Techno-economics of the integration of (data centre) waste heat into (existing) district heating systems

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Private research and consulting organization based in Vienna

Spin-off from Technische Universität Wien – Energy Economics Group

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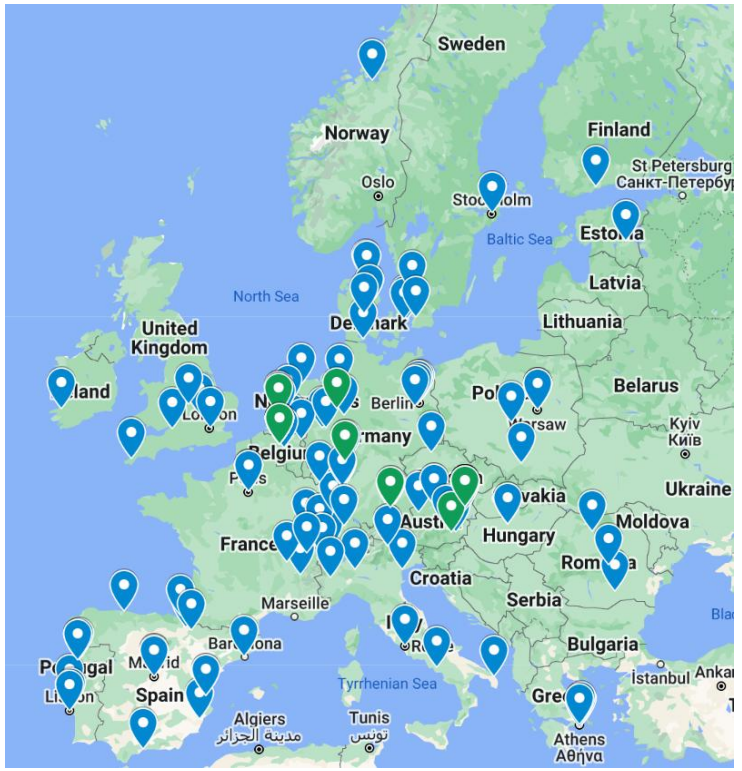

Content

- Aspects of integrating waste heat of data centers into district heating
- What is the value of waste heat in district heating?
- Tool for assisting the contract negotiations
- Conclusions and outlook

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Data center and District Heating System

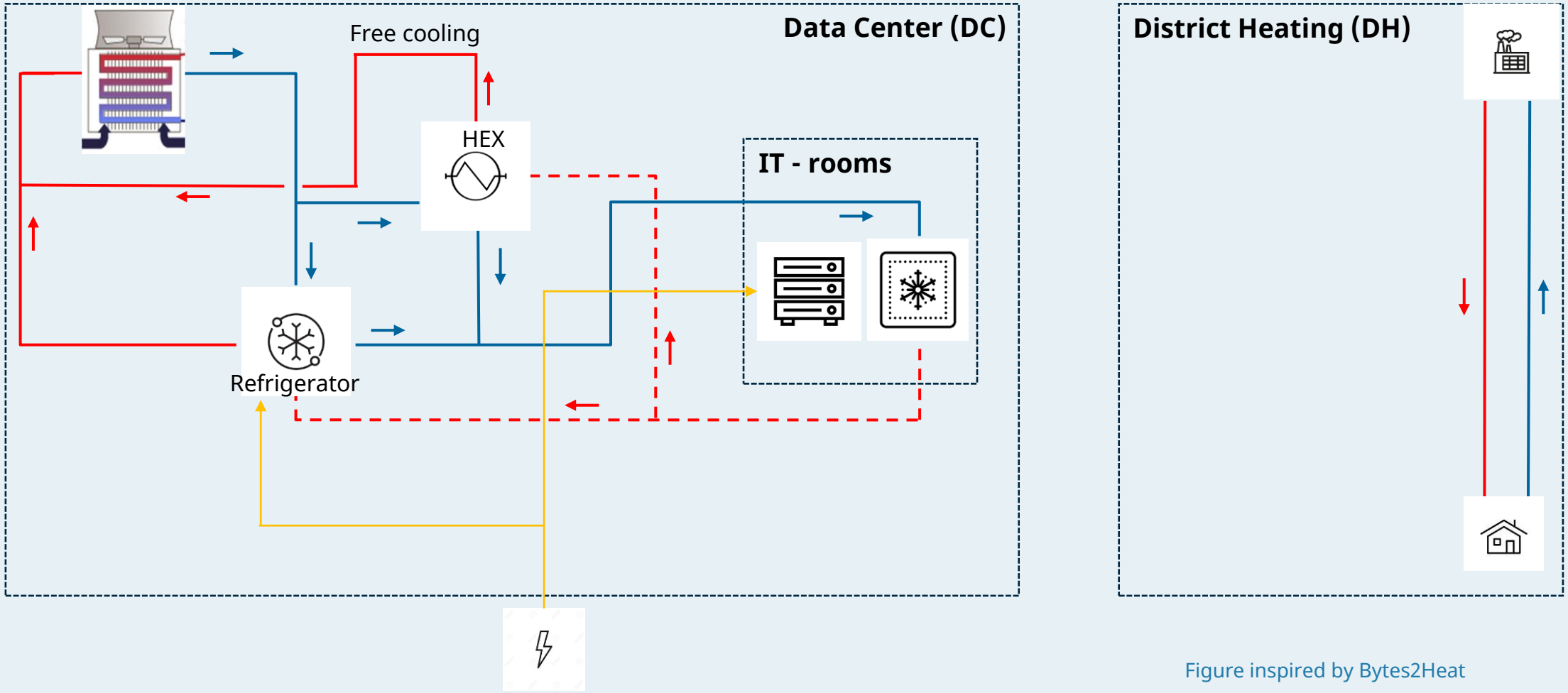
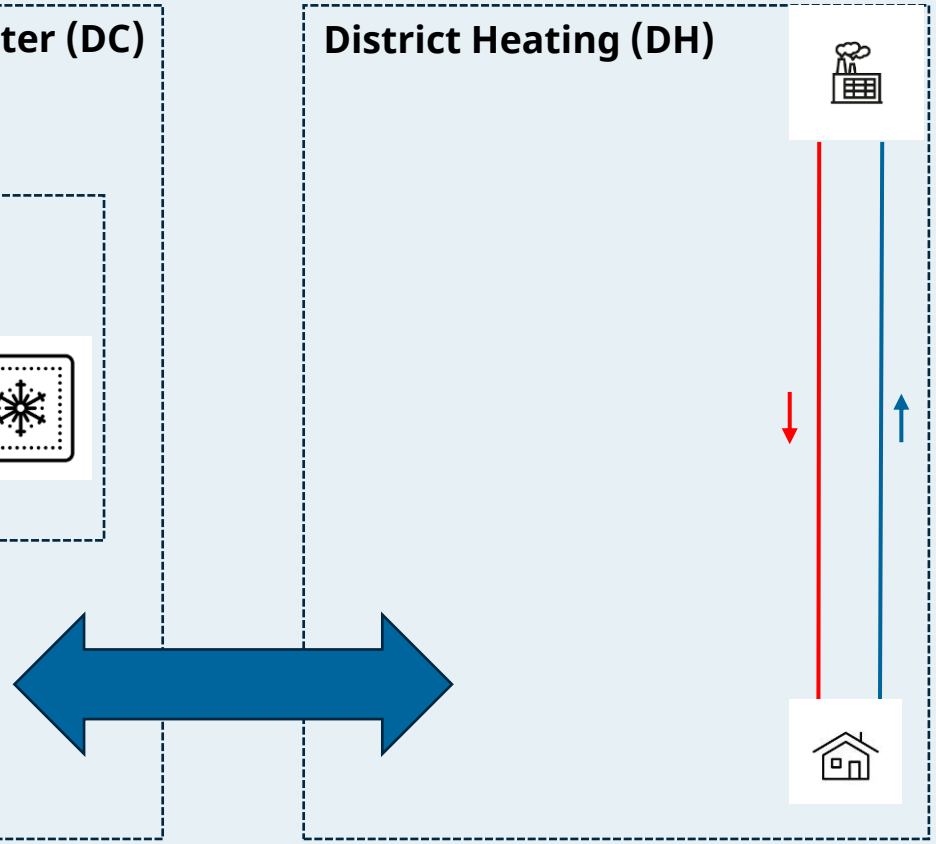


