Evaluation of strategies with multiple heat sources for the larger heat pump capacity range

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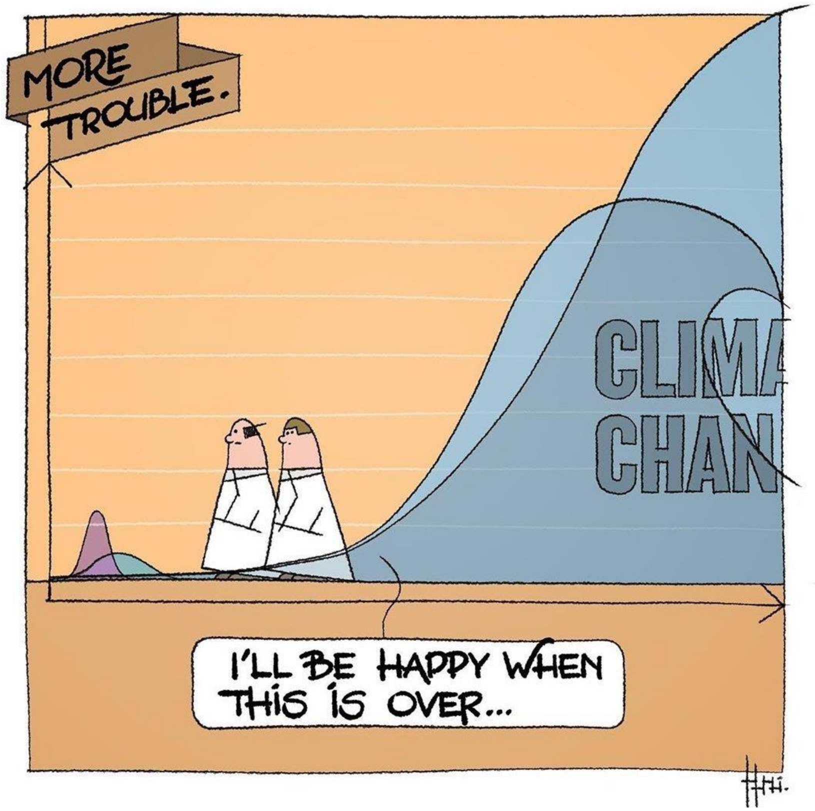
Introduction

- Phase-out of fossil fuel boilers is an urgent task for the future which enables rapid and massive CO_2-reductions
- Heat pumps are seen as future heating systems in many scenarios around the world
- However, a massive implementation also needs high quality heat sources
- In particular in retrofit projects limitation of the heat source can be a major obstacle especially for higher capacities
- Integration of multiple heat sources can mitigate or overcome limitations of individual heat sources
- Due to complementary properties of the heat sources synergies among heat source can even increase performance and cost-effectiveness



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Motivation

- **Enable HP-system instead of fossil fuel boilers**

  => overcoming of limitations, e.g.

    - Air: noise problem in the higher capacity range
    - Ground: limitation of drilling space and depth for ground probes

- **Reduction of (Investment-)cost (CAPEX)**
  - Cheaper air-source combined with less ground probes
  - Reduction of number of ground probes by regeneration with second source

- **Increase of efficiency / Reduction operating cost (OPEX)**
  - e.g. use of the favourable heat source with the better temperature conditions (ground in winter, air in summer)

Objectives

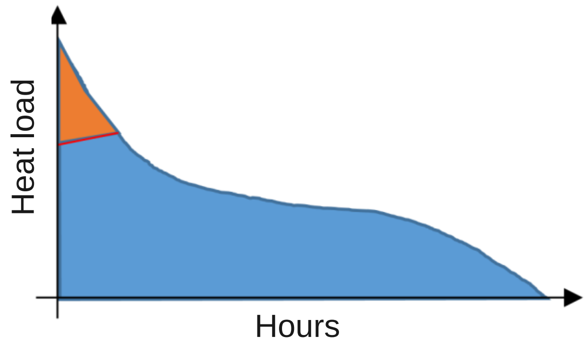
- Identification of favourable heat source integration in the higher capacity range (> 50 kW)
- Investigation of design, control and integration of the heat sources
- Evaluation of the energy and economic performance
- Recommendations for favourable heat source integration
- Primary scope are residential buildings and space heating operation
- Extension to office and retail as well as space cooling possible

