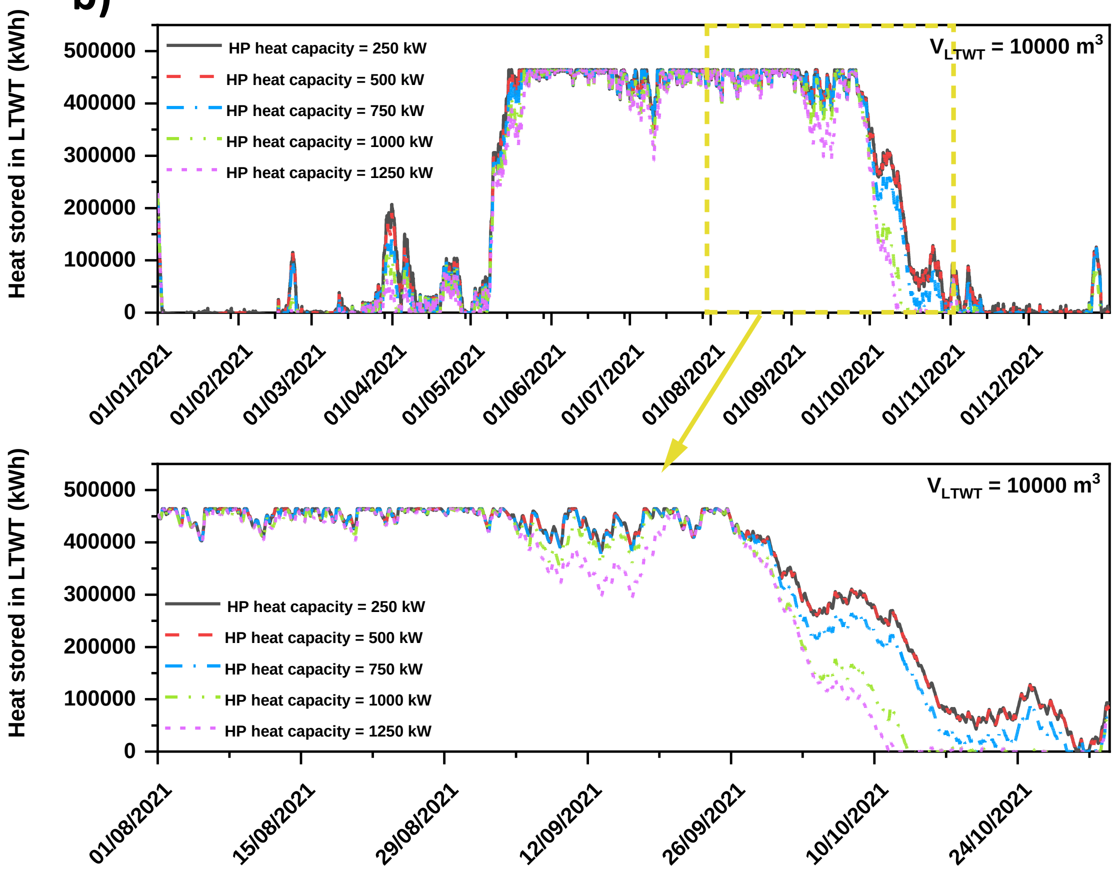
- ✓ η_{DH} increases with $HP_{heat\ capacity}$, due to the lower amount of heat produced by HPs (due to restrictions regarding the minimum amount of electricity required to run the HPs) and stored in LTWT, which leads to i) lower heat losses in the LTWT, ii) lower heat losses in pipes and iii) lower heat shed from ETSTC.
- ✓ η_{DH} decreases with V_{LTWT} due to the higher heat losses in both LTWT and pipes, in despite of the decrease of the heat shed produced by ETSTCs.