Figure inspired by Bytes2Heat

Location of DC and DH

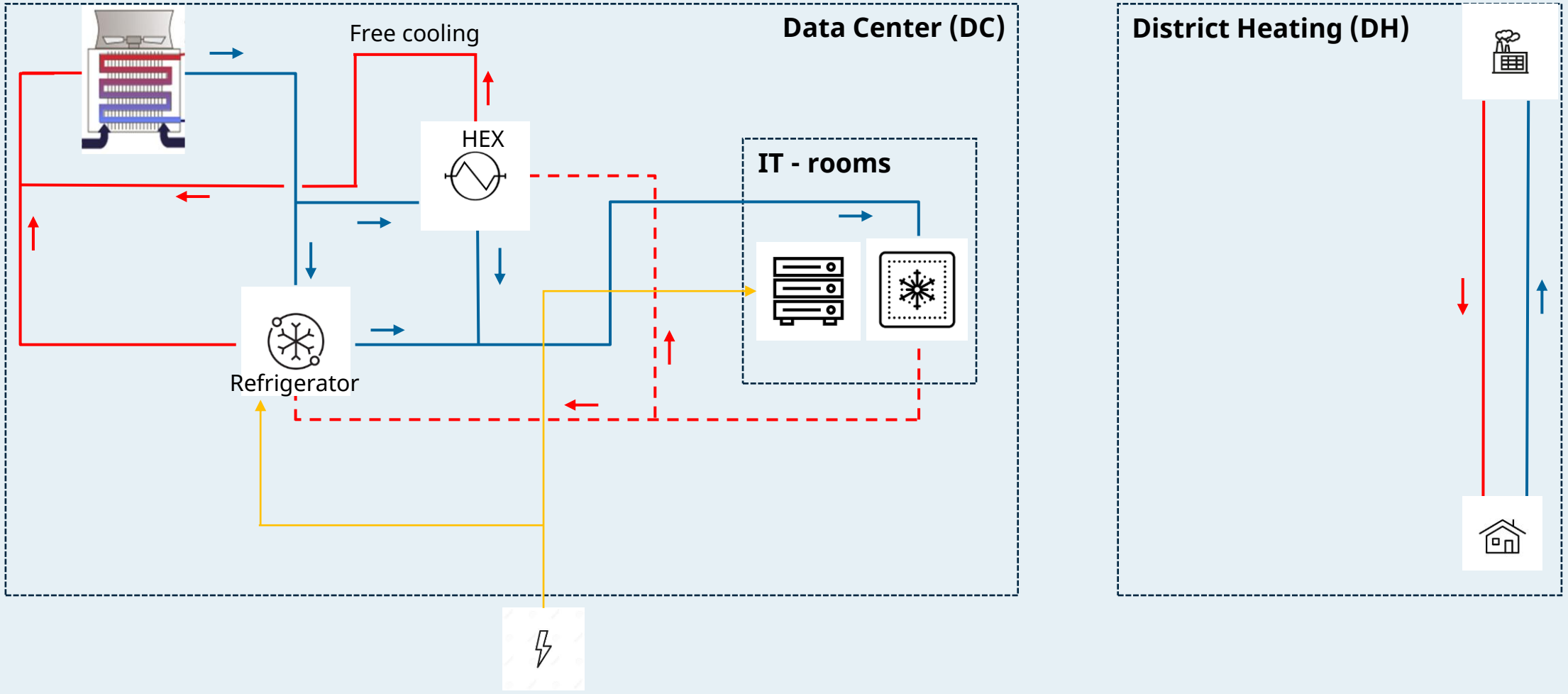
Location of both DC and DH

- Distance between DC and DH → length of connecting pipes
- Territory → in cities more expensive / complicated to lay pipes
- Relation to temperature level → $Q = m\ c_p\ dT$
- Is there already a grid or does it need to be built?

