# DECARBONIZING DISTRICT HEATING UNDER FUTURE UNCERTAINTY

## The role of geothermal energy, seasonal storage, and reduced network temperatures

**19. Symposium Energieinnovation**

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# DeRiskDH – PROJECT OVERVIEW

**DeRiskDH:** Risk minimization in the decarbonization of urban heating networks through network temperature reduction and the use of flexibility

**Case studies**: Vienna, Graz, Linz, Salzburg, Klagenfurt

**Project duration**: January 2023 - June 2026

**Funding:** This project is supported by the funds from the Climate and Energy Fund and implemented in the framework of the RTI-initiative “Flagship Region Energy”.

https://www.ait.ac.at/en/research-topics/flexibility-business-models/projects/deriskdh

# CASE STUDY

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- **Austrian city** (~100,000 inhabitants)
- **DH network:**
  - annual heat demand: ~ **428 GWh**
  - peak heat demand: ~ **170 MW**
- Current heat supply portfolio:
  - **External heat supply from biomass CHPs** covering ~ 90% of heat demand and
  - **A natural gas boiler** for peak loads

## MOTIVATION

- External supply ends in 2039 → need assessment of alternative renewable sources for 2040 onwards
- Potential for **geothermal energy** as a heat source

# OBJECTIVES

## PRIMARY OBJECTIVE:

- **Techno-economic assessment** of integrating **geothermal energy** as an alternative to external heat supply from biomass CHPs for an Austrian **district heating system** in **2040**. Considering:
  - **Forecasted heat demand**
  - Additional/alternative **heat supply technologies**
  - **Storage** options
  - **Network temperatures**

## SECONDARY OBJECTIVE:

- Analysis of **system performance under future uncertainty** through **Monte-Carlo Simulation (MCS)**. Considering:
  - Electricity prices
  - Heat demand

# METHODOLOGY OVERVIEW

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| Technology options and boundary conditions definition | Investment optimization | MCS of operation optimization | LCOH calculations | Scenario analysis |
|---|---|---|---|---|

**Technology options and boundary conditions definition**

- System configurations
- Electricity prices
- Heat demand
- Temperatures
- Probability density functions for Monte Carlo Simulation (MCS)

**Investment optimization**

- Determine optimal component sizing and investment costs for defined scenarios:
  - Without/ with geothermal
  - Low/high electricity prices

IESopt-DHC [1]

1x

**MCS of operation optimization**

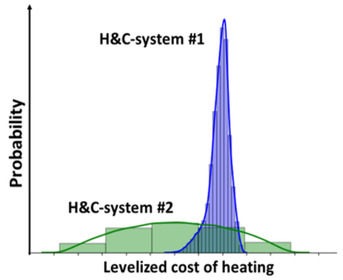
- Operation optimization considering future uncertainty through MCS
- Wide range of heat demand and electricity price scenarios considered

IESopt-DHC [1]

1000x

**LCOH calculations**

- Levelized cost of heat (LCOH) for investment runs
- Mean LCOH and standard deviation across MCS runs




Exemplary visualization

**Scenario analysis**

- Consideration of further scenarios:
  - Seasonal storage inclusion
  - Reduced network temperatures
  - Both

1. Strömer, S., Schwabeneder, D., & contributors. (2021-2024). *IESopt: Integrated Energy System Optimization [Software]. AIT Austrian Institute of Technology GmbH.* https://github.com/ait-energy/IESopt

# SYSTEM CONFIGURATION FOR 2040

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**Existing technologies in 2040:**

- Baseload biomass boiler (10 MW)
- Biomethane boiler (120 MW)

**Investment options for 2040:**

- Biomass, biomethane or electric **boilers**
- Biomass or biomethane **CHPs**
- Air-sourced **heat pump (HP)**
- Short term **storage** (hot water tank)

\+ **Investment in deep geothermal** with option to invest in a heat pump to further reduce reinjection flow

