RANKING OF HEAT SOURCES AND SINKS BASED ON SEASONAL PERFORMANCE ESTIMATION AND DEMANDS FOR HEATING AND COOLING AREAS

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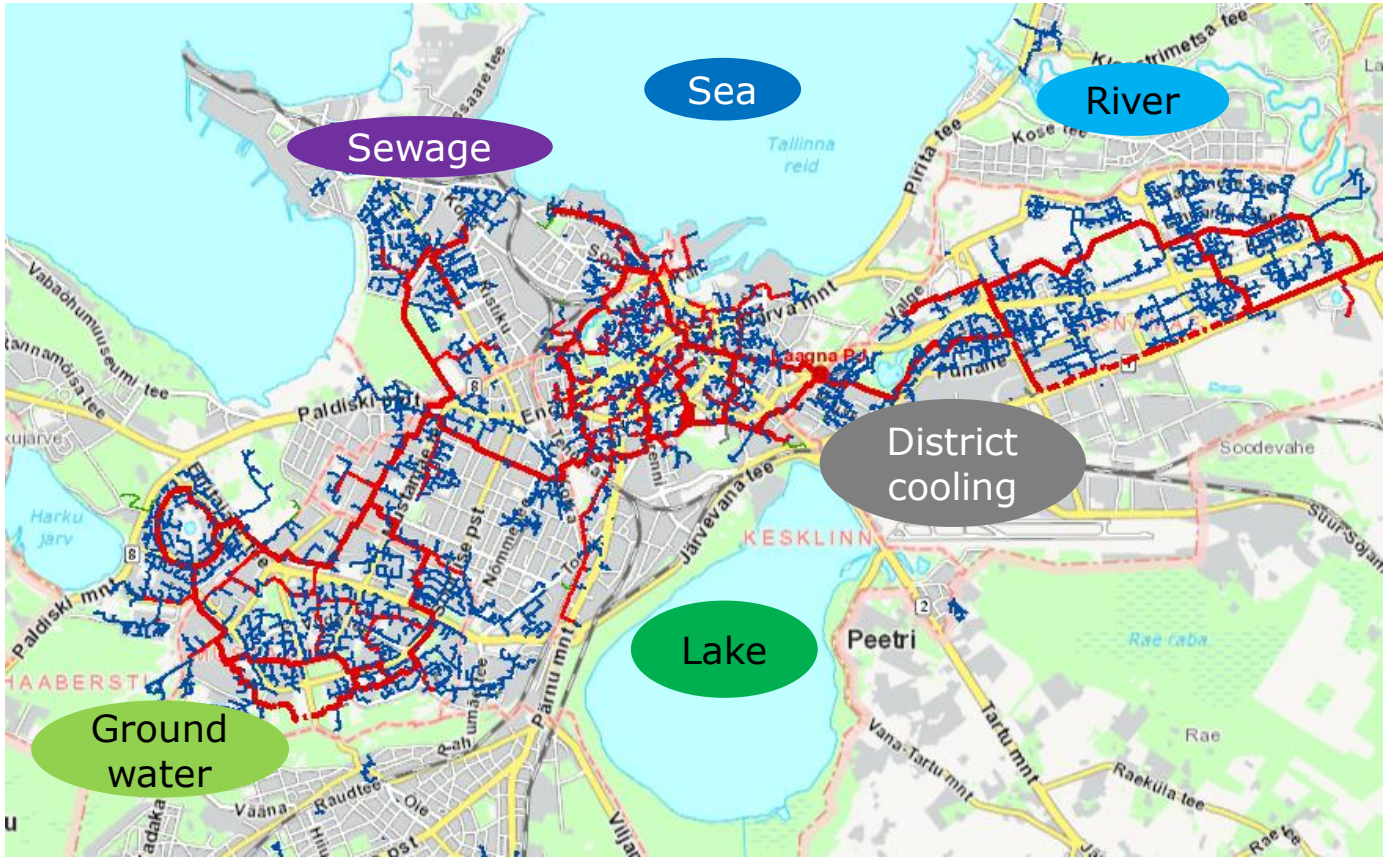
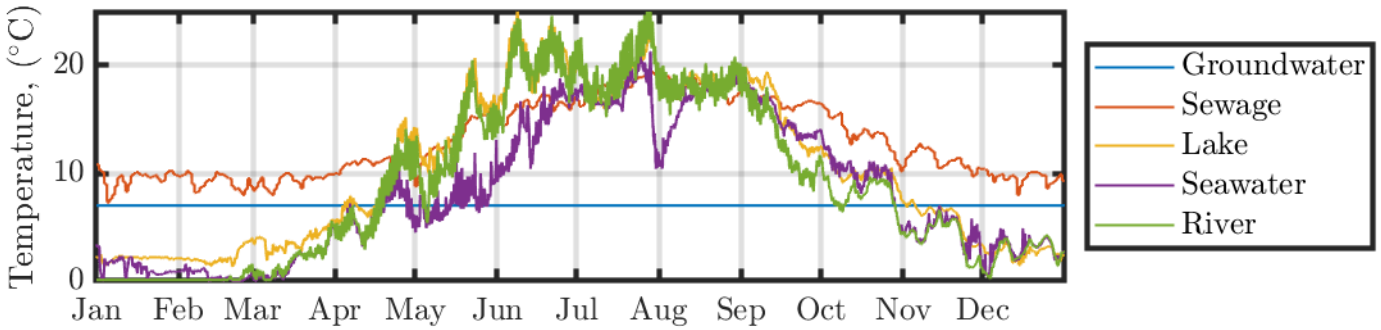
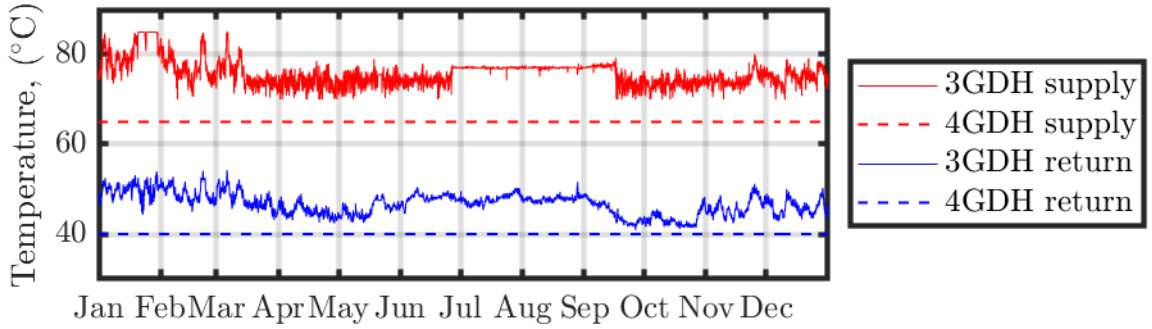
MOTIVATION: DH NETWORK OF TALLINN, ESTONIA