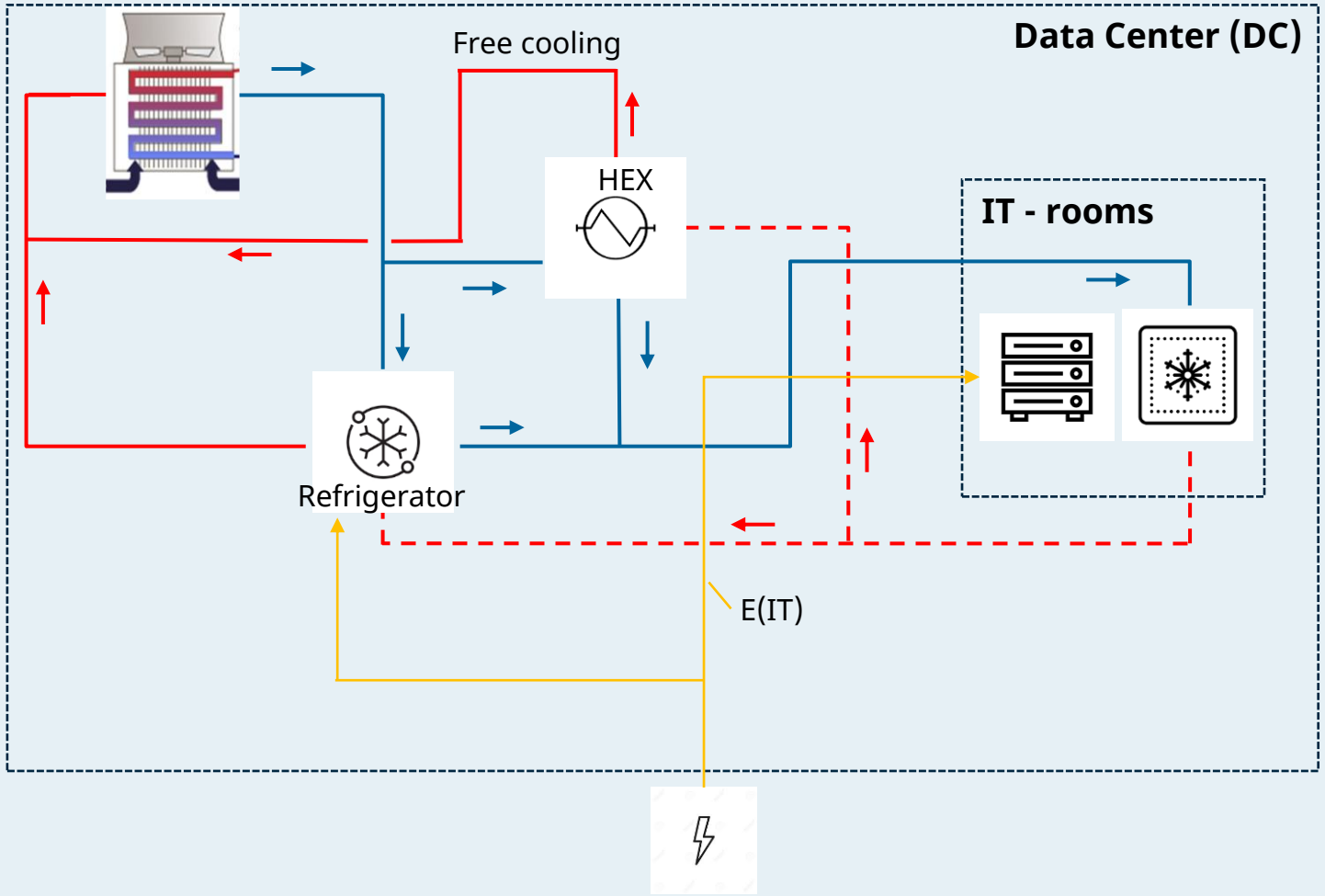


Load characteristics DC and DH

Load characteristics



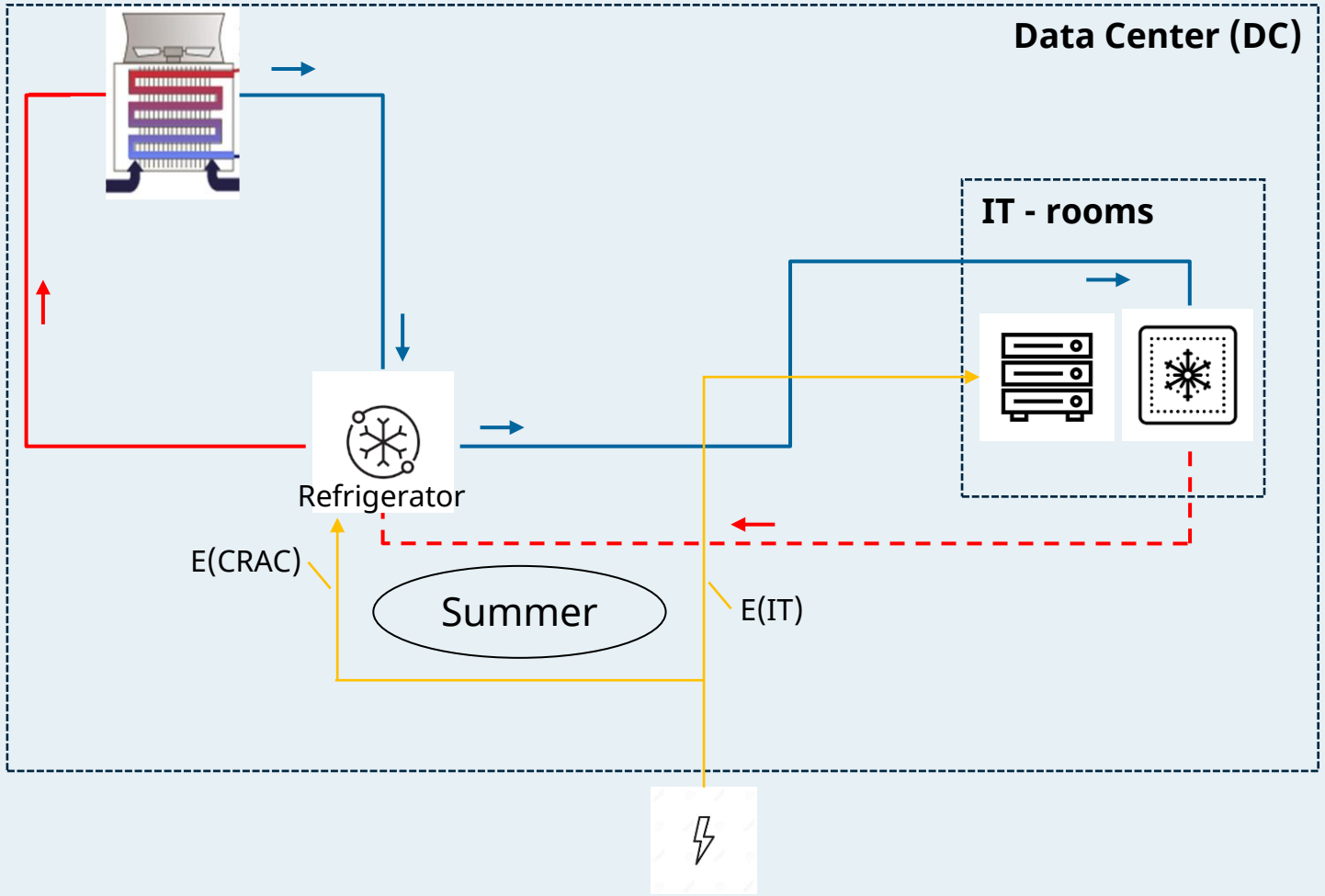
Load characteristics – Data center



- Overall stable IT load 24/7
- Ramp up of plants after build up
- Difference between IT capacity and IT load:
  - Depends on type of DC
  - E(IT) * ITEU (0-1)
  - ITEU can be between 25 – 75%
- Difference summer /winter

E(IT) ... IT capacity
ITEU ... IT Equipment Utilisaton

Load characteristics – Data center



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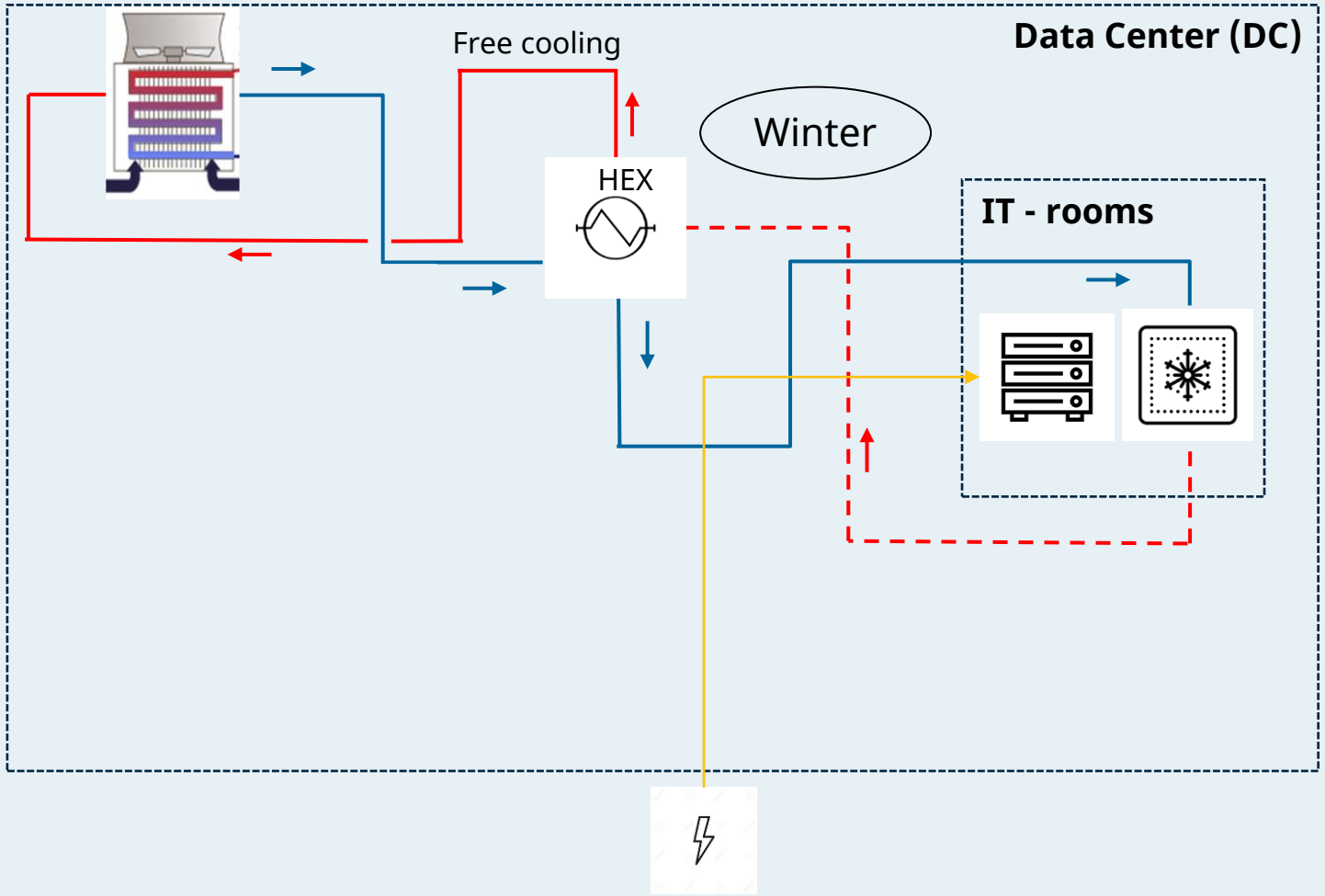

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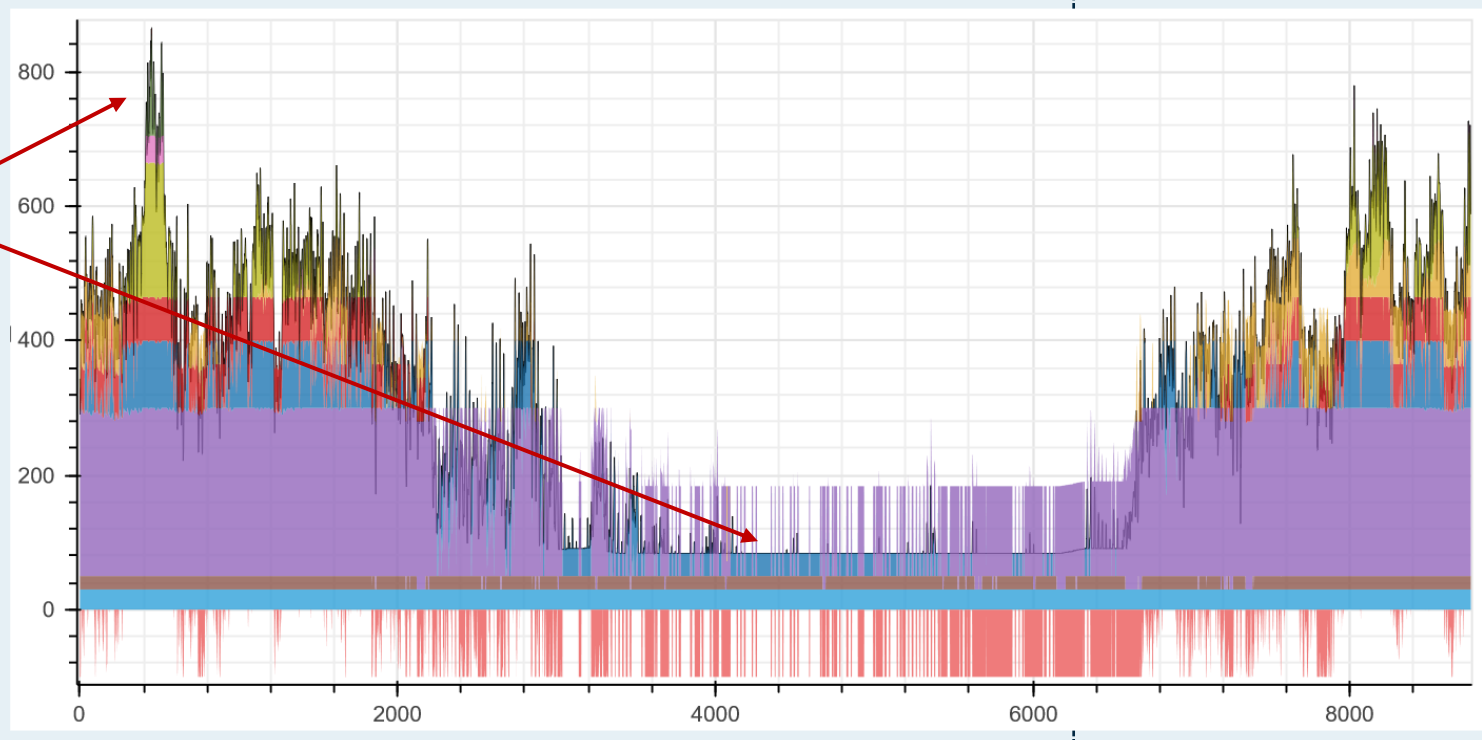
Load characteristics – District Heating