1. Reference system

2. Reference system
**+ Deep geothermal**

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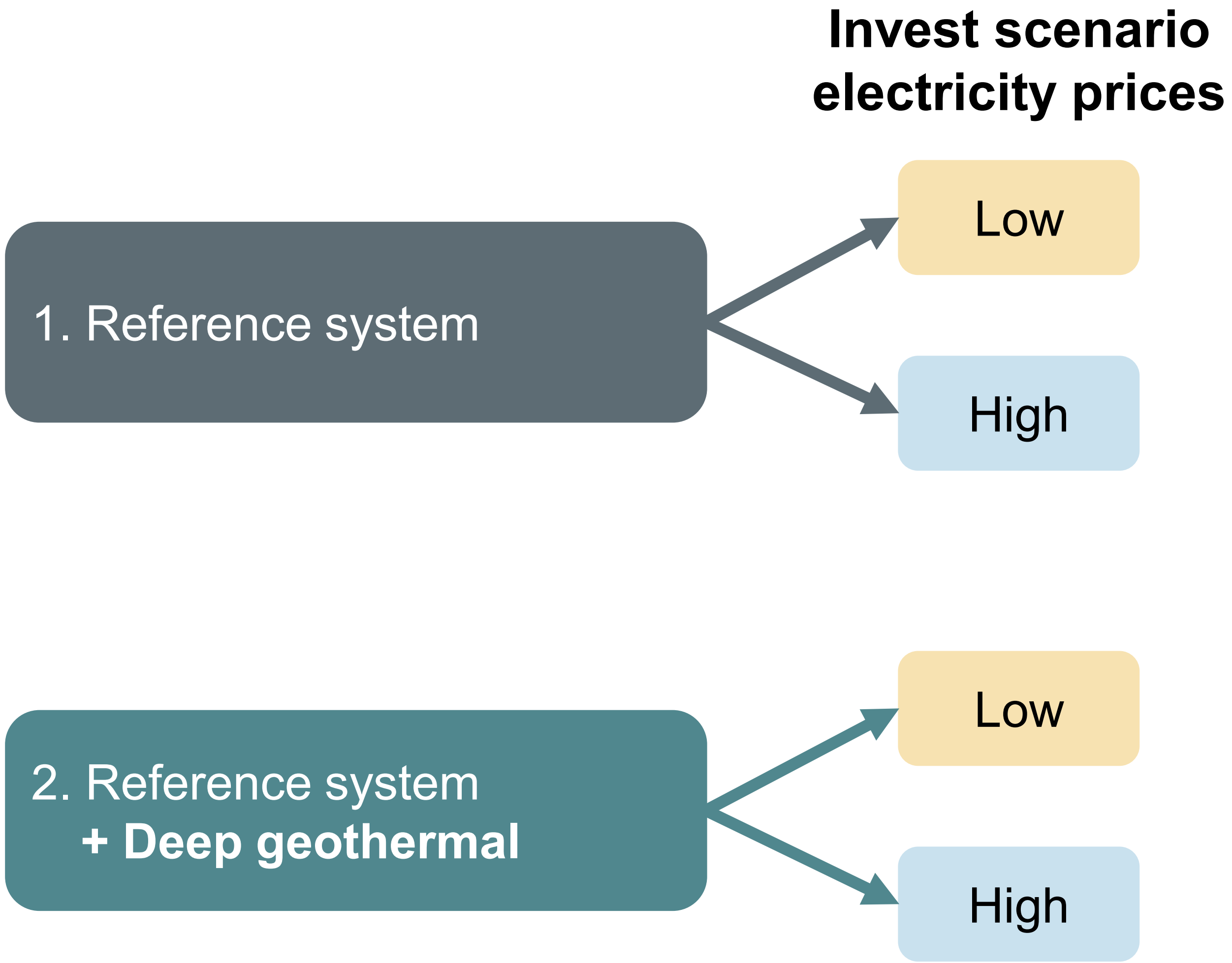
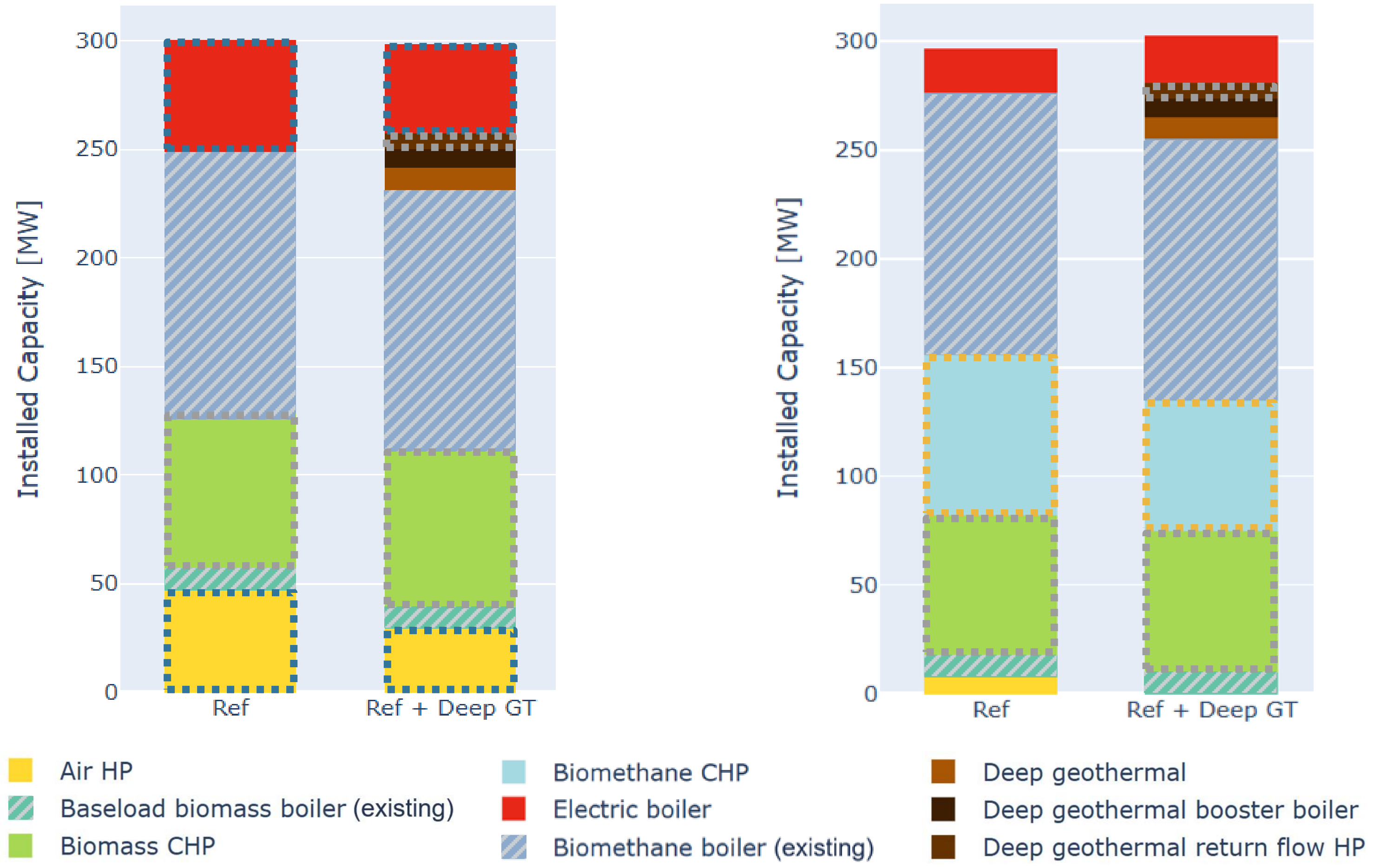