RESULTS: a) Effect of V_{LTWT} on the energy efficiency of the DH system (η_{DH}) for different $HP_{individual\ heat\ capacity}$ values; b) Heat stored in LTWT along the year 2021 (half-hourly basis) for for different $HP_{individual\ heat\ capacity}$ values and for V_{LTWT} = 10000 m^3.

a)

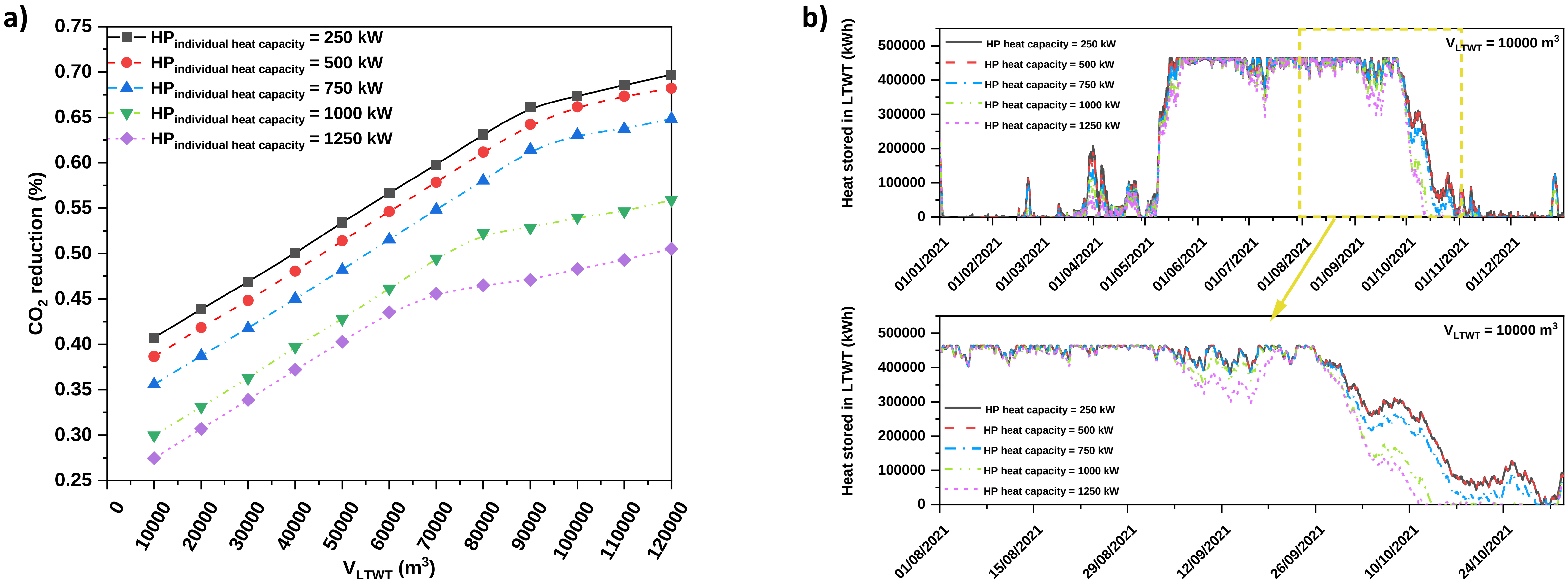


b)



- ✓ η_{DH} increases with $HP_{heat\ capacity}$, due to the lower amount of heat produced by HPs (due to restrictions regarding the minimum amount of electricity required to run the HPs) and stored in LTWT, which leads to i) lower heat losses in the LTWT, ii) lower heat losses in pipes and iii) lower heat shed from ETSTC.
- ✓ η_{DH} decreases with V_{LTWT} due to the higher heat losses in both LTWT and pipes, in despite of the decrease of the heat shed produced by ETSTCs.