Methodology

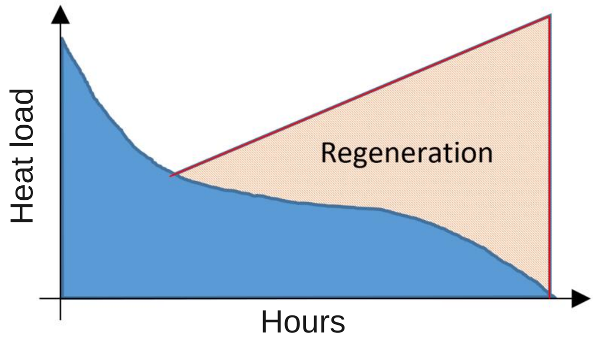
- Investigations by simulation for design heat load of 60 kW – 240 kW
- **Case studies**
  - **Existing building,** space heating (SH) demand160 kWh/(m^2yr) 80% SH, 20% domestic hot water (DHW)
  - Radiator emission system, supply temperature 55 °C
  - **New building,** SH demand 45 kWh/(m^2yr) 33% SH, 66% DHW fraction Floor heating, supply temperature 35 °C
- DHW temperature 55 °C, tapping energy acc. to SIA 2024 plus 50% losses
- Weather data Zurich SMA normal / cold year
- Ground: 2.4 W/(mK) as standard for Swiss middleland grouting 2 W/(mK), varied to 0.85 W/(mK)
- **Design to minimum probe length acc. to SIA 384/6:2021 "no decrease of average fluid temperature below -1.5 °C after 50 yrs", e.g. -3 °C / 0 °C**

Investigated strategies

- **Mitigate limitations of individual heat sources by multiple sources**
  - Limitation noise in case of outdoor air source,
    space and depths restrictions for borehole heat exchangers
- **Strategy Peak load coverage**
  - Both sources can be reduced
    (e.g. design to 50% of heat source capacity at design heat load)
  - Efficiency improvement compared to air-source-only