# INVEST SCENARIO: INSTALLED CAPACITY

**LOW** electricity price

**HIGH** electricity price




**Low** electricity prices →
**air HP** and **electric boilers**
**+ ~267 MWh storage** capacity

**High** electricity prices →
**biomethane CHP**
**+ 372 MWh storage** capacity

**Both** :

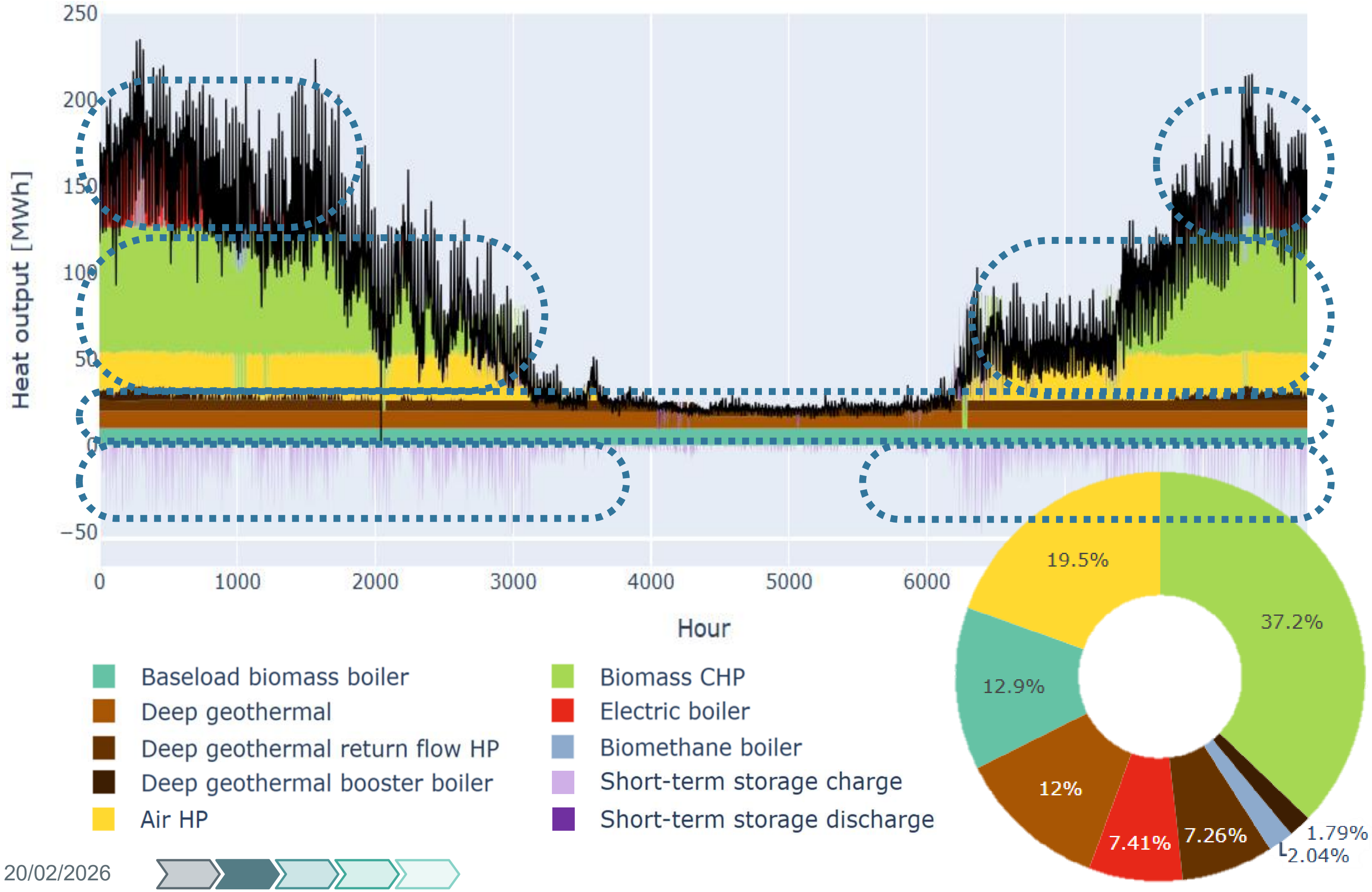
→ **Biomass CHP**

