What A Waste

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Energy Consumption and Heat Reuse

~460 TWh were consumed by DCs in 2022

~40% of total energy is used to cool the DC

Generated heat is often released into environment - This is a wasted valuable resource

Possible alternative is to capture and reuse this heat to offset CO_2 emissions and reduce costs for the DC and surrounding community

Limitations of Heat Reuse

Limitations

- Low-temperature waste heat
- Difficult to capture
- Challenging to transport
- Cost

Applications exist that can overcome these issues

Can use heat pump to increase quality of heat to 65-70°C

Why Reuse Heat

DECREASE COSTS

DECREASE ENVIRONMENTAL IMPACTS

No way to compare heat reuse practices for DCs

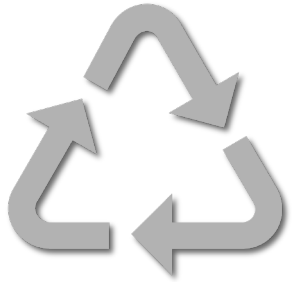
Previously Presented Metrics

Differences With Other Metrics

PUE

Power Usage Effectiveness

Captures facility power usage but does not reflect heat reuse



ERE/ERF

Energy Reuse Effectiveness/Factor

Captures how much energy was reused but does not reflect heat reuse

No way to see which heat reuse option is most cost and environmentally-friendly

Motivation and Relevance

Enables DCs to evaluate different heat reuse options before committing

Can be used for comparisons between DCs and their green practices

Proposed Metrics

Heat Reuse Factor Definition

$$HRF = \frac{Heat\ Reused\ (BTU)}{Total\ Heat\ Generated\ (BTU)}, 0 \leq HRF \leq 1$$

- How much heat is being reused out of the total heat that is generated

CO_2 Offset Definition

$$CO_2\ Offset = \frac{CO_2\ Saved}{CO_2\ Generated\ Energy\ Cost},\ 0 \leq CO_2\ Offset \leq 1$$

- Numerator = CO_2 that would have been generated but is prevented by heat reuse
- Denominator = CO_2 generated by DC + CO_2 emissions prevented by heat reuse

Green Supercomputing Ratio Definition

$$GSR = HRF \times CO_2\ Offset,\ 0 \leq GSR \leq 1$$

- Each metric in isolation is not an accurate representation of the DC's green practices
- Ex. Amusement park where heat is reused but CO_2 is not offset because it would not otherwise exist = *high HRF but low CO_2 Offset*
- Ex. Using green energy and reusing existing architecture but not reusing any heat, the generated heat is being wasted = *high CO_2 Offset but low HRF*
- Both metrics are required to paint an accurate picture

Case Studies

HRF Calculation Granularity: Practical

Table 1: Summary of theoretical DC information used for Tier 2 half load analysis.

	Tier 2 Half Load
DC Size (ft^2)	100,000
Number of Racks	5,989
Electricity Cost (USD/kWh)	0.0733
DC Electricity (TWh/year)	2.33
Server Electricity Amount (TWh)	1.95
Cooling Electricity Amount (TWh)	0.23
Other Electricity Amount (TWh)	0.15
Type of Cooling System	Liquid
Server Electricity Cost (USD/year)	171.1 million
Type of Power Plant	Coal
CO_2 Produced/million BTU (lb.)	205.7