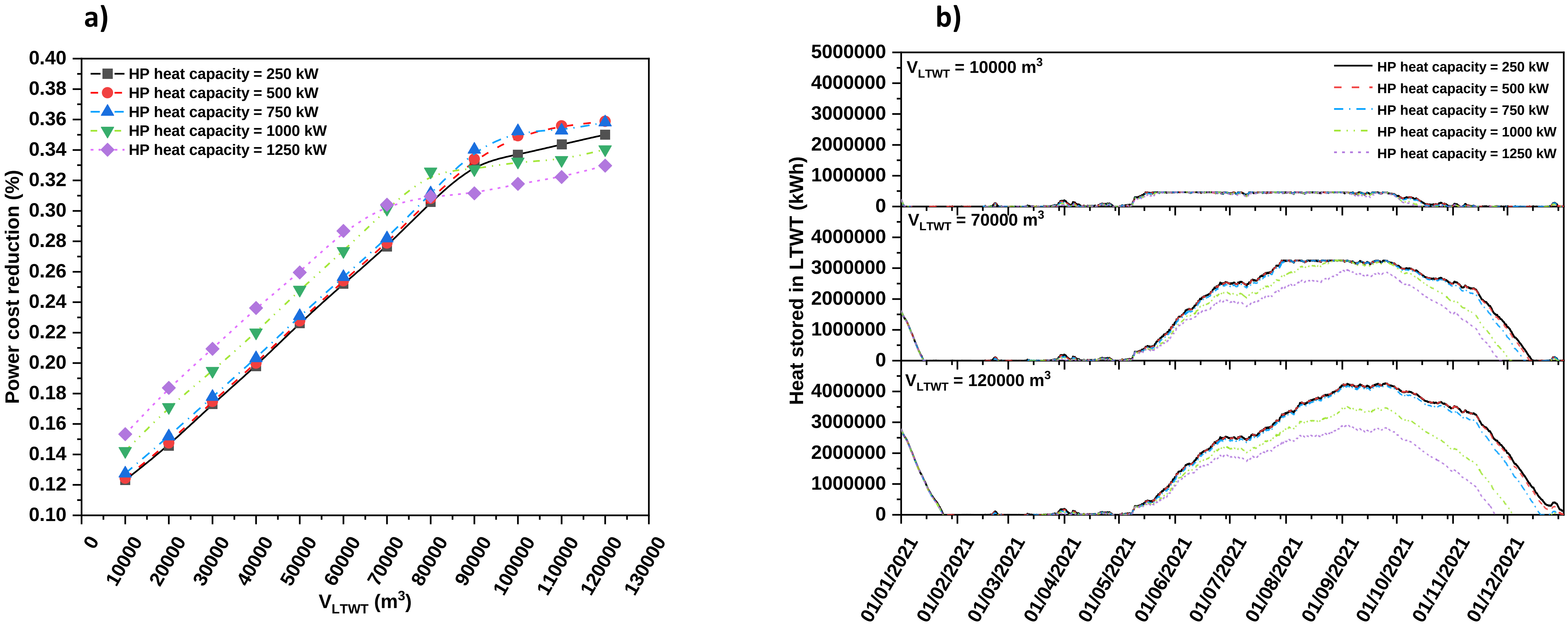
RESULTS: a) Effect of V_{LTWT} on the CO_2 emissions reduction when comparing with the scenario with no TES for different $HP_{individual\ heat\ capacity}$ values; b) Heat stored in LTWT along the year 2021 (half-hourly basis) for for different $HP_{individual\ heat\ capacity}$ values and for V_{LTWT} = 10000 m³.