→ **Return flow HP** for **deep geothermal**

→ **Similar technology share** for Reference and Ref + Deep GT

# INVEST SCENARIO: HEAT OUTPUT PER SOURCE

**LOW** electricity price




**Peak load:** electric & biomethane boilers

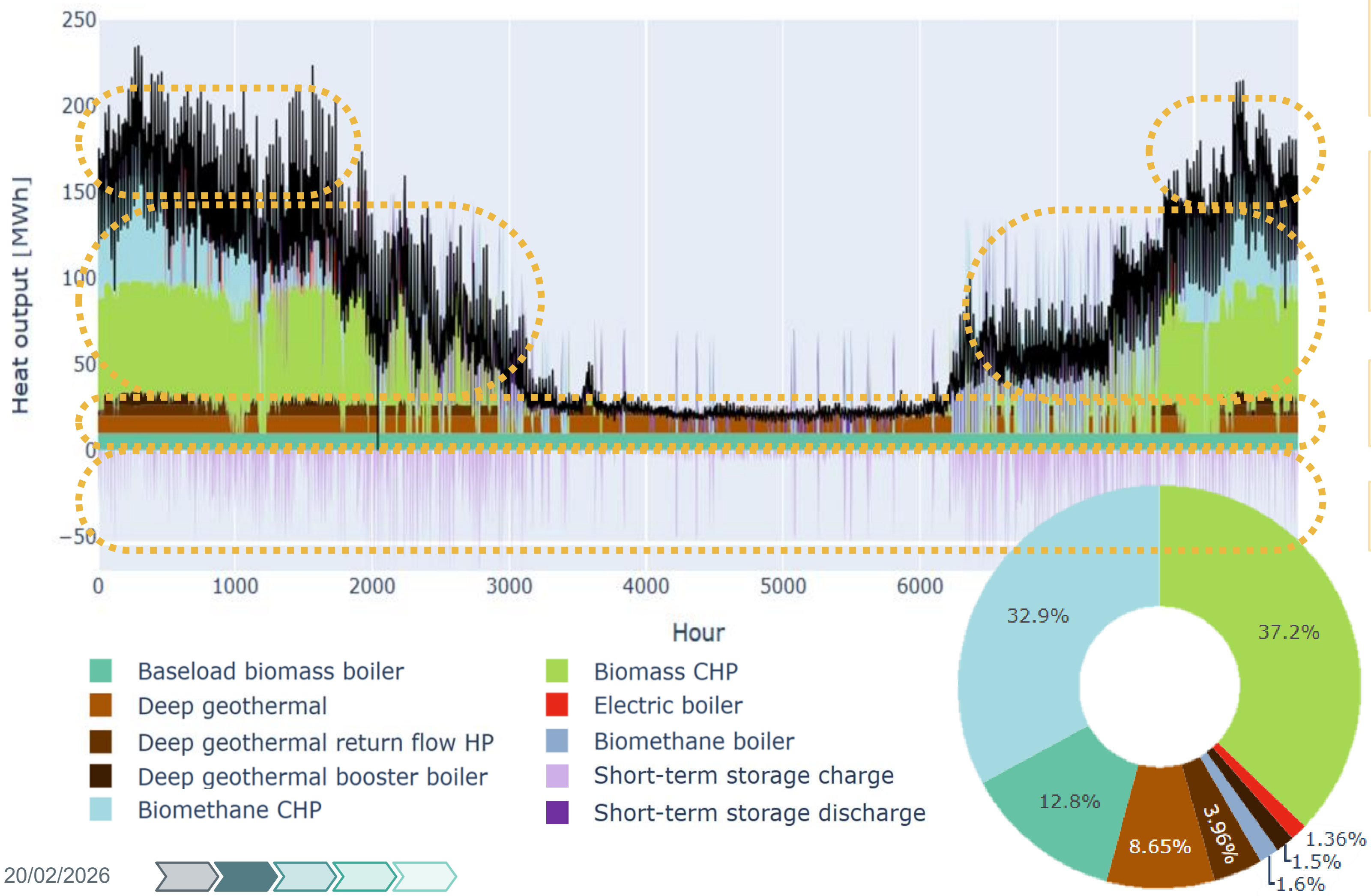
**Medium load:** biomass CHP & air HP due to low biomass and electricity cost