District Heating

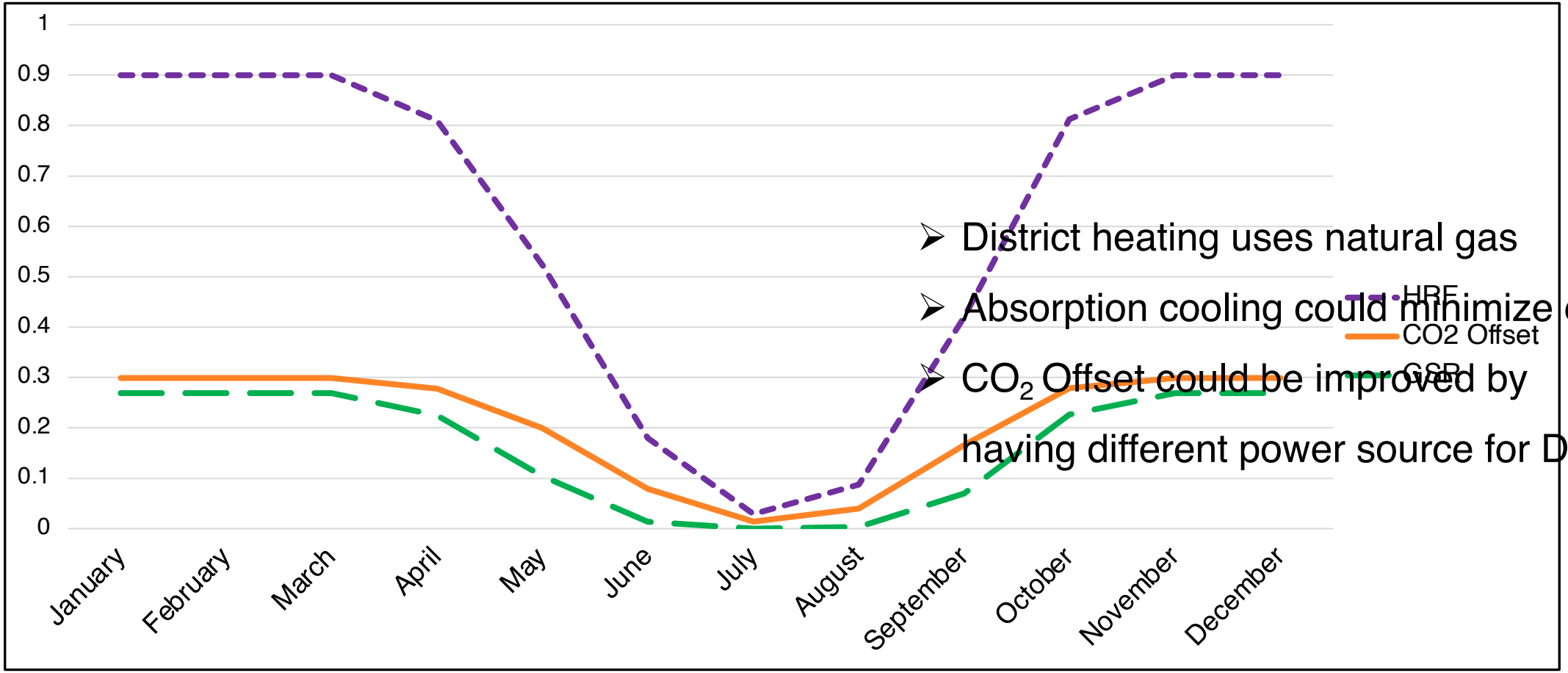