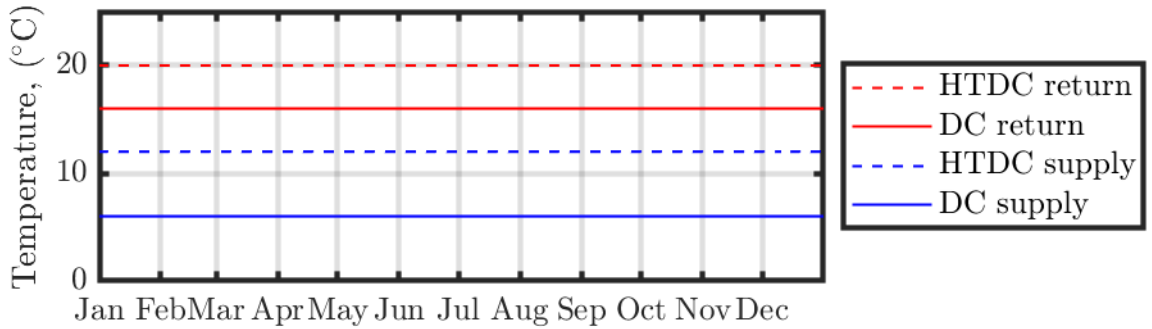
- Various heat sources & heat sinks
- Heat pumps, chillers, free cooling
- Which one is best suitable for
  - DH and/or DC supply
  - High performance
  - Best economics
  - Small or large capacities

MOTIVATION: SIMPLIFY AND REDUCE EFFORT FOR COP CALCULATION





- 5 heat sources & sinks
- 3GDH & 4 GDH
- DC & HTDC
- 14 different combinations
- Hourly calculations (8760 h)
- ≈ 122,640 calculation steps
- Linear approximations for energy planning models helpful