**Baseload:** biomass boiler & deep geothermal

**Storage** used in winter

# INVEST SCENARIO: HEAT OUTPUT PER SOURCE

**HIGH** electricity price




**Peak load:** electric & biomethane boilers, less than in low electricity price scenario

**Majority load:** biomass & biomethane CHPs due to high electricity revenues

**Baseload:** biomass boiler & deep geothermal

**Storage** use increased, but still mainly in winter

# INVEST SCENARIO: LCOH

**Geothermal**

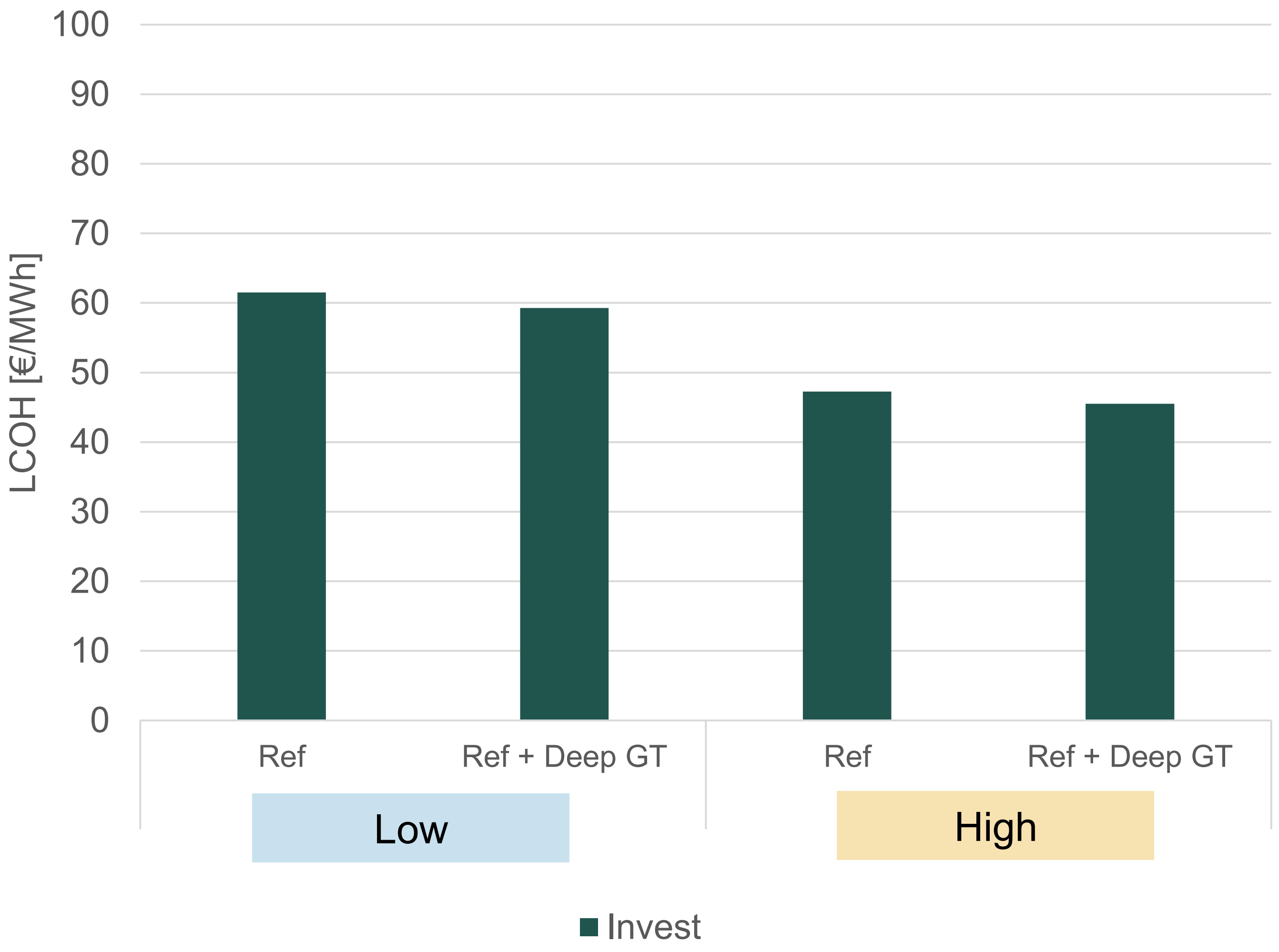