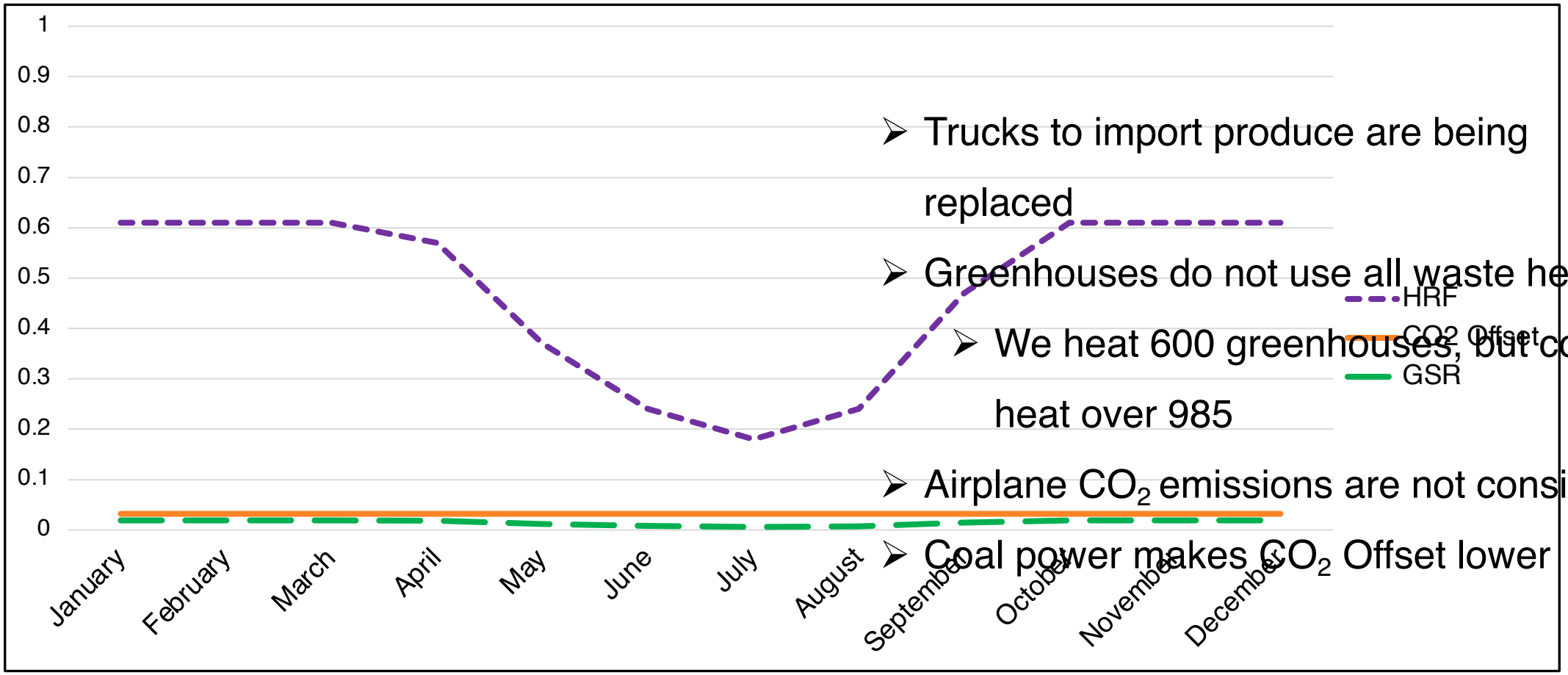