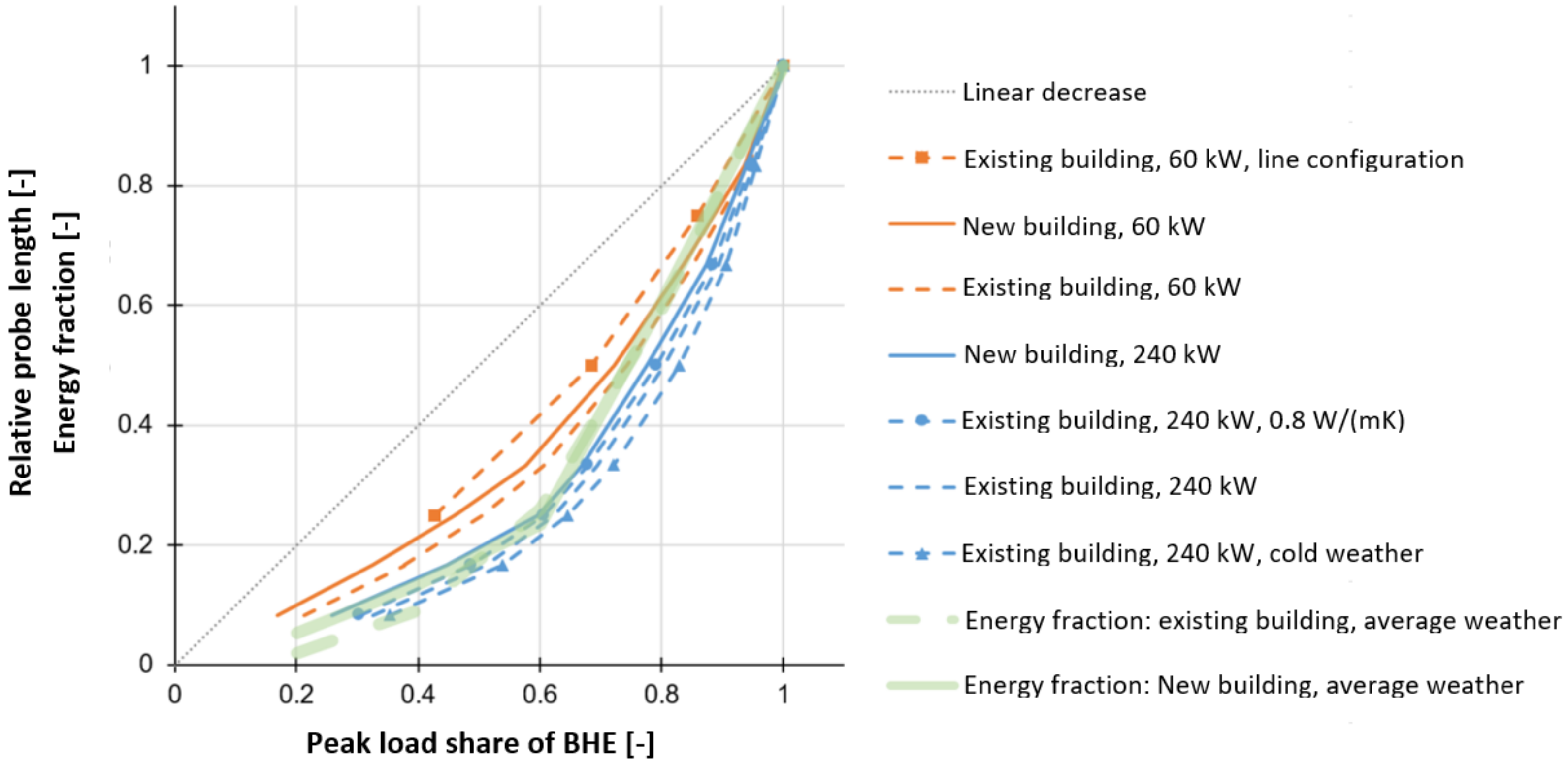


- **Strategy Regeneration**
  - Less ground probes and lower spacing in the ground probe field
  - Also direct use of regeneration source possible
  - Regeneration source can be refunded by the savings in the borehole field
- For higher capacity the strategies can also be combined



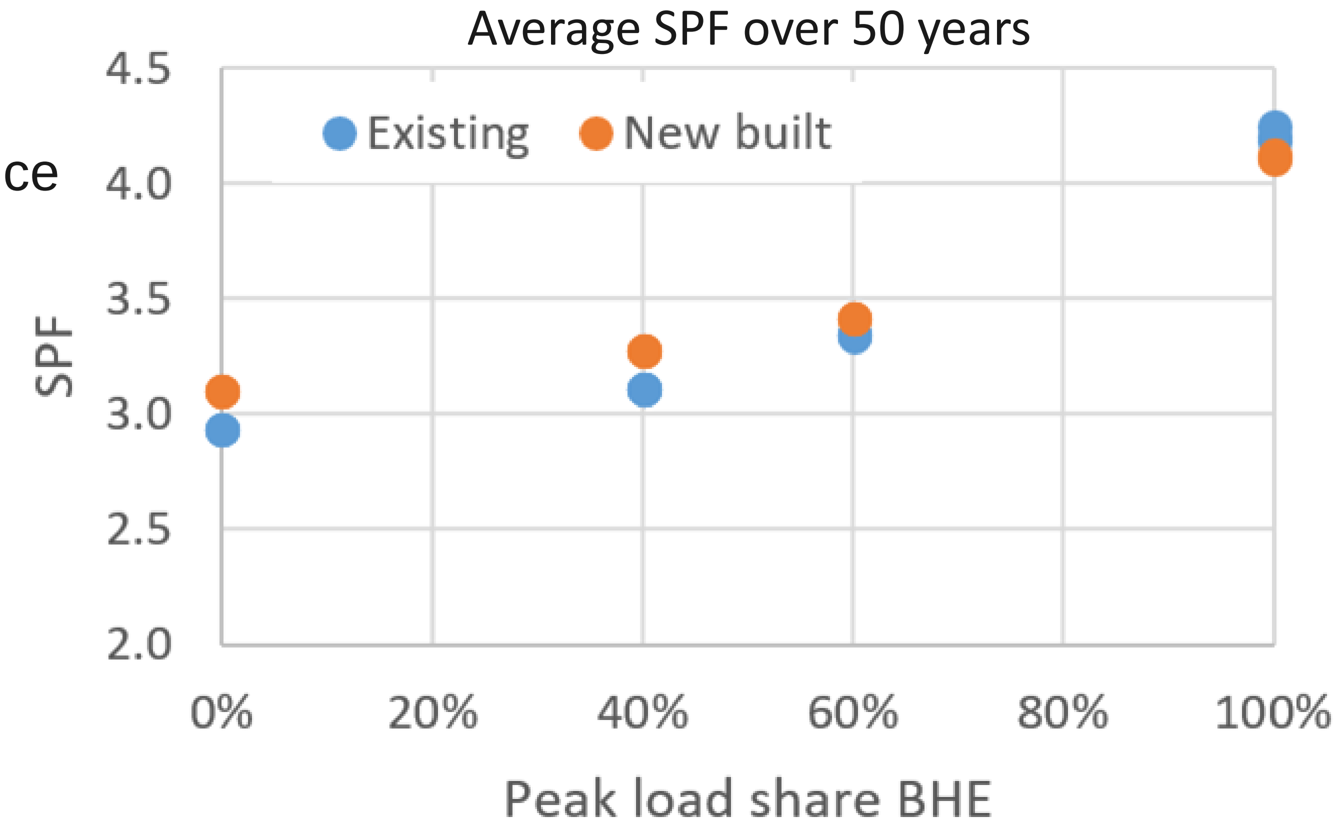
Results peak load coverage by ground source