- Deep geothermal reduces LCOH

**Investments under LOW electricity prices**

- Higher LCOH in the invest run

**Investments under HIGH electricity prices**

- Low LCOH in the invest run due to high profits from CHPs



# LCOH UNDER FUTURE UNCERTAINTY

**Geothermal**

- Deep geothermal reduces LCOH

**Investments under LOW electricity prices**

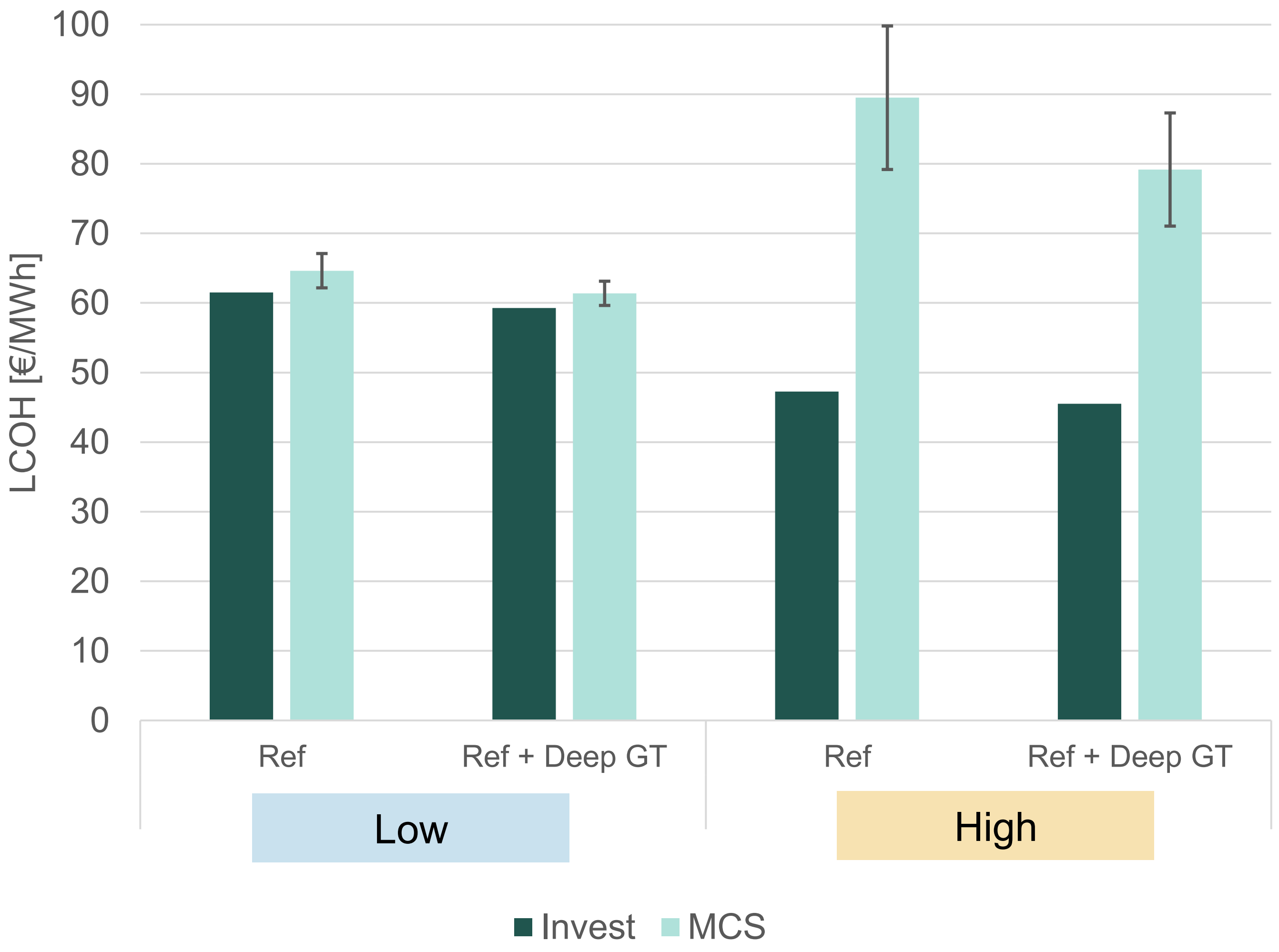
- Higher LCOH in the invest run
- But more robust under future uncertainty