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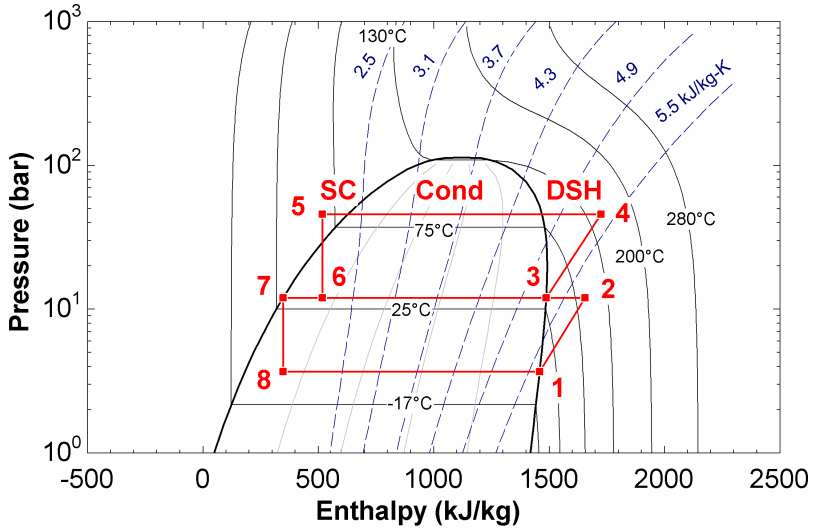
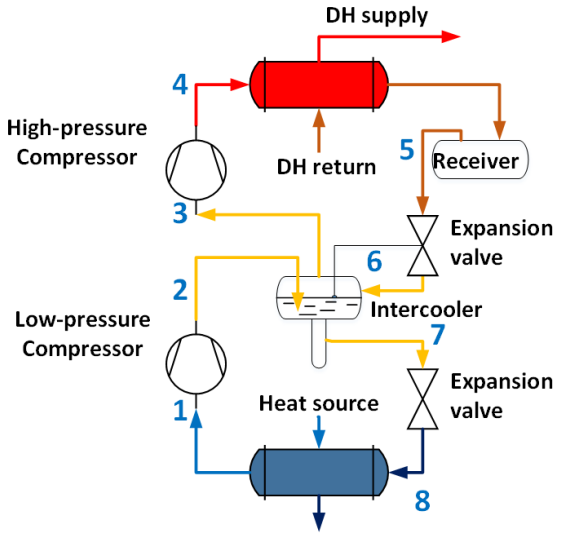
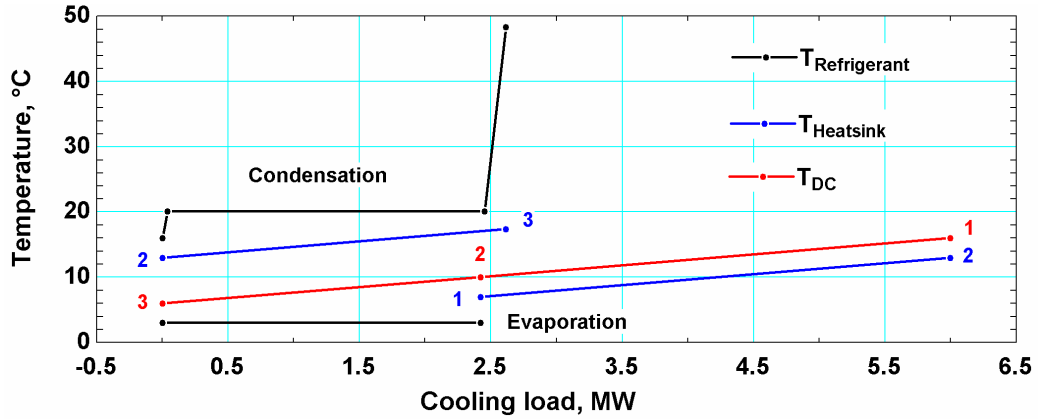
METHODS: THERMODYNAMIC MODELLING