Figure 1: The HRF, CO_2 Offset, and GSR values for reusing waste heat from the Tier 2 Half Load DC for district heating in Ottawa, Ontario, Canada.

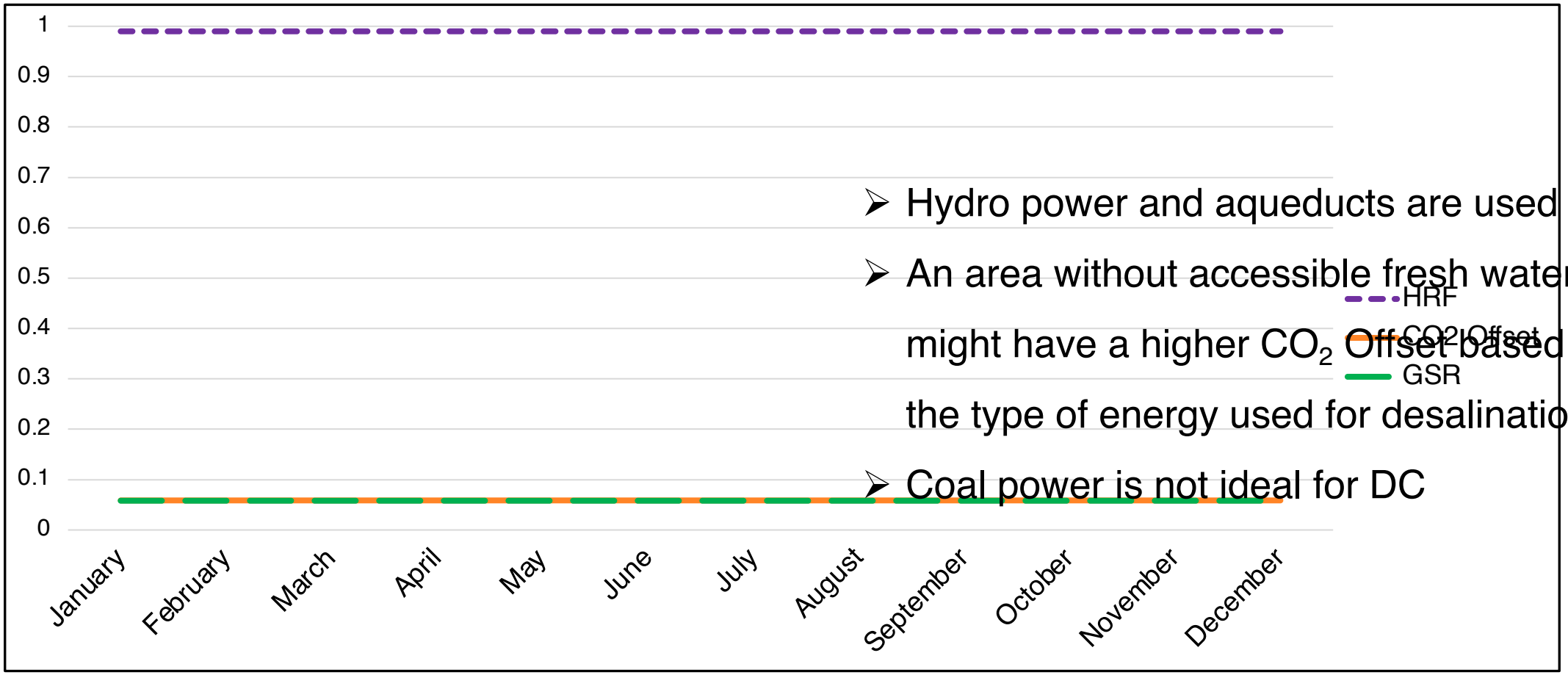
Agriculture



- Trucks to import produce are being replaced
- Greenhouses do not use all waste heat
- We heat 600 greenhouses, but could heat over 985
- Airplane CO_2 emissions are not considered
- Coal power makes CO_2 Offset lower

Figure 2: The HRF, CO_2 Offset, and GSR values for reusing waste heat from the Tier 2 Half Load DC to heat greenhouses in Juneau, Alaska, USA.

Desalination



- Hydro power and aqueducts are used in LA
- An area without accessible fresh water might have a higher CO_2 Offset based on the type of energy used for desalination
- Coal power is not ideal for DC

Figure 3: The HRF, CO2 Offset, and GSR values for reusing waste heat from the Tier 2 Half Load DC for desalination in Los Angeles, California, USA.

Important To Note

Three different locations were chosen to perform a location survey

The types of heat reuse chosen for this study were based on publicly available data

A greener power source would make the CO_2 Offset values change

Importance of Comparisons

Comparison of Results

Table 2: The minimum, average, and maximum HRF and GSR values for the heat reuse options of district heating, greenhouses, and desalination.

	Minimum HRF	Average HRF	Maximum HRF	Minimum GSR	Average GSR	Maximum GSR
District Heating	0.029	0.613	0.900	0.00039	0.16588	0.26947
Greenhouses	0.177	0.477	0.609	0.00560	0.01509	0.01928
Desalination	0.990	0.990	0.990	0.058	0.058	0.058