**Investments under HIGH electricity prices**

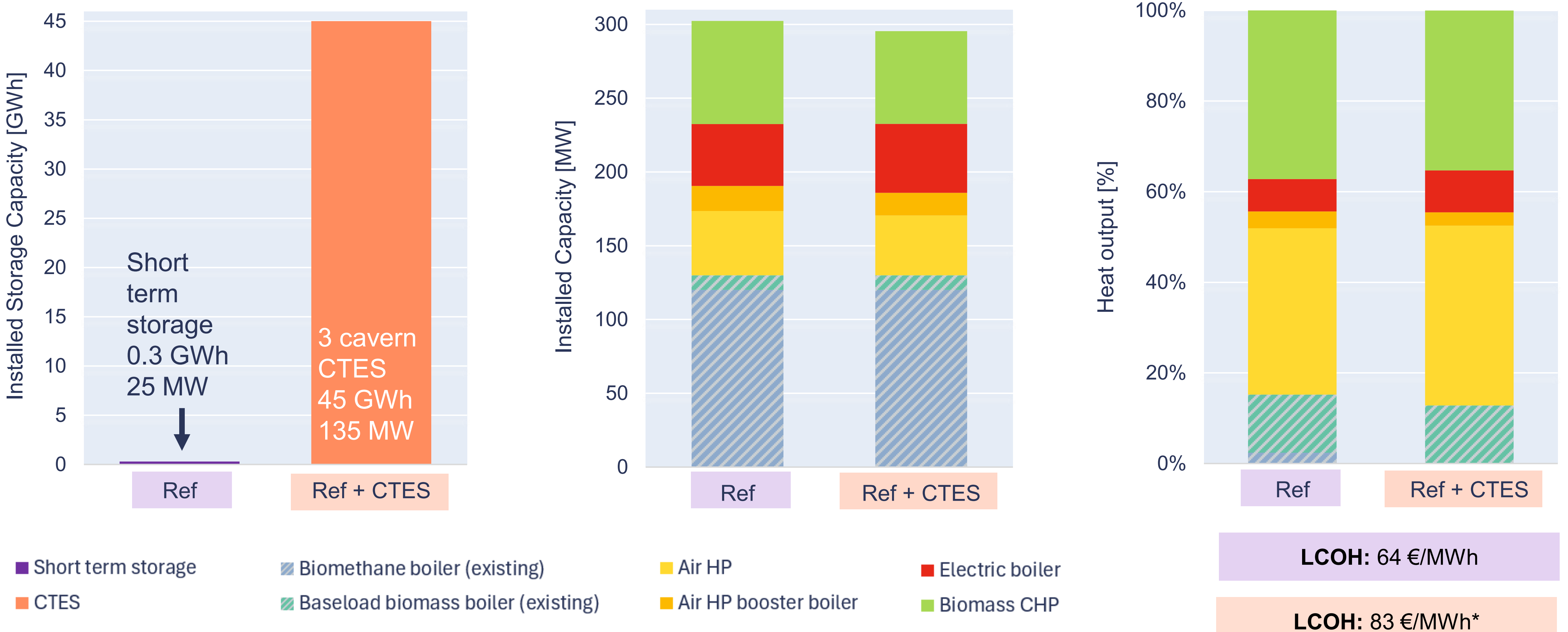
- Low LCOH in the invest run due to high profits from CHPs
- But less robust under future uncertainty

→ Price forecasts in invest run are important

→ *Note: this is influenced by electricity scenario probabilities input to MCS*



# 3 CAVERN SEASONAL STORAGE INCLUSION
## REFERENCE, LOW EL. PRICES




**LCOH:** 64 €/MWh

**LCOH:** 83 €/MWh*

**Note: it was assumed the CTES storage temperature was the district heating supply temperature though in reality it would be higher. This results in higher investment costs per MWh storage capacity, leading to a higher LCOH.*