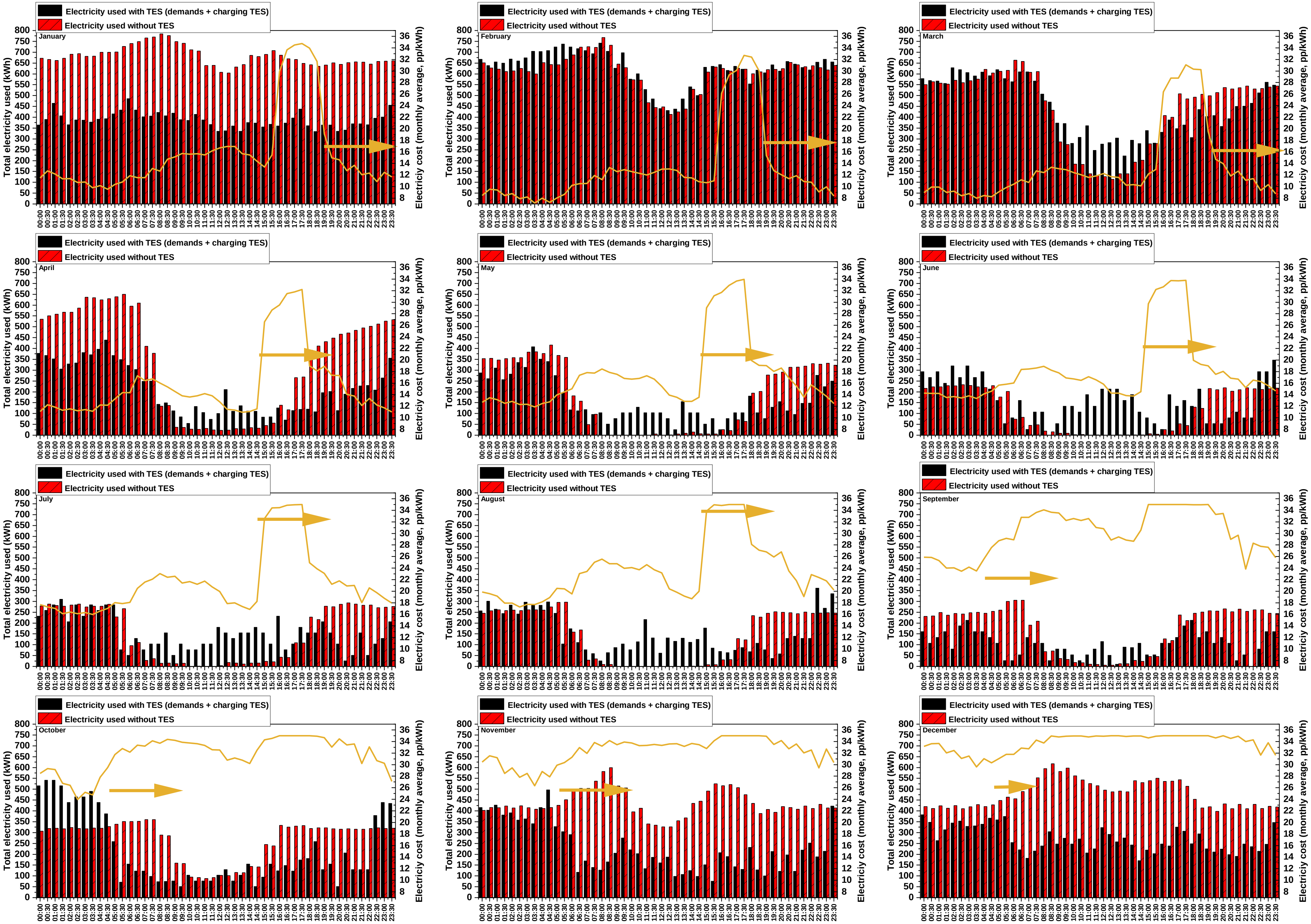
- ✓ Less $HP_{heat\ capacity}$ leads to an increase of the CO_2 emissions reduction (when compared with the scenario with no TES) due to the higher amount of heat produced by HPs (using electricity from renewable sources) that can be used to meet demands and/or to be stored in LTWT.

- ✓ Higher V_{LTWT} also leads to an increase of the CO_2 emissions reduction due to the more heat stored in the LTWT that can be used to meet demands.