Comparison of HRF and GSR Values

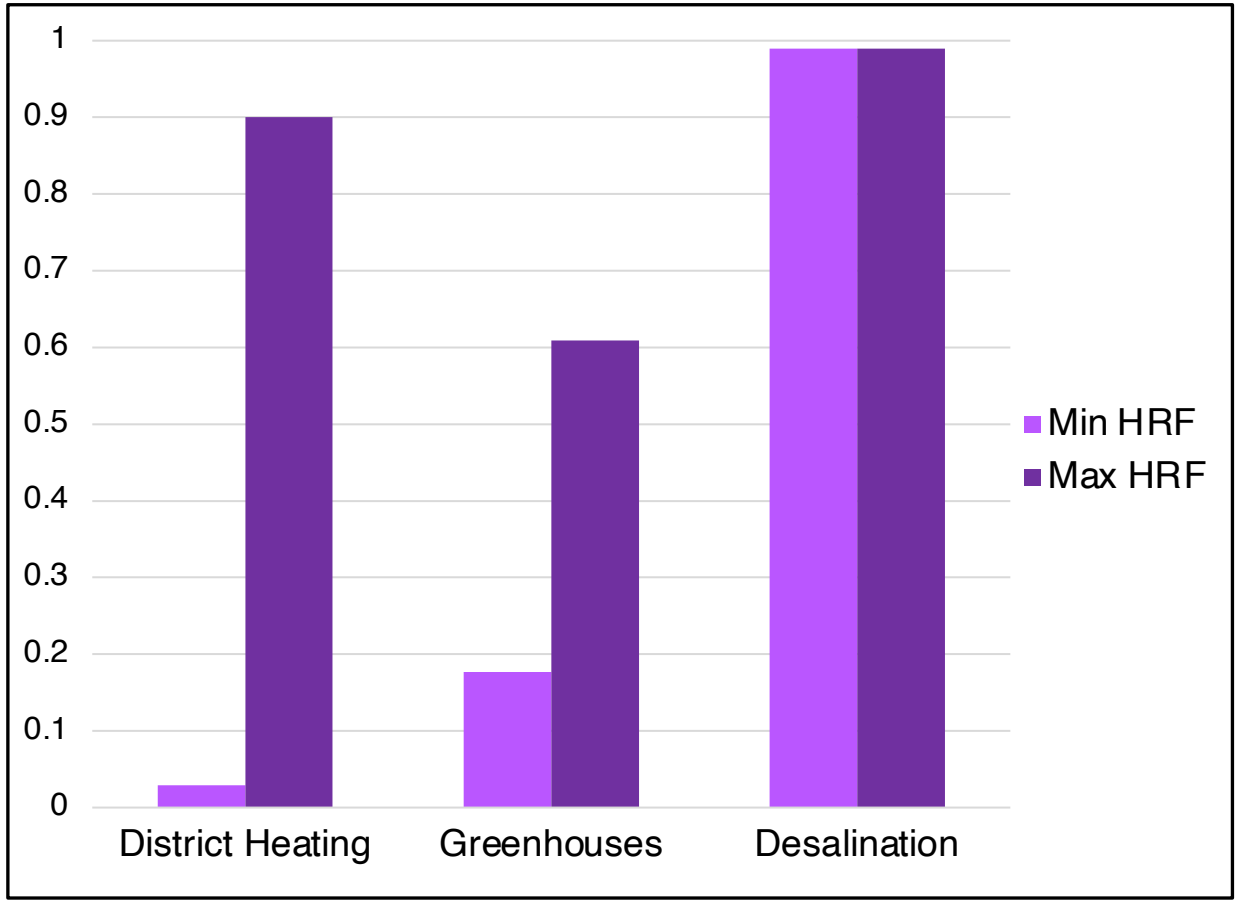


Figure 4: The minimum and maximum HRF values for the heat reuse options of district heating, greenhouses, and desalination.