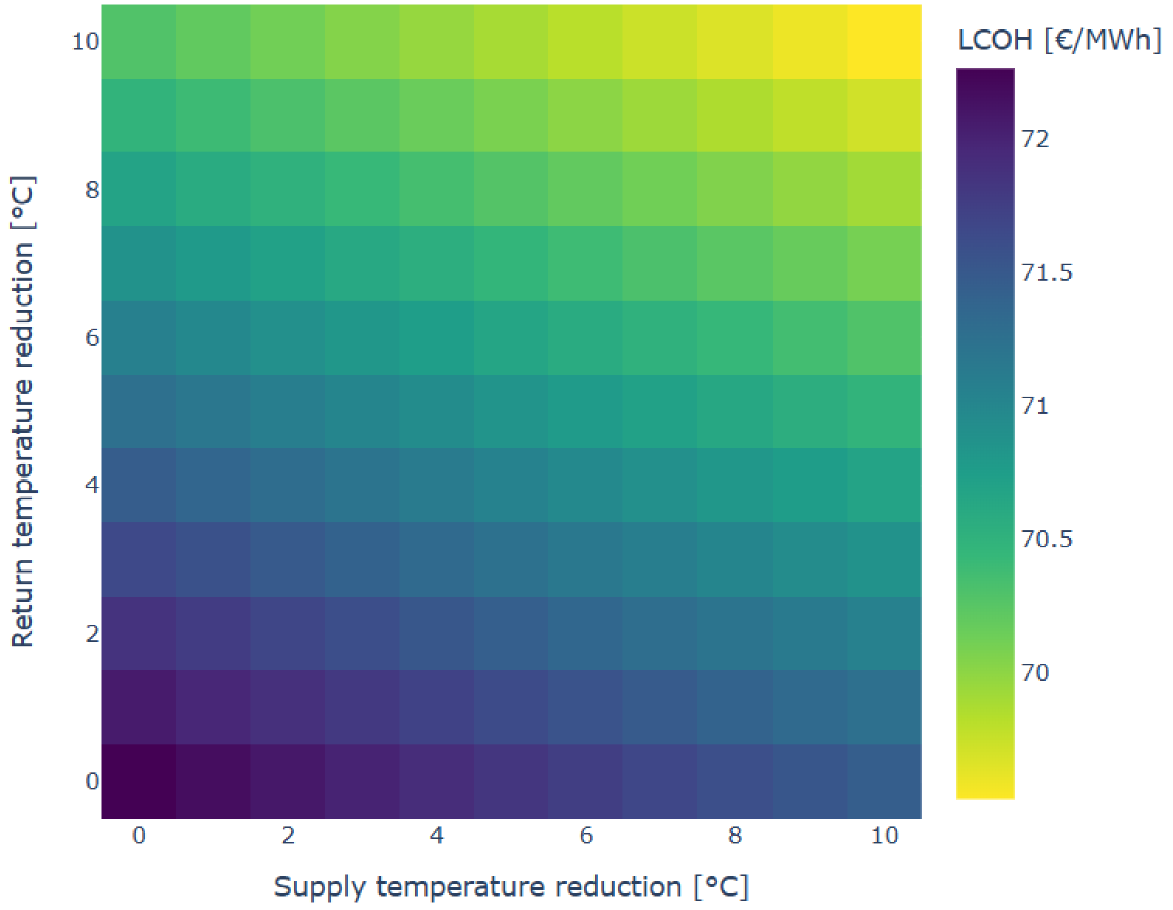
→ Considering 140 °C storage temperature : 69.4 €/MWh*

# TEMPERATURE REDUCTION
## REFERENCE, LOW EL. PRICES

Reduced **supply** and/or **return temperatures** lead to **lower LCOH** due to:

- Reduced network losses
- Improved heat pump performance
- Increased temperature range for storage to operate at

Reducing the supply and return temperature by **10°C** saves **2.73 €/MWh**, amounting to **1.87 M€/year.**



# KEY FINDINGS & OUTLOOK

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## Key findings

- **Deep geothermal** is used as **baseload heat source** and (slightly) **lowers LCOH** compared to the reference scenario
- It is economic to invest in a **return flow heat pump** to reduce reinjection flow temperatures
- **Electricity prices** strongly influence **investment** and **operation optimization**
  - Investments expecting low electricity prices are **robust** across a range of electricity price and heat demand scenarios in the MCS
  - **CHP investments** can **lower LCOH** under high electricity but are **less robust** under future uncertainty
- **Seasonal storages** increase output from **power to heat** units and eliminate the need for the biomethane boiler, but lead **to higher LCOH** due to high investment costs
- **Reduced network temperatures** lead to **reduced LCOH** per heat consumption

## Outlook

- Consideration of **further uncertainties** (e.g., geothermal temperatures and capacity)
- Applying MCS to **reduced network temperature** and **seasonal storage scenarios**
- **Improve seasonal storage model** by considering high temperature of storage

# THANK YOU!

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