- Disproportional savings of ground probes
- Approximation by energy fraction
- High impact: Field effect
  - System size
  - Compactness of probe field
- Lower impact
  - Properties grouting
  - Weather profile
  - Existing building or new building (DHW-tapping profile)



System performance

- SPF increasing with BHE fraction
- Existing vs. new built: hardly any difference
- 100% BHE-System:
  - SPF 4.9 in the first year
  - SPF 4.0 in the last year
- Peak load system:
  - SPF relatively constant over 50 years



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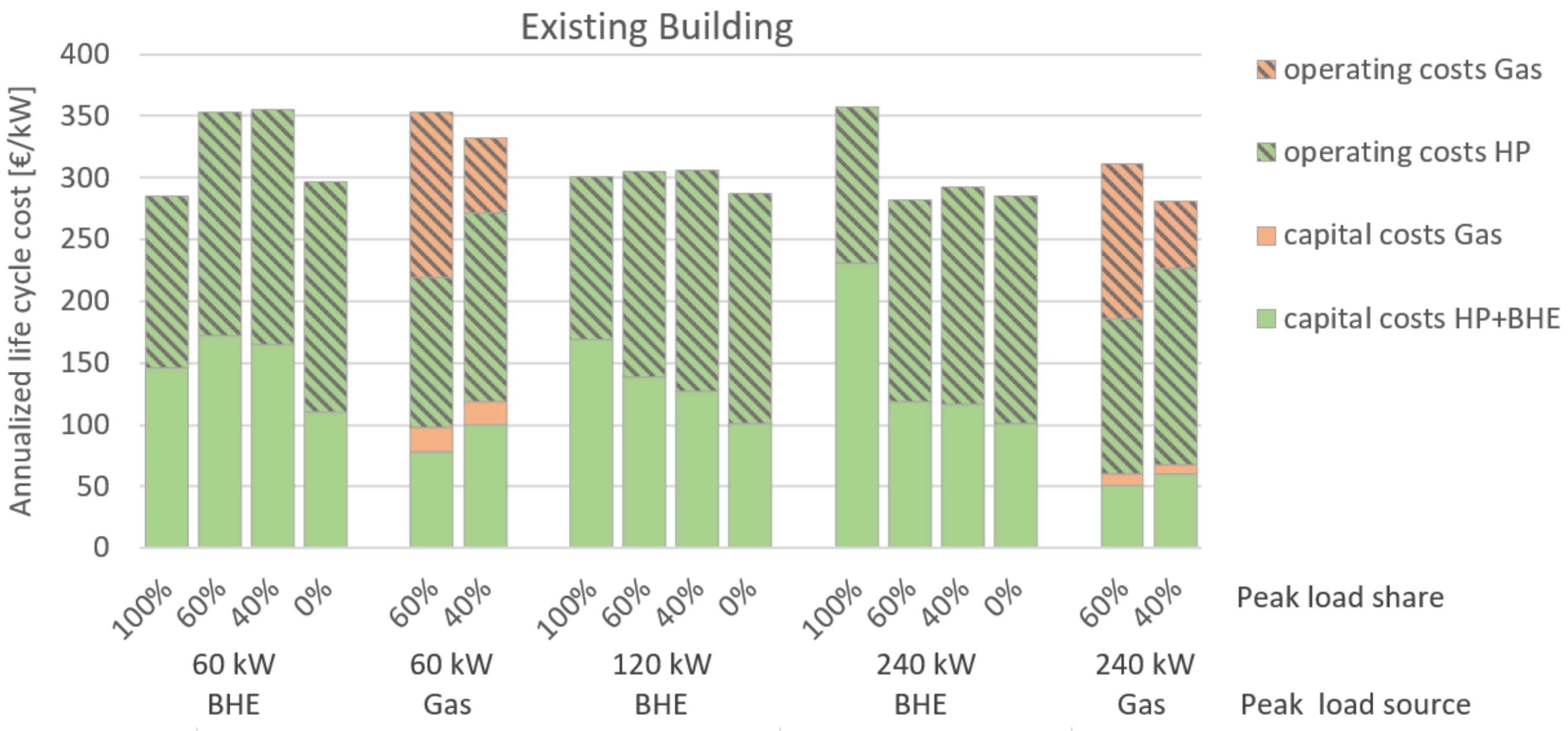
Strategy peak load coverage