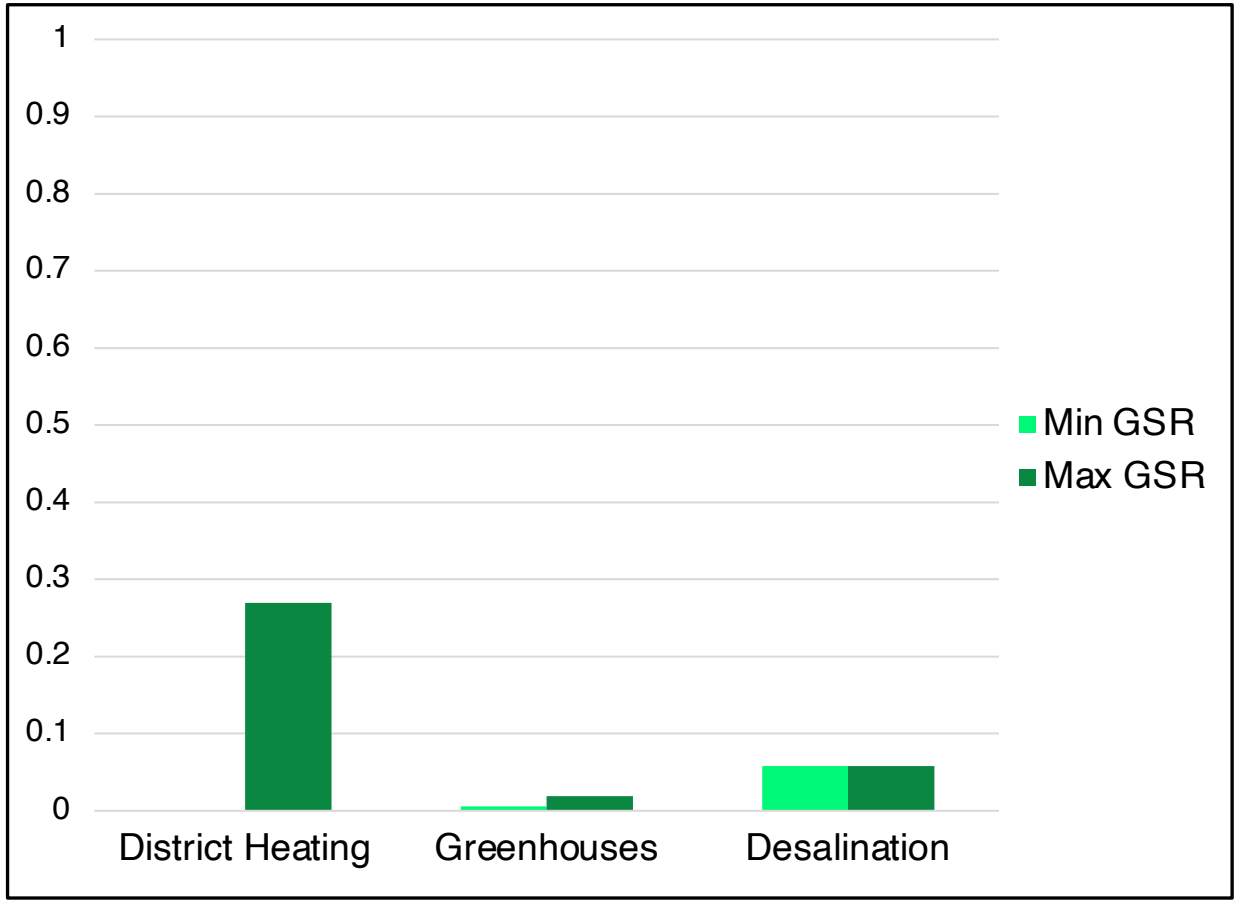


Figure 5: The minimum and maximum GSR values for the heat reuse options of district heating, greenhouses, and desalination.

Conclusion

Enables DCs to evaluate different heat reuse options before committing

Can be used for comparisons between DCs and their green practices

Proposed two metrics: HRF and GSR

Combining heat reuse applications can be beneficial

Using a greener power source would improve HRF and GSR values

Future Work

Standardize policies to make metric feasible for global comparisons

Create a facility-side TOP500 list

Investigate using waste heat for multiple applications and best locations for each

Examine impact of heat reuse on cost and determine monetary value of heat

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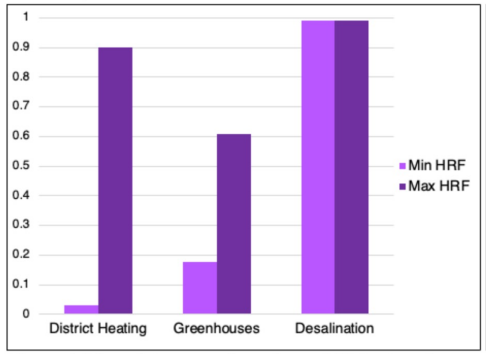

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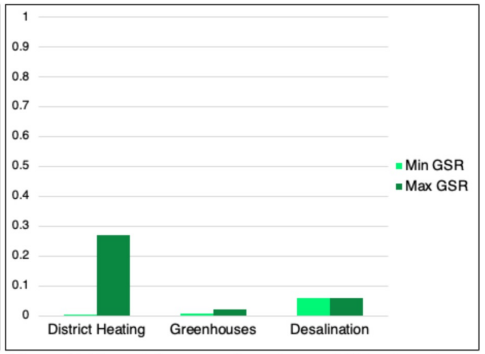

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