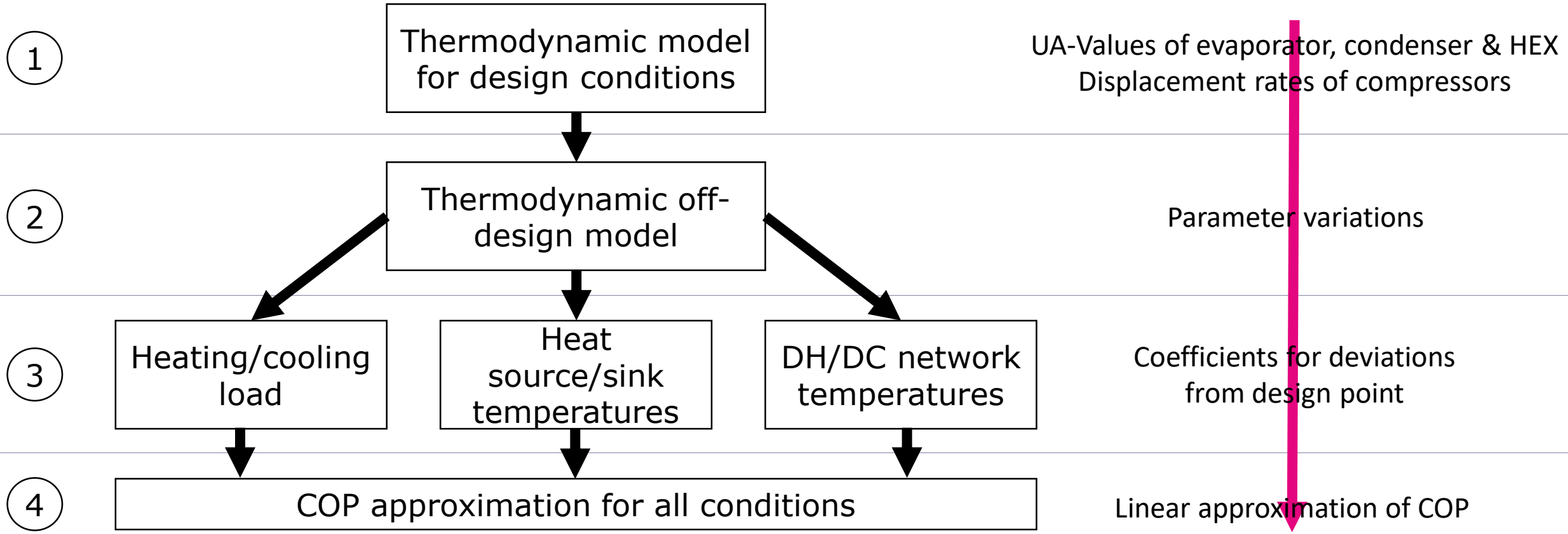


- EES (Engineering Equation Solver)
- 2-stage HP with open intercooler
- Ammonia as refrigerant
- Screw compressor polynomial



- 1-stage chiller & heat exchanger
- 3 operation modes:
  - 100 % free cooling
  - 100 % mechanical cooling
  - Mix of both (HEX pre-cooling)

METHODS: COP APPROXIMATION



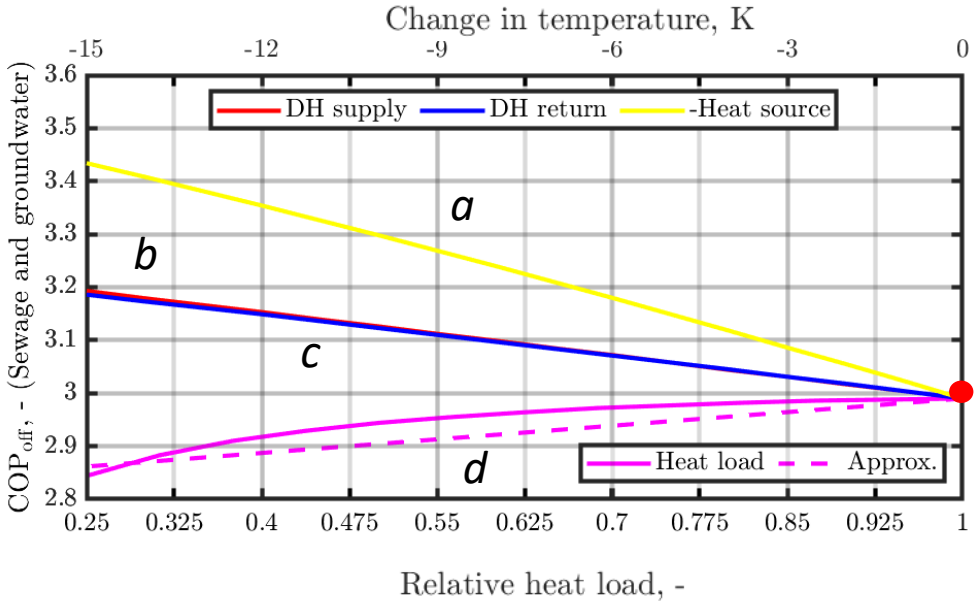
METHODS: COP APPROXIMATION FOR HEAT PUMPS