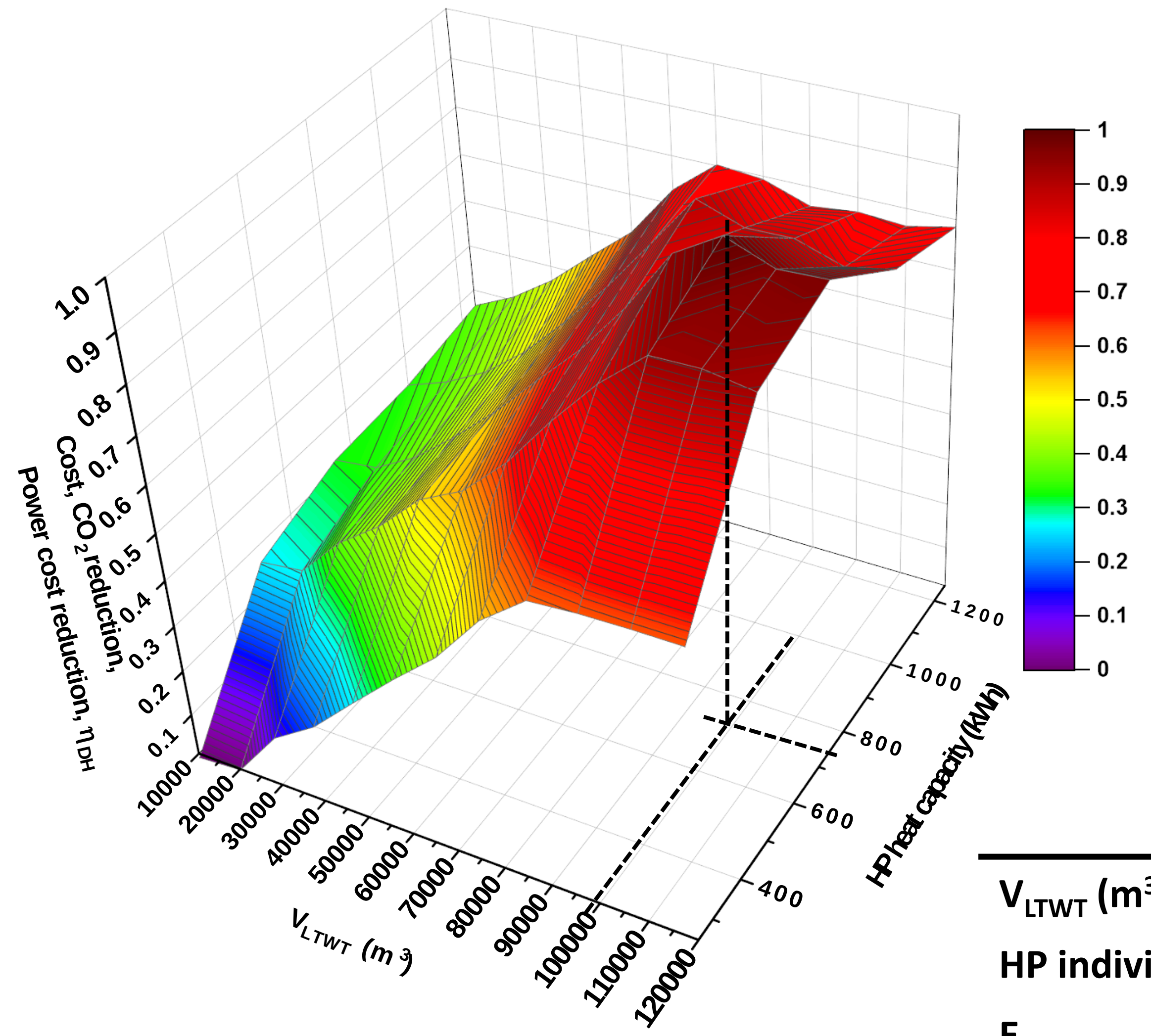
RESULTS: a) Effect of V_{LTWT} on the electricity cost reduction when comparing with the scenario with no TES for different $HP_{individual\ heat\ capacity}$ values; b) Heat stored in LTWT along the year 2021 (half-hourly basis) for different $HP_{individual\ heat\ capacity}$ values, for V_{LTWT} = 10000, 70000 and 120000 m^3.