Cost comparison

- **Peak load coverage can be cost-competitive**
- In midsize and larger systems cost benefits
- With additional cooling also for smaller systems (not depicted)
- To mitigate limitations moderate extra cost tolerable
- Fossil bivalent systems do not have cost benefits (at prices as of June 2022)



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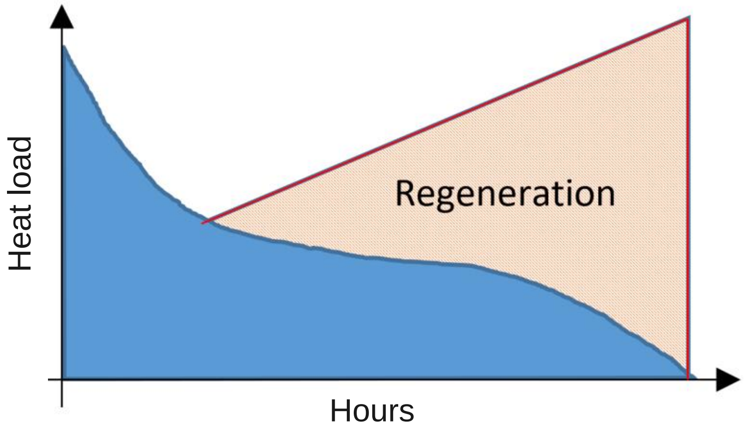
Strategy Regeneration



- **Enable the application of heat pumps with limitations of an individual heat source**
  - e.g. for space limitation by a lower number of ground probes with regeneration (ground source designed to cover design heat load)
  - Regeneration source can also be applied as second heat source => further reduction of use of primary heat source
- **Efficiency benefits.** e.g. by the use of the heat source with better temperature level
- **Cost benefits** by savings of investment cost for the ground probes to refund the regeneration source
- **Research questions (with focus on economy)**
  - How can be regenerated (favourable regeneration sources)?
  - Is it worthwhile to regenerate?
  - In which cases is regeneration necessary?
  - How much should be regenerated?

Regeneration sources

- **Solar Regeneration (PV/T, uncovered selective collector)**
  - Well introduced
  - Experience with design, implementation and cost
  - Different suppliers

  + architectural antegration, acceptance

  - limited for retrofit (roof size and condition, orientation)

- **Air heat exchanger (AHX)**
  - Less projects, less experience
  - Product variety by industry applications
  - Acceptance? (noise issue, architectural integration)
  - Less space requirement → benefit retrofitting
- **Ground water, river/lake water, district heat, waste heat**