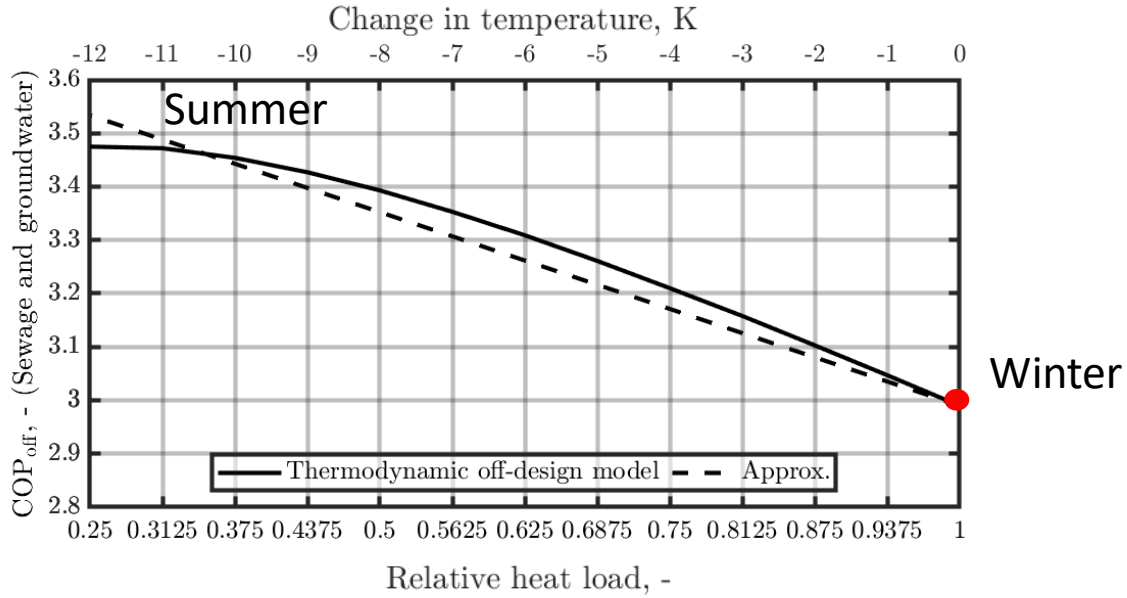
$$\mathrm{COP}_{\mathrm{off}} = \mathrm{COP}_d + \underbrace{a\left(T_{\mathrm{source},i} - T_{\mathrm{source},i,d}\right)}_{\text{Heat source}} + \underbrace{b\left(T_{\mathrm{DH},s} - T_{\mathrm{DH},s,d}\right)}_{\text{DH supply}} + \underbrace{c\left(T_{\mathrm{DH},r} - T_{\mathrm{DH,r},d}\right)}_{\text{DH return}} + \underbrace{d(\mathrm{LR} - \mathrm{LR}_d)}_{\text{Heat load}}$$

Design parameter	Groundwater & Sewage	River, Lake & Seawater	DC	HTDC
$T_{\mathrm{source},i,d}$	7	4	16	20
$T_{\mathrm{source},o,d}$	1	1	6	12
$T_{\mathrm{DH},s,d}$	85			
$T_{\mathrm{DH,r},d}$	60			
LR_d	1			
COP_d	2.99	2.99	3.17	3.51

Parameter variation	Groundwater & Sewage	River, Lake & Seawater	DC	HTDC
$T_{\mathrm{source},i}$	7...22	4…19	12…20	17…24
$T_{\mathrm{DH},s}$	70…85			
$T_{\mathrm{DH},r}$	45…60			
LR	0.25…1			