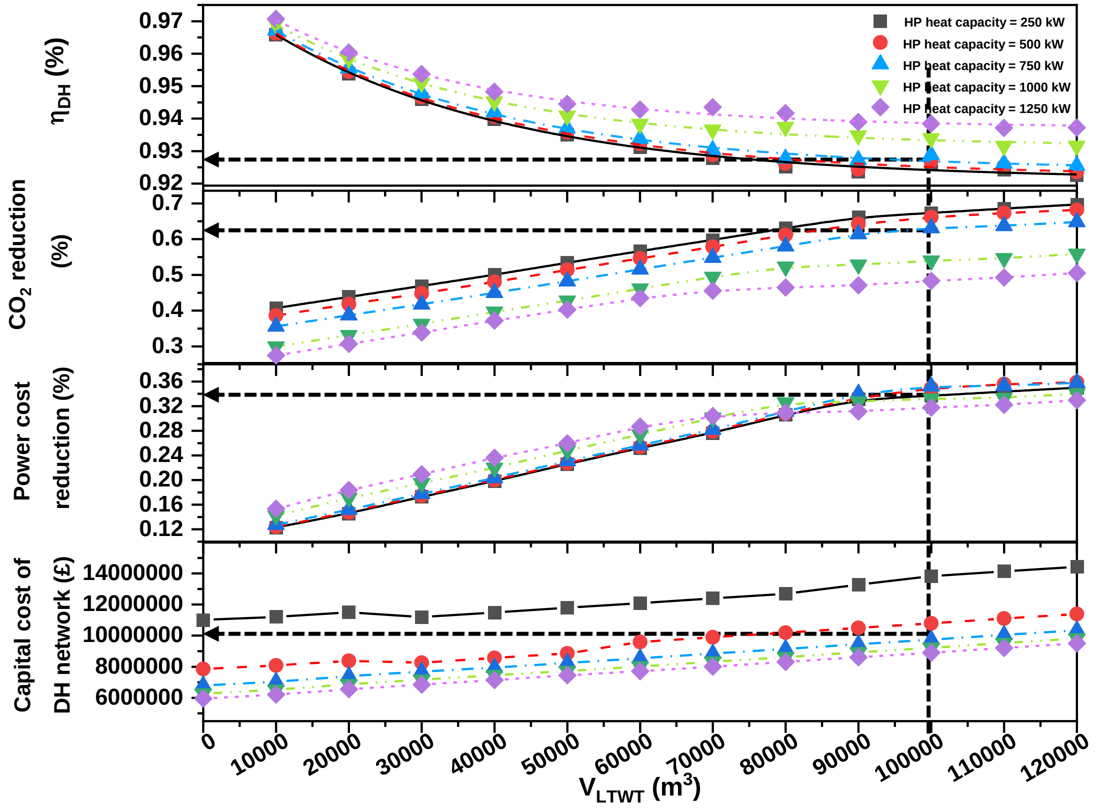


- ✓ For V_{LTWT} ≤ 7000 m^3 the higher $HP_{individual\ heat\ capacity}$ the higher reduction of cost associated to power consumption, due to the less heat produced with HPs with high heating capacity as a result of the restrictions regarding the minimum power needed to run the HPs.
- ✓ For V_{LTWT} > 7000 m^3 the reduction of cost increases with $HP_{individual\ heat\ capacity}$ for $HP_{individual\ heat\ capacity}$ ≤ 500 kW. For $HP_{individual\ heat\ capacity}$ > 500 kW, the reduction of cost associated to electricity drops with $HP_{individual\ heat\ capacity}$ due to more heat stored in the LTWT.