- Difference summer / winter
- Highest heat demand in times when DC has lower cooling demand

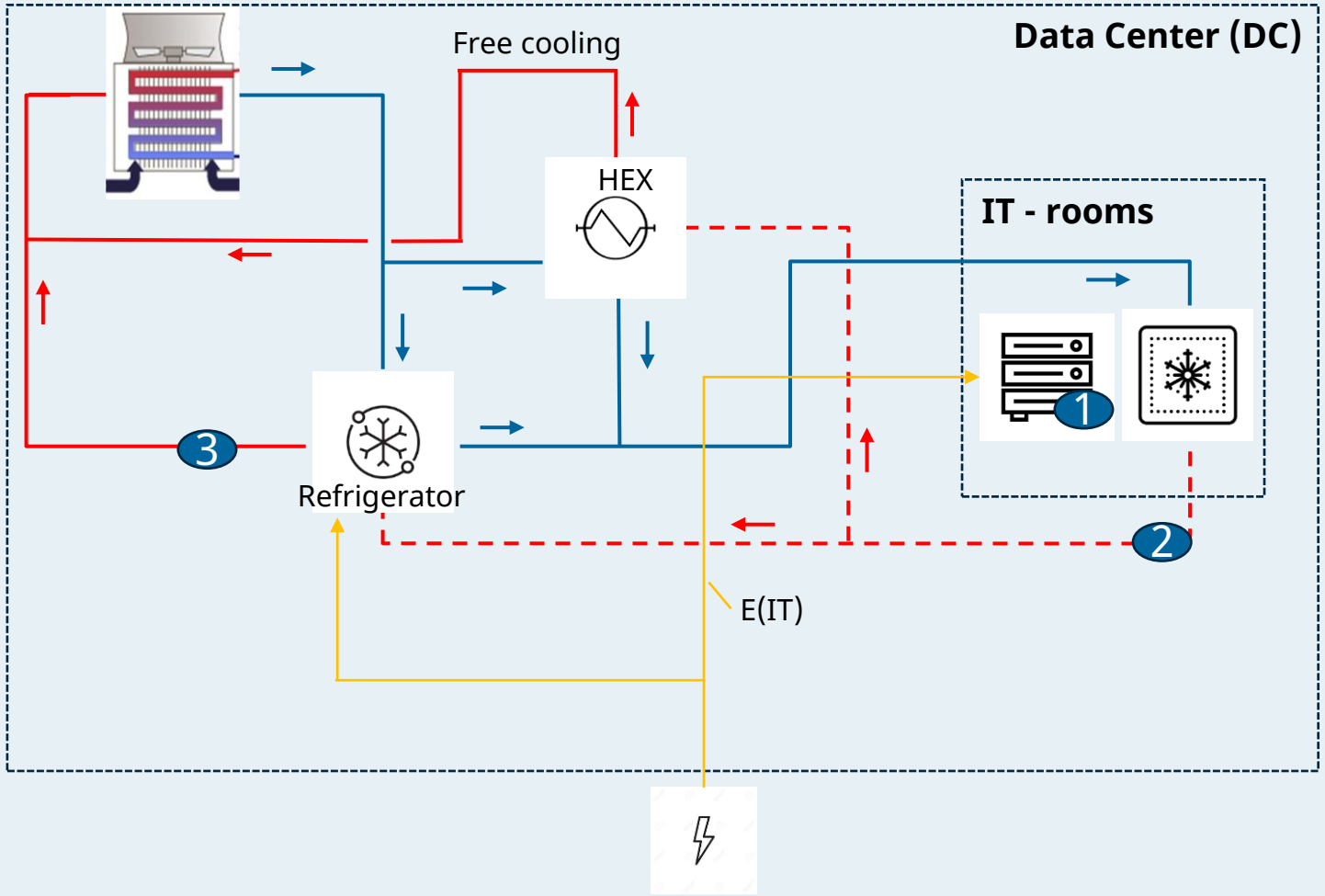


→ No heat supply in winter much less attractive and clearly an issue

Source: e-think

Temperature characteristics in DC and DH

Temperature characteristics – DC

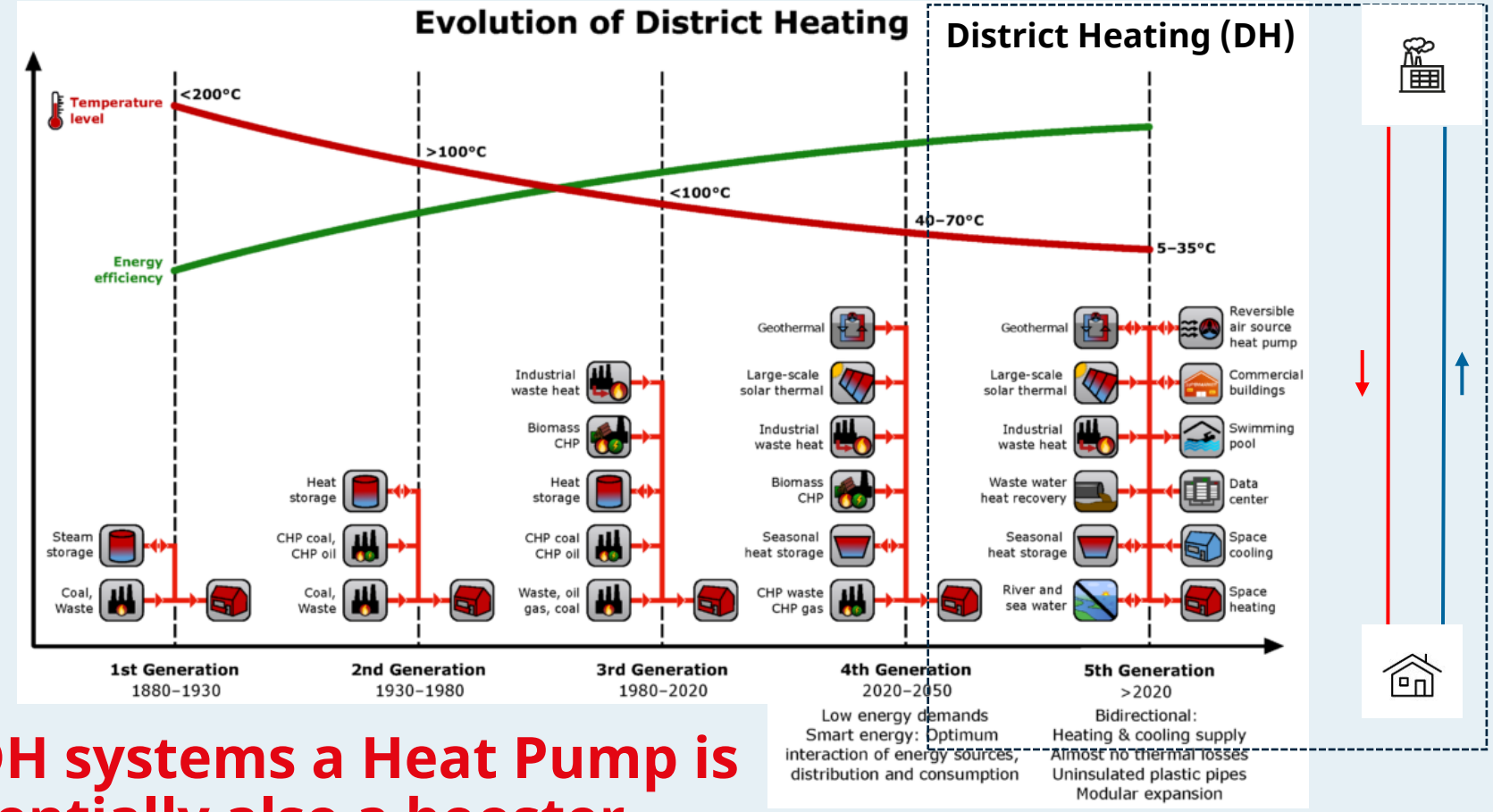


Waste Heat temperature depends on type of DC and where heat is captured

1. 40 - 60°C or more for water cooled server racks
2. 25 – 45°C for air cooled rack rooms
3. Up to 50°C after the refrigerator