RESULTS: COP APPROXIMATION FOR HEAT PUMPS



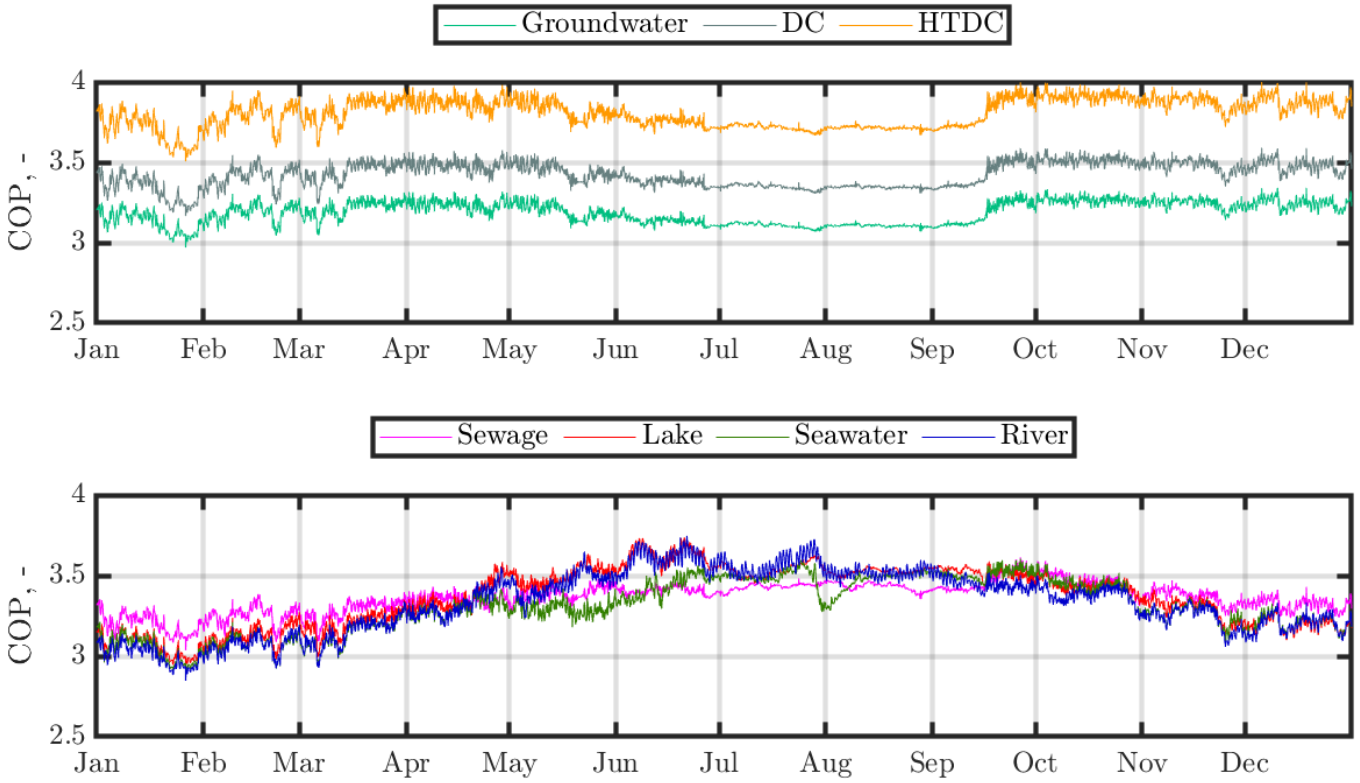


Parameter	Coefficients (slope)	Groundwater & Sewage	River, Lake & Seawater	DC	HTDC
Heat source	*a*	0.0296	0.0298	0.0305	0.0383
DH supply	*b*	−0.0136	−0.0136	−0.0162	−0.0186
DH return	*c*	−0.0128	−0.0128	−0.0141	−0.0167
Heat load	*d*	0.1712	0.1839	0.1443	0.1695

- Design conditions

COP deviations < 3.5 %

RESULTS: RANKING OF HEAT SOURCES BASED ON PERFOMRANCE ESTIMATION



Heat source	Seasonal COP	Average temperature	Weighted average temperature
HTDC	3.81	20	20
DC	3.43	16	16
Sewage	3.32	13.01	11.20
Lake	3.27	10.32	6.43
River	3.22	9.10	4.90
Seawater	3.22	8.24	4.90
Groundwater	3.20	7	7

DISCUSSION

- Coefficients also for other DH design temperatures and heat sources
- COP approximation for cooling (heat exchanger and chiller)
- Comparison to other COP estimation methods
- Comparison with real heat pump performance

CONCLUSION

- HP COP approximation for different heat sources
- Deviations of COP < 3.5 %
- Ranking of heat sources for Estonian conditions

- Practical application:
  - Steps 1-3: HP manufacturer/researcher (thermodynamic model)
  - Step 4: Utility company/energy planner (apply COP approx.)

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