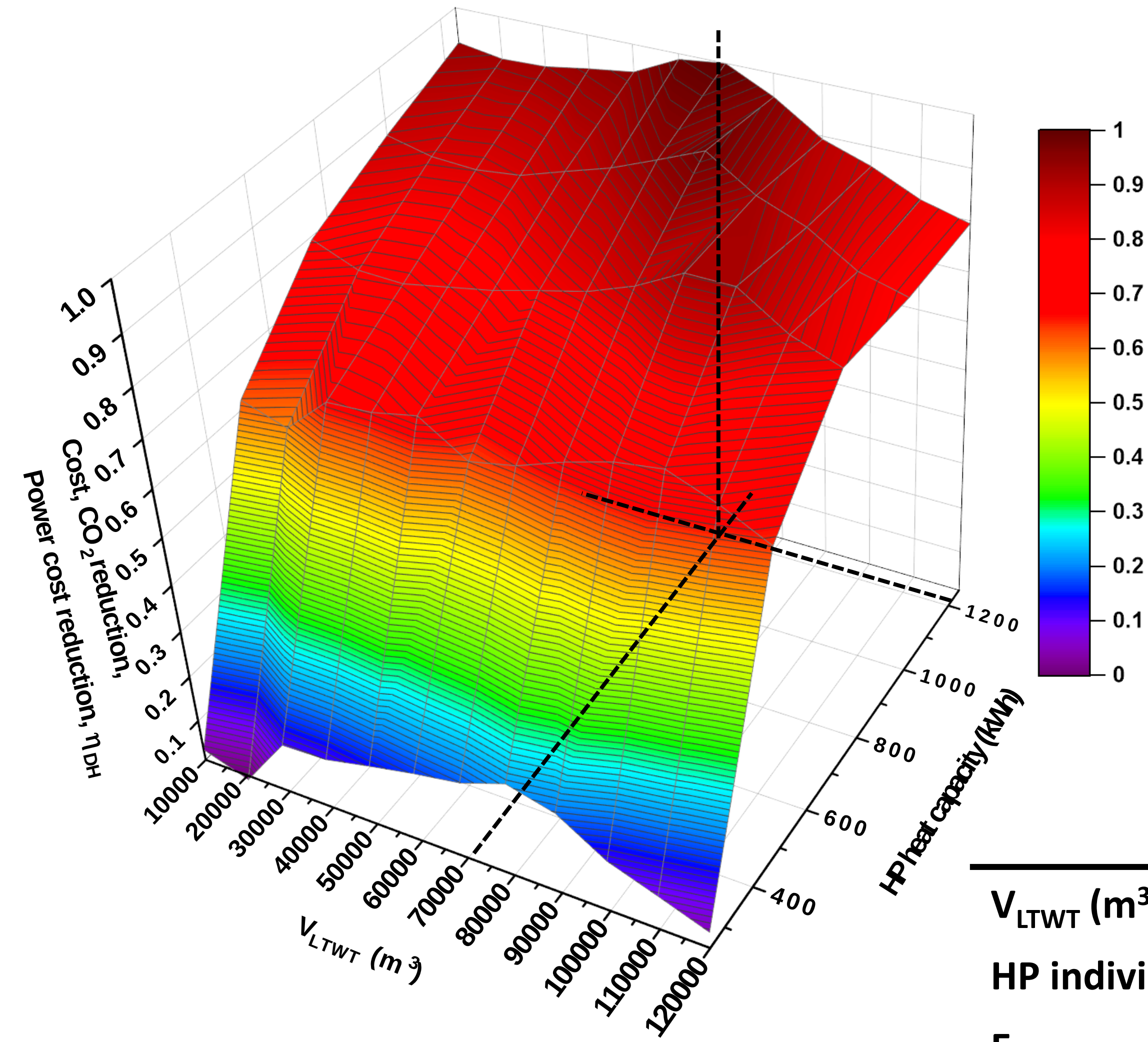
Electricity used with TES (demands + charging TES)
Electricity used without TES
January
February
March
April
May
June
July
August
September
October
November
December
Total electricity used (kWh)
Electricity cost (monthly average, pp/kWh)