Temperature characteristics – DH

- Lower for new grids (4th and 5th generation)
- Higher for existing grids (2nd and 3rd generation) (90°C +)

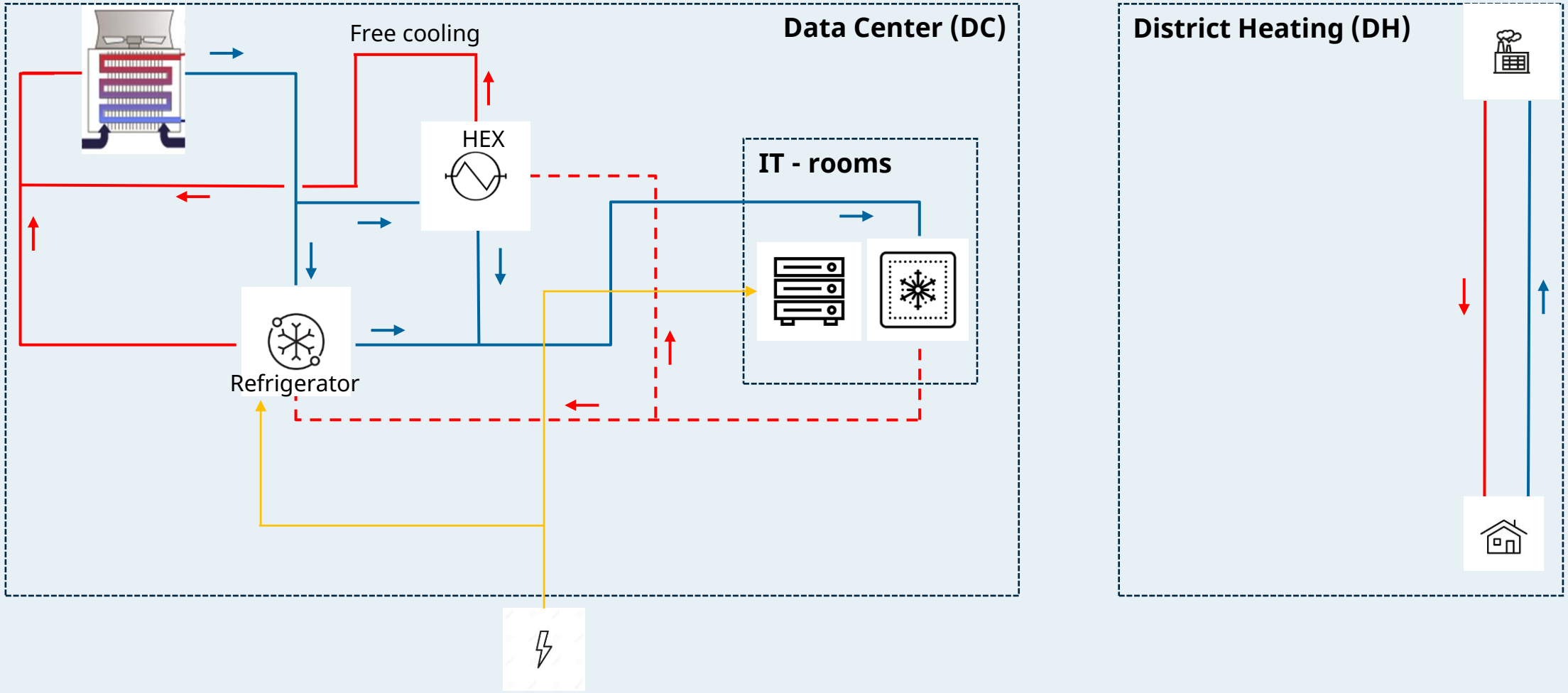


→ For existing DH systems a Heat Pump is needed, potentially also a booster

Source: buildingsdecarb.org

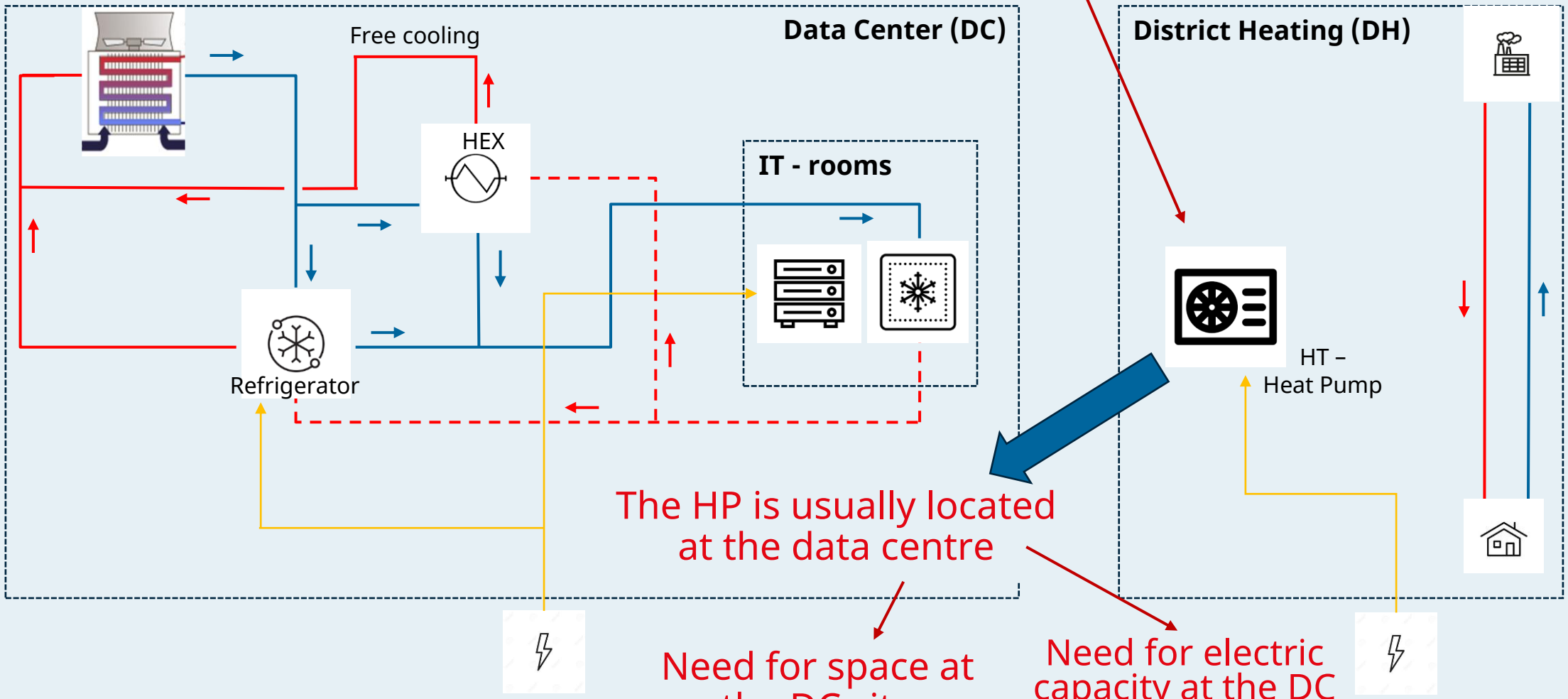
Heat pump integration

Heat pump integration



Heat pump integration

HP will be in the energy and emission balance of the DH system

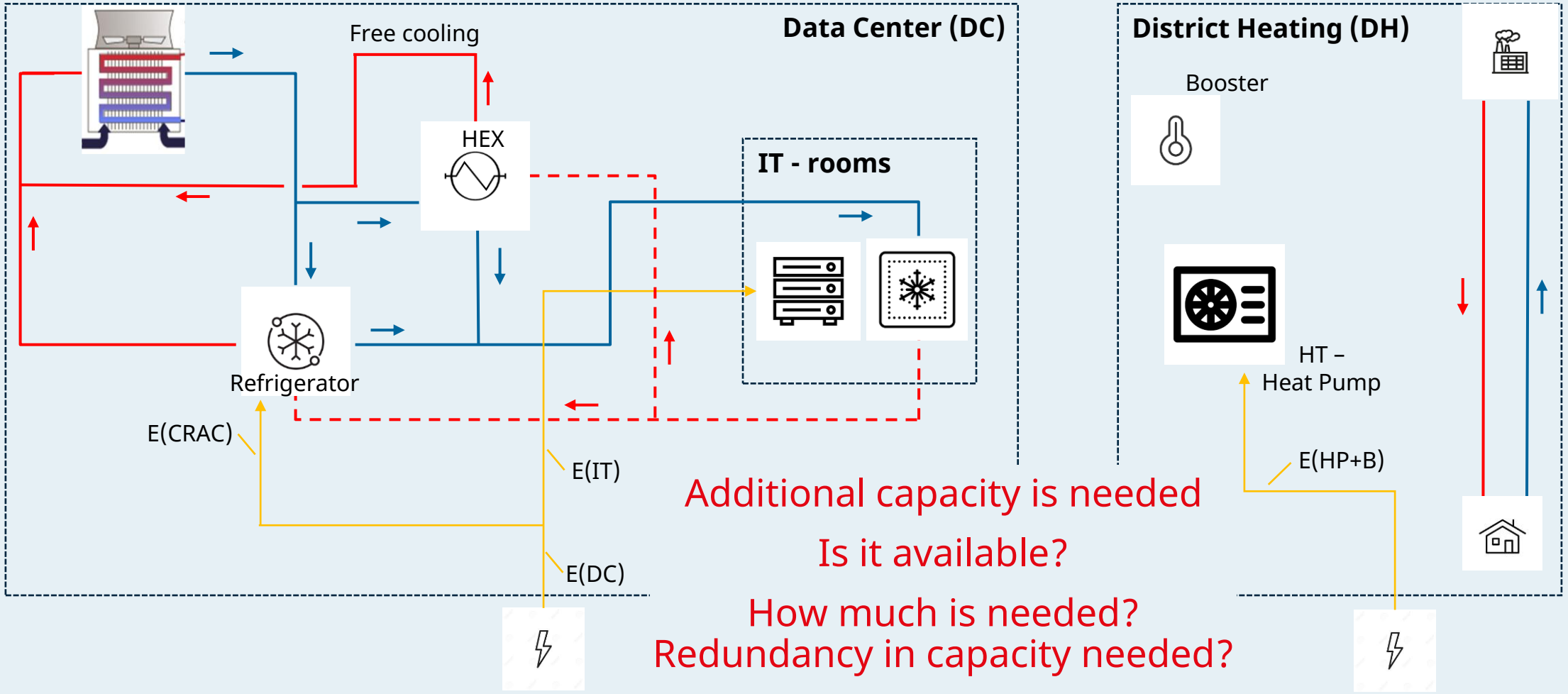


The HP is usually located at the data centre

Need for space at the DC site

Need for electric capacity at the DC site

Heat pump integration



Additional capacity is needed

Is it available?

How much is needed?
Redundancy in capacity needed?

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Questions

„**How to determine the economic value of waste heat** in district heating in relation to load profile, temperature profile and characteristic of existing district heating system?”

“**How to determine a price for waste heat to be paid** by a district heating operator?”

… in an existing district heating system

Differences in answering

Short-term vs. long-term:

- Short-term:
  - Waste heat + related system components for using the waste heat (e.g. Heat Pump and connecting pipes) compete with heat from the existing DH system