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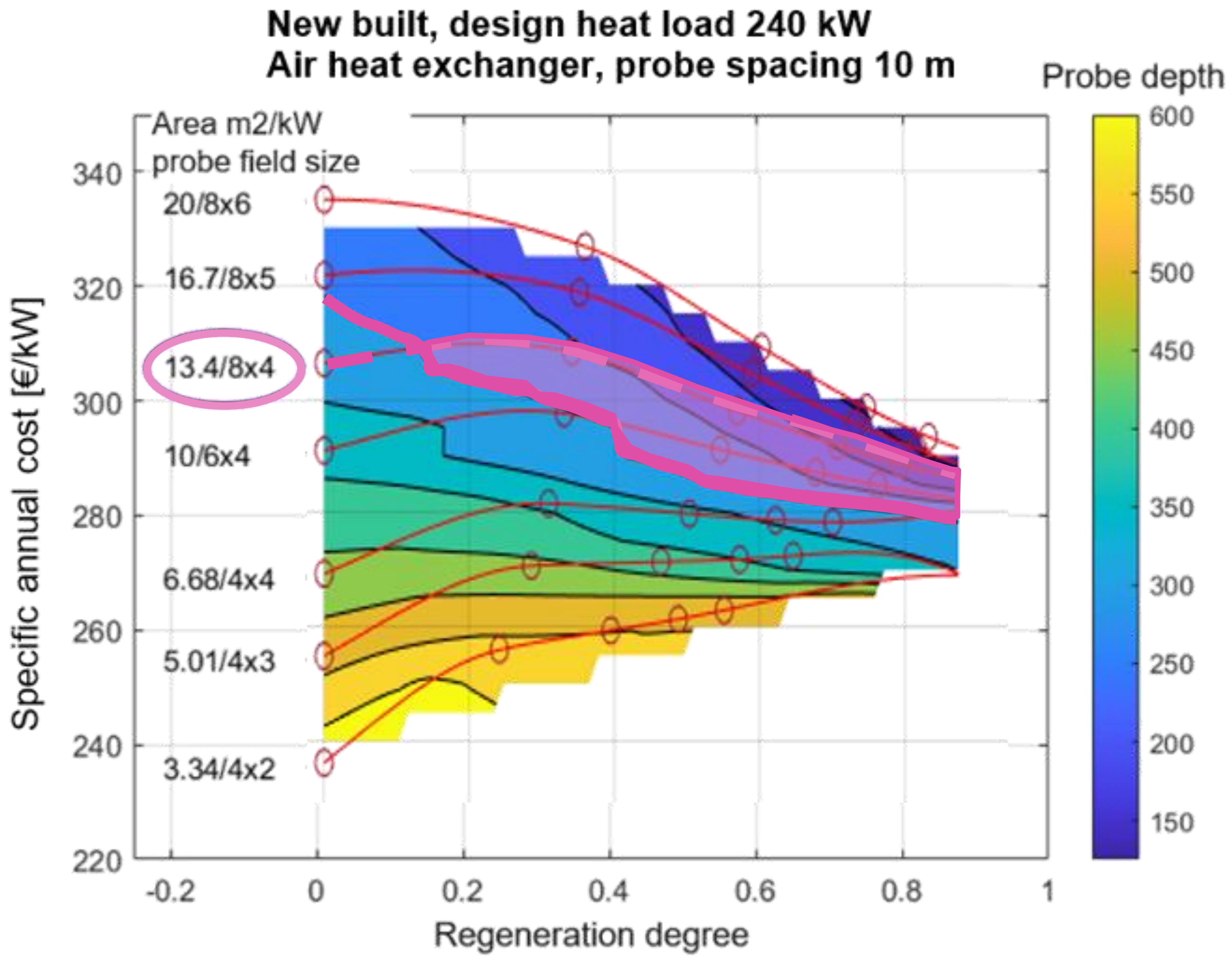
Depiction of cost optimised design

- Case study:
  - Heat load 240 kW
  - Borefield area 3200 m² (13.4 m²/kW)
    → Max. 32 probes at 10 m spacing
  - Depth limitation at ca. 300 m

    → without regeneration not possible
    (at minimum ca. 15% regeneration)

    → min. cost at 60-85% regeneration rate

    → specific annual cost 280 €/kW



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Take home messages

- **Potential for different Integration strategies**
  (peak load coverage, regeneration)
  - Also combination of strategies possible (e.g. at higher capacities)
- **Mitigation of source limitation of individual heat sources by integration**
  - Enables the application of heat pumps with higher capacity in monovalent operation
  - In particular interesting for existing buildings and retrofit projects
  - Entirely renewable alternative to fossil peak load coverage
- **Cost reduction by synergies of heat sources**
  - Integration of multiple heat sources can be equally or more cost-effective than individual heat sources
- **Efficiency potentials by synergies of heat sources**
  - Use of best source temperatures, better temperature conditions by regeneration etc.
    can increase the overall performance

P&D Project boiler replacement

- **P&D of boiler replacement in two multi-family houses**
  - Replacement boiler of 200 kW in two multi-family house (treated area ca. 4200 m^2)
  - Original concept:
    - Ground probe field at 300 m with regeneration by air-source
    - Space restriction due to steep surroundings (limited to parking lot)
    - After first drilling additionally depth restriction to 120 m due to artesic water
- **Present concept for P&D project**
  - Larger air heat exchanger and ground as peak load coverage
  - Combination peak load coverage with regeneration can limit cost
  - Validation of simulation results and extended design recommendations
  - Control strategies for multi-source integration

Quelle: A+W

Thank you for your attention

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