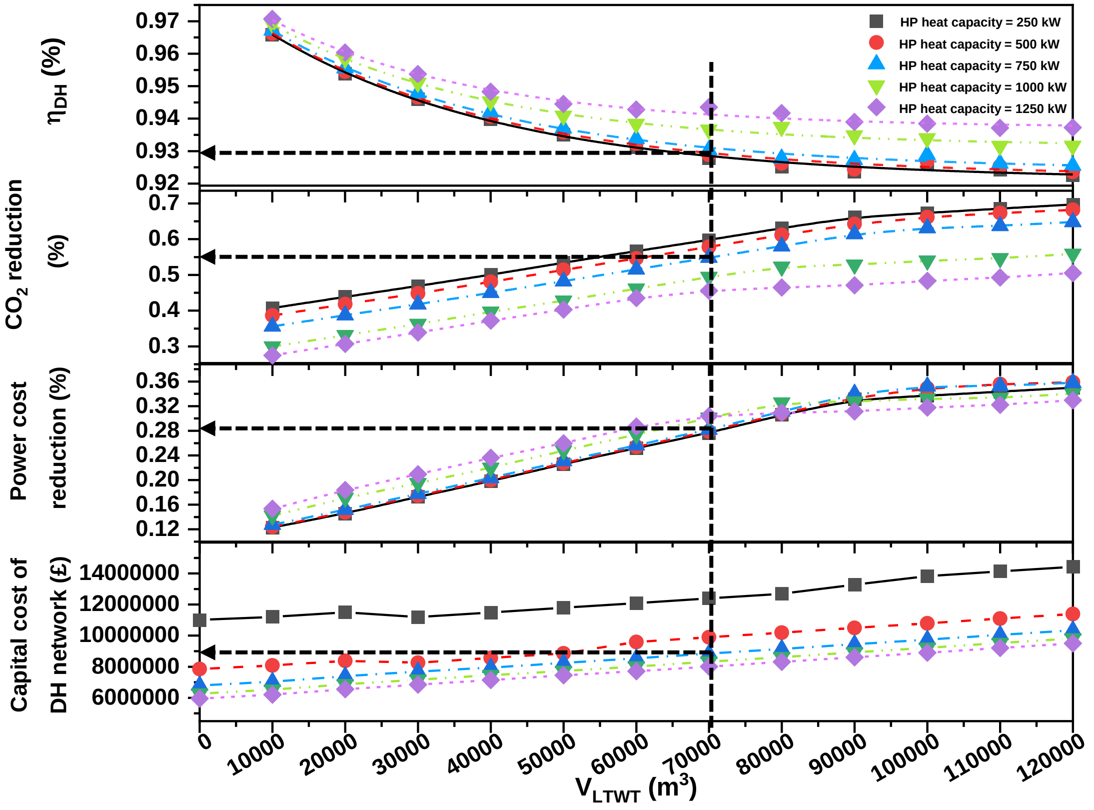




	Factor
CO_2 reduction	1
η_{DH}	0.5
Cost	1
Power cost reduction	1

V_{LTWT} (m^3)	100000
HP individual heating capacity (kW)	750
$E_{CO2 = 0 \max TES}$ (kW)	800
CO_2 reduction (%)	63.1
η_{DH} (%)	92.9
Cost (£)	9745808
Power cost reduction (%)	35.2





	Factor
CO_2 reduction	1
η_{DH}	0.5
Cost	3
Power cost reduction	1

V_{LTWT} (m^3)	70000
HP individual heating capacity (kW)	1250
$E_{CO2\,=\,0\ max\ TES}$ (kW)	800
CO_2 reduction (%)	45.6
η_{DH} (%)	94.4
Cost (£)	8006532
Power cost reduction (%)	30.4

Summary and main conclusions:

- ✓ **A simulation of a theoretical DH network located in Holywell campus at Loughborough University (Loughborough, UK) for the time period from the 01/01/2021 00:00 to 31/12/2021 23:30 was undertaken.**
- ✓ **The DH network includes a long-term TES system (namely Long-term water tank, LTWT).**
- ✓ **The simulation considers the use of heat pumps and evacuated-tube solar thermal collectors to both provide heat for dwellings and charge the TES system.**
- ✓ **The model assumes that HPs can only be used to charged TES at those times when the CO_2 emissions generated from electricity production are 0, i.e. when all electricity available at the grid is generated by means of renewables and/or zero-carbon sources.**
- ✓ **The study uses real half-hourly CO_2 emissions data per kWh of electricity produced in UK in the year 2021 and real half-hourly heat demand data for the buildings located at Holywell Campus.**

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