  - **Short-run marginal costs (SRMC) of existing units** are the **threshold** for economic evaluation
- Long-term:
  - Waste heat + related system components for using the waste heat are part of the DH system
  - **Long-run marginal costs of entire system** is relevant for economic evaluation

Detailed vs. simplified:

- Detailed:
  - **Hourly calculation / optimisation of dispatch**
  - Change in DH system components over time
  - E.g. EnergyPRO calculations with varying parameters of e.g. electricity prices, units over time, price of waste heat
- Simplified:
  - Analysing **representative moments over the year**
  - Only consider most relevant relations for question
  - E.g. Heat Merit Order analysis

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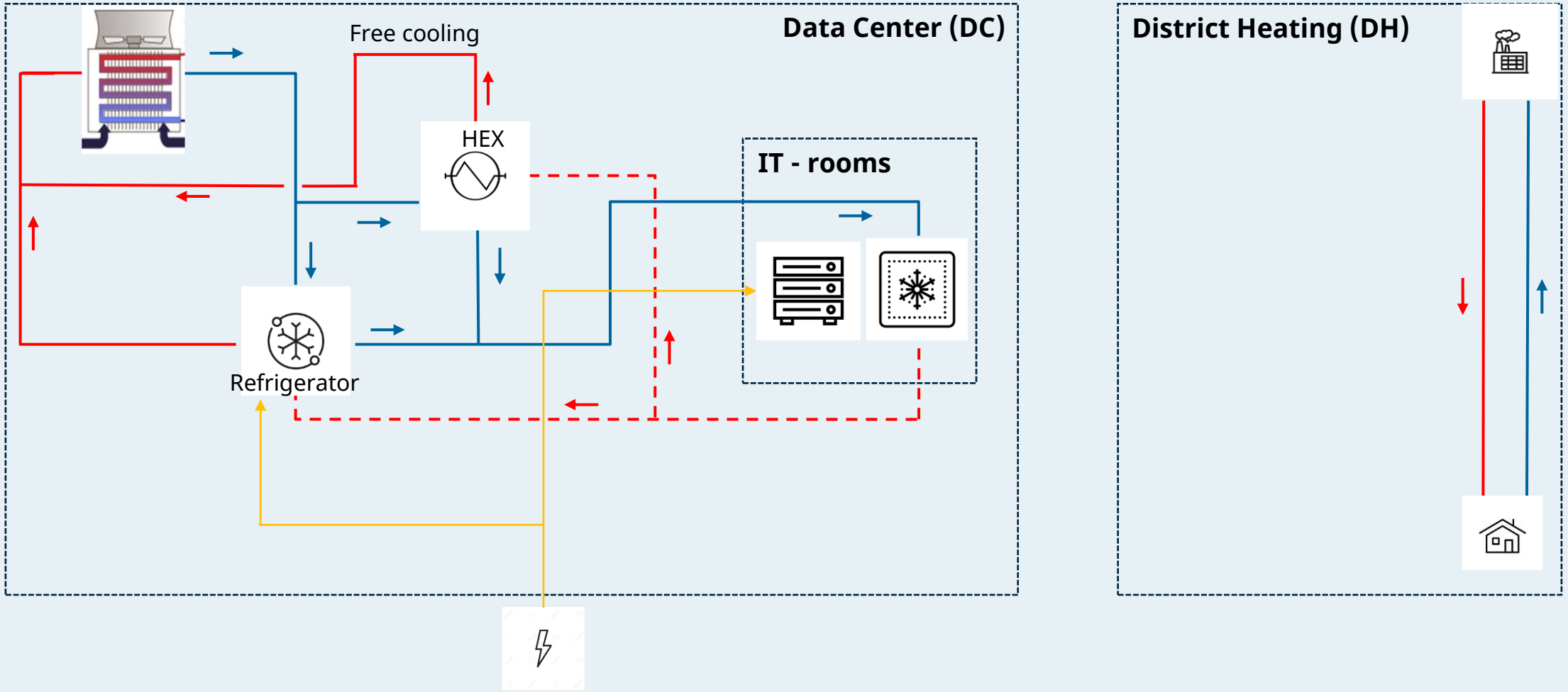
Requirements for the tool

- Tool **as simple as possible** (minimum input data, no complex calculations), **as sophisticated as needed** (correct and usable results)
- Tool needs to be **transparent**, **reproducible** and **easy to** further develop / **adapt** to needs (→ Excel)
- Tool should be **usable in negotiations** between DH operator and DC operator
- In first place focus on German law, but be flexible to other countries

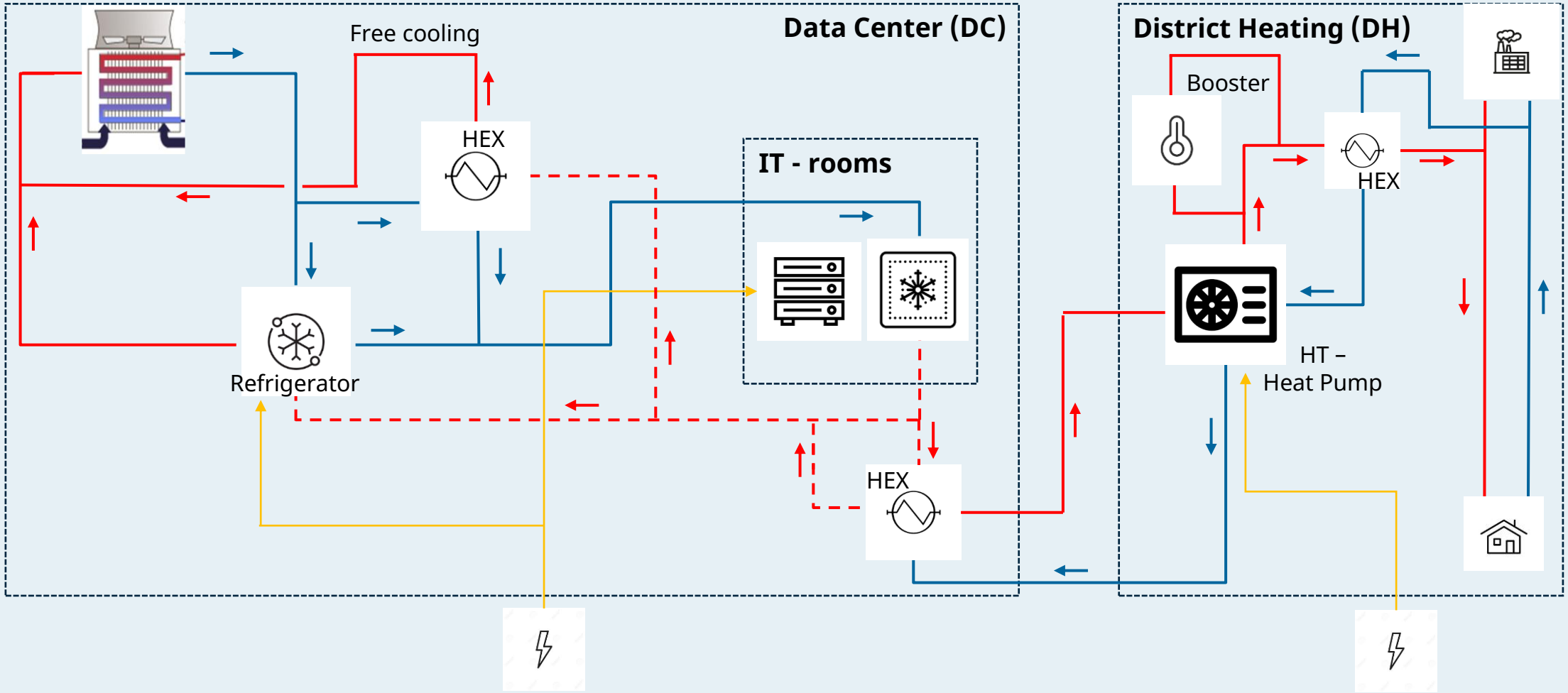
Overview of the approach

- Time slice approach:
  - **representative days in hourly resolution** (e.g. coldest winter day, average winter weekday, summer weekend, …)
  - whole year modelled consisting of up to 20 representative days
- Heat from **HP only used** in hours **when**
  - it is **cheaper than alternative generation** (existing DH system)
  - **capacity is needed** in the grid (potentially in summer other base load providers)
- Different **business models** integrated:
  - A **price** for the wate heat **is paid**: „take-or-pay“, „pay-as-you-go“
  - **Waste heat** is **for free**
- Economic parameters:
  - **Split of costs** for **waste heat recovery system** between DH and DC operator (important input for negotiation)
  - **Break-even price** / value of waste heat determined via marginal costs of DH system (alternative generation) minus levelized costs of heat extraction and integration
  - **IRR** for DC and DH operators **calculated**

Heat pump integration modelled



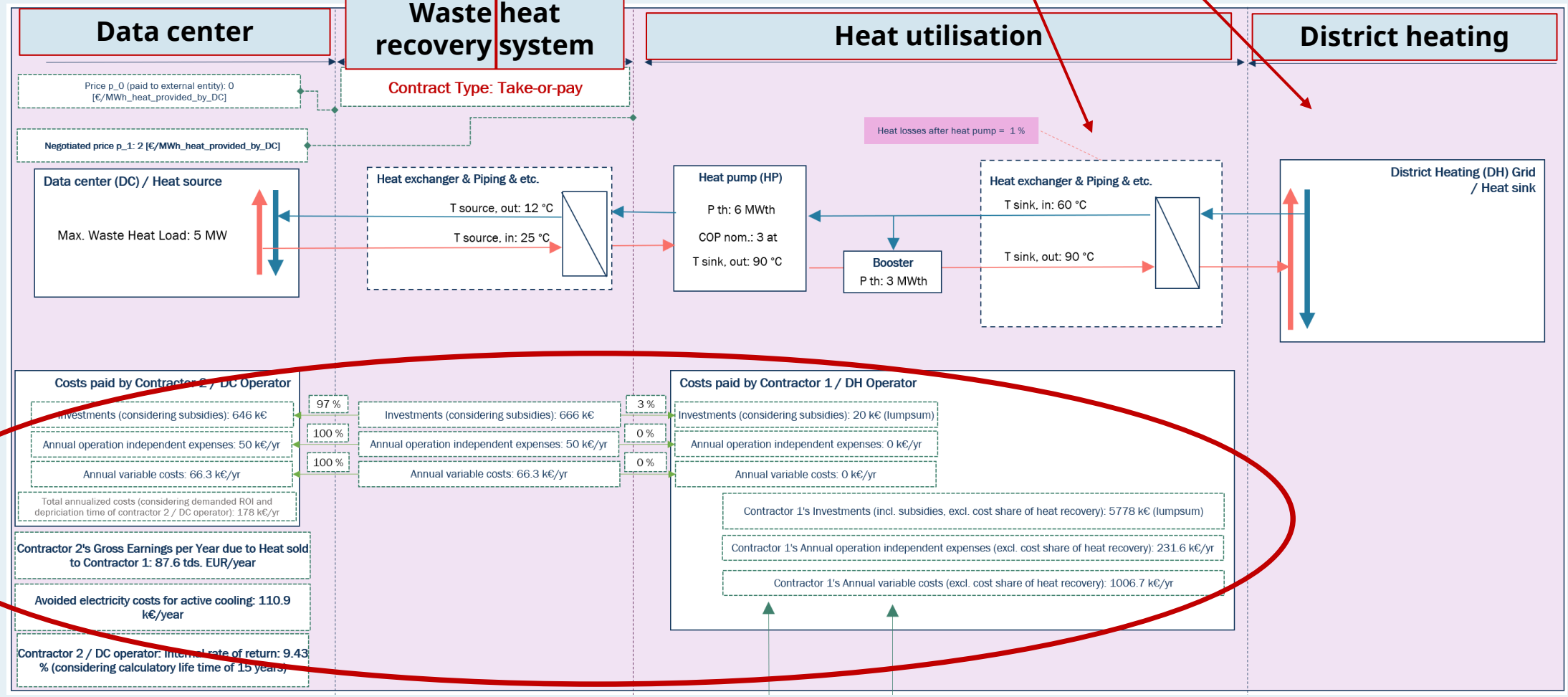
Heat pump integration modelled



Data center operator

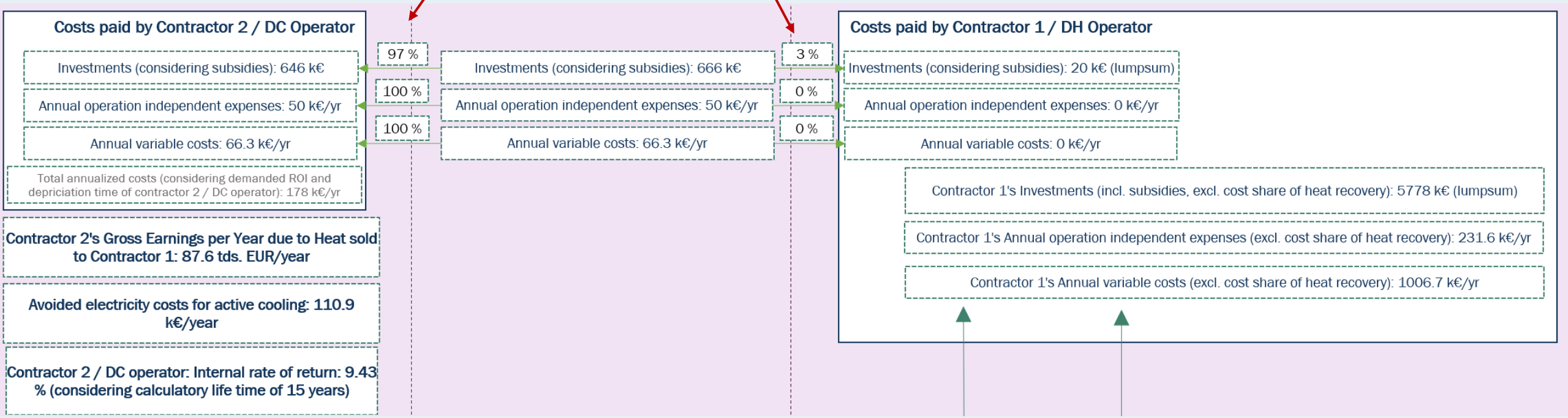
District heating operator

Overview of system



Overview of system

Share of costs for heat recovery system and resulting costs



Overview of negotiation parameters

Economics of heat recovery			
Contract type between Contractor 1 and Contractor 2	Take-or-pay	1	Select cont
Negotiated energy price p_1	[€/MWh_heat_provided_by_DC]	2.00	Price p_1 f… opera…
Energy price p_0 paid to external entity	Take-or-pay [€/MWh_waste_heat_provided]	0.00	Price p_0

Contract type and price of waste heat

Total investment			Share paid by Contractor 1 / DH operator
Investment costs: equipment, installation, heat exchangers	EUR	500,000	0%
Heat network	EUR	126,000	0%
Planning	EUR	40,000	50%
Total	EUR	666,000	

Annual operation independent O&M expenses			Share paid by Contractor 1 / DH operator
Regular annual expenses	EUR / year	50,000	0%
		0	0%
		50,000	

Spilt of costs between operators

CAPEX Investment subsidies			Share received by Contractor 1 / DH operator
Total subsidies	EUR	0	50%
Total	EUR	0	

			Share paid by Contractor 1 / DH operator
Variable O&M costs per year	EUR / year	66,314	0%
Total annual operation dependent expenses	EUR / year	66,314	

Costs paid by Contractor 2 / DC operator			Share	Total costs of Waste Heat Recovery System	Costs paid by Contractor 1 / DH operator		Share
Investments	€	646,000	97%	666,000	€	20,000	3%
Annual operation independent O&M expenses	€/year	50,000	100%	50,000	€/year	0	0%
Annual variable costs	€/year	66,314	100%	66,314	€/year	0	0%

Total annual expenses (excluding annualized investments)	€/year	116,314
Annual earnings (under negotiated price p_1)	€/year	87,600
Annual reduced electricty costs for active cooling	€/year	110,911

Resulting costs, earnings and IRR

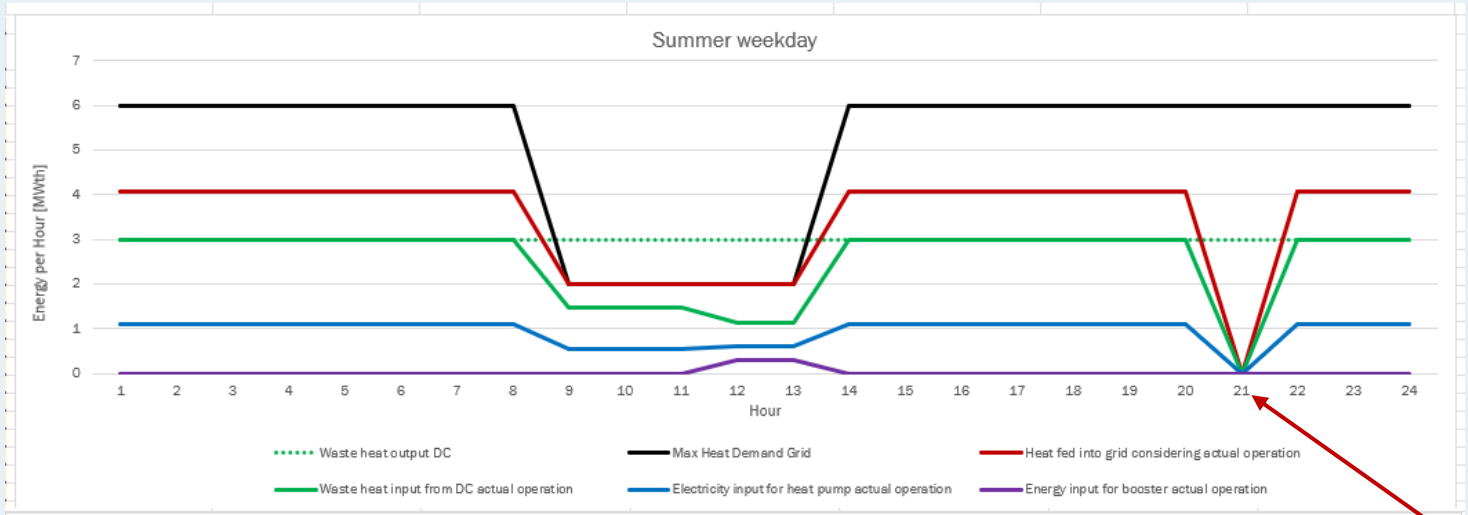
Internal Rate of Return of Contractor 2 / DC Operator	9.43 %
Considering a underlying lifetime of 15 year for Contractor 2 / DC Operator	

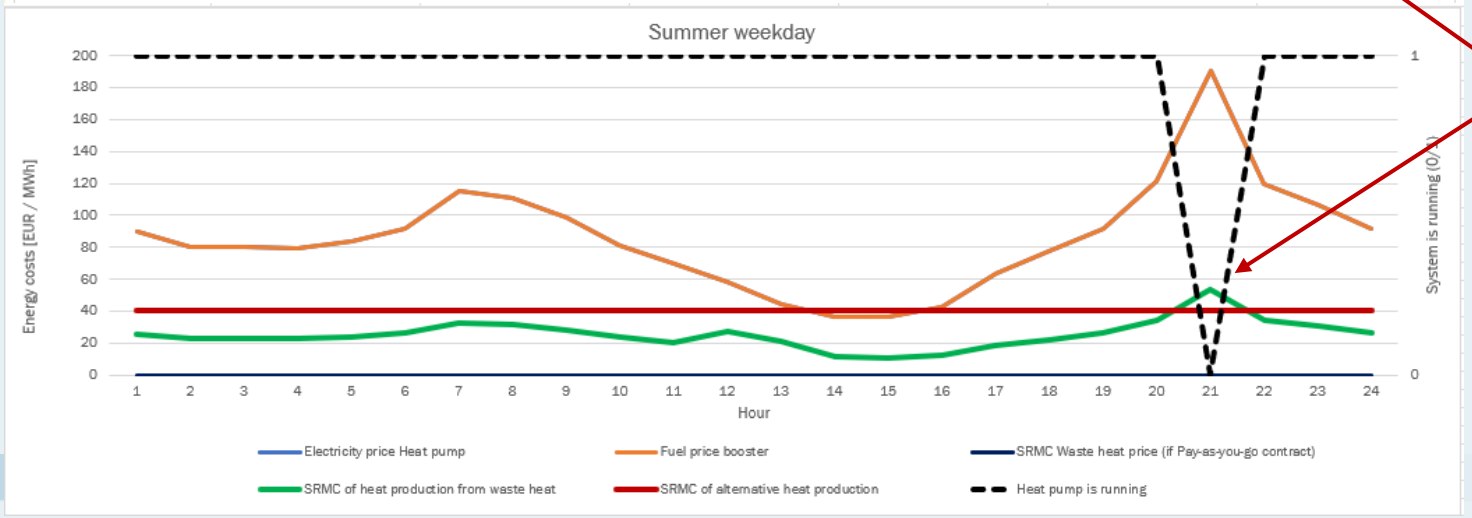
Operation at typical days – winter day

Booster running as temperature lift not possible only by HP

Temperature dependency of COP of HP

Operation at typical days – summer day





HP not running → high electricity prices lead to SRMC higher than alternative production

SRMC … short run marginal costs

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Conclusions

- **Value of** / potential price for **waste heat in district heating**:
  - Not straight forward to assess
  - Depends on a number of factors

→ **Tool** available to assess this and **ease contract negotiations**

- **Spatial and local planning**:
  - Data:
    - **Databases of DC** → important to identify options
    - Knowledge about (potential) DH areas or decentral HP areas (like in **municipal heat plans**) → relevant for grid planning
  - Planning process:
    - **Integration of planning of different infrastructures** at local, regional, national level
    - **Redundancy needs** for infrastructure?
    - Long-term and coordination is important

- **Financing**:
  - Potentially financial assistance needed (subsidies, tariffs, etc.) → will evolve over time
  - Managing the risk of loosing the waste heat source: de-risking instrument for waste heat?

Outlook

- Tool available for follower cases now, lateron will be publicly available

- **If there is interest in the tool**, please come back to me for organising a **dedicated support session**

Thank you!

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