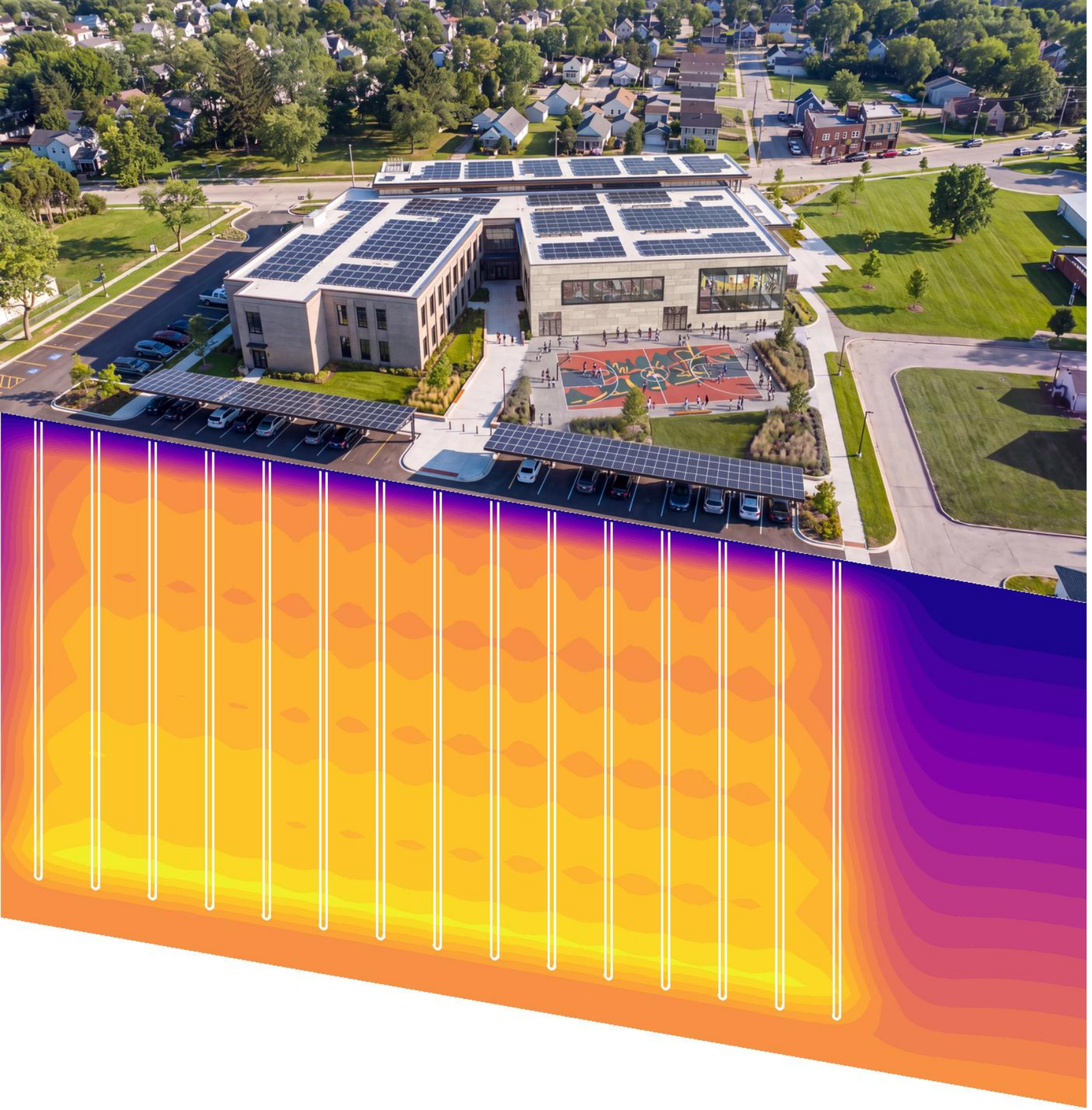


Extracting Value from Modelica: De-Risking of GSHP Systems

Victor Braciszewski

SMITHGROUP
Design a Better Future

Lone Meertens

KU LEUVEN
THERMAL SYSTEMS SIMULATION
University of Leuven Belgium

Lieve Helsen

Energy Ville

INTERNATIONAL COLLABORATION

INDUSTRY + RESEARCH





ACKNOWLEDGMENTS

“Unleashing the power of a committed few” *Wangari Maathai*

- **IBPSA Modelica Working Group**
- **Modelon**
- **Massimo Cimmino – Polytechnique Montreal**
- **Michael Wetter – DOE Lawrence Berkeley National Lab (LBNL)**
- **National Lab of the Rockies**
- **SEEDs Project – Horizon Europe Programme, European Union**

SMITHGROUP

Architecture + Engineering Design

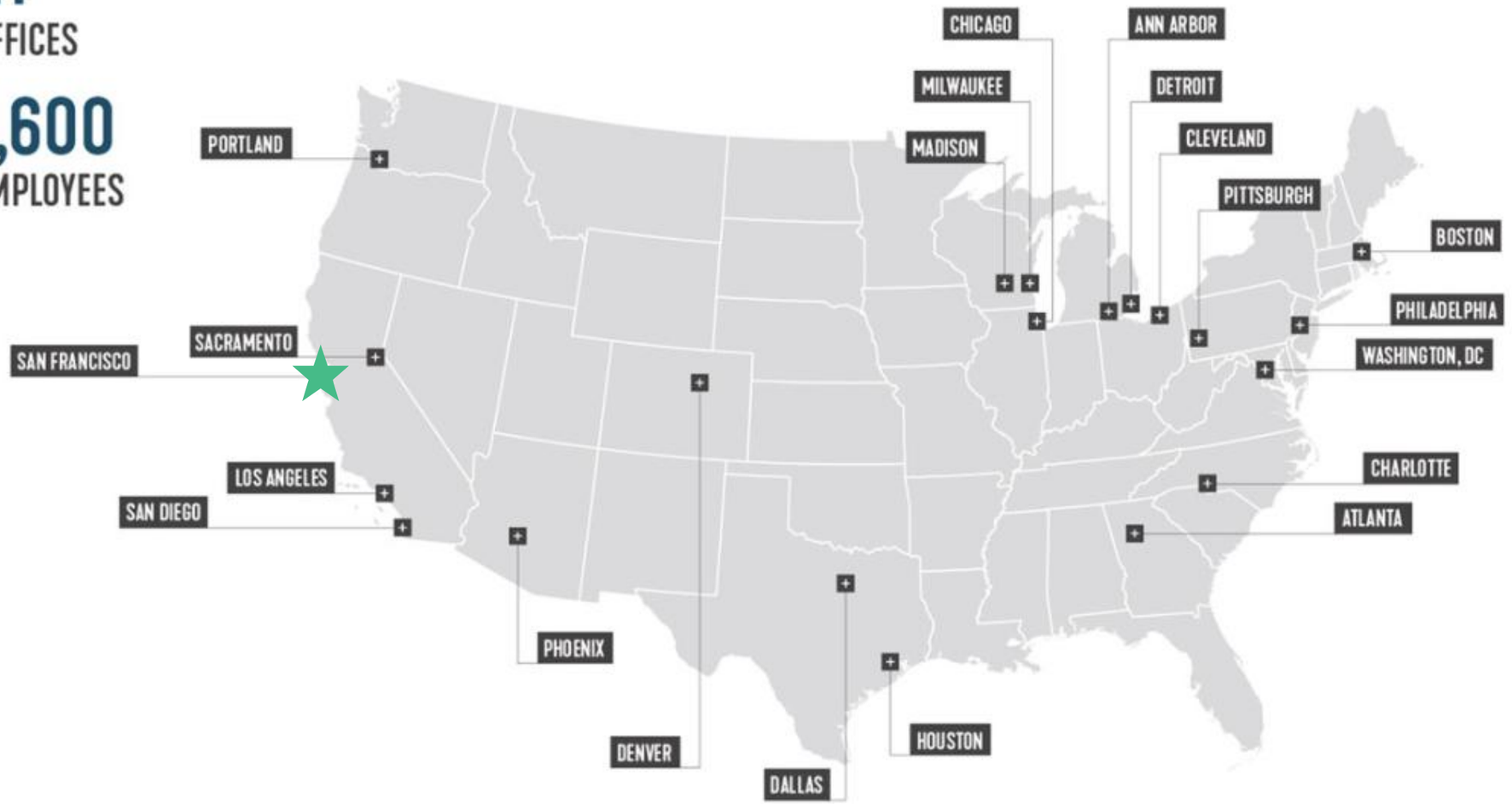
170+
Years Experience Planning & Designing High-Performance Projects

TOP 5
Architecture & Engineering Firms, *BD+C 2022*

AIA 2030
MEP 2040
SEI 2050

21
OFFICES

1,600
EMPLOYEES



KU LEUVEN THERMAL SYSTEMS SIMULATION SMITHGROUP

IMPACT

INTEGRATED

MULTIDISCIPLINARY

PERFORMANCE ANALYTICS

(Positive) CLIMATE IMPACT TEAM

KU LEUVEN THERMAL SYSTEMS SIMULATION SMITHGROUP

OUTLINE

1. Intro: Geothermal Technology
2. Overview of Modelica Buildings Library Development
3. Applied Research:

Case Study: Racine Lincoln King Community Center



TECHNOLOGY: GEOTHERMAL OVERVIEW

DRILL DEPTH

SHALLOW
GROUND SOURCE HEAT PUMP

MIDDLE
DIRECT USE HEATING

DEEP
ELECTRIC POWER GENERATION

GROUND HEAT EXCHANGER

SINGLE U-BEND



LOWEST RISK
+
EASIEST TO DEPLOY

Ground Source Heat Pump Benefits….

LESS DEMAND ON GRID (even in cold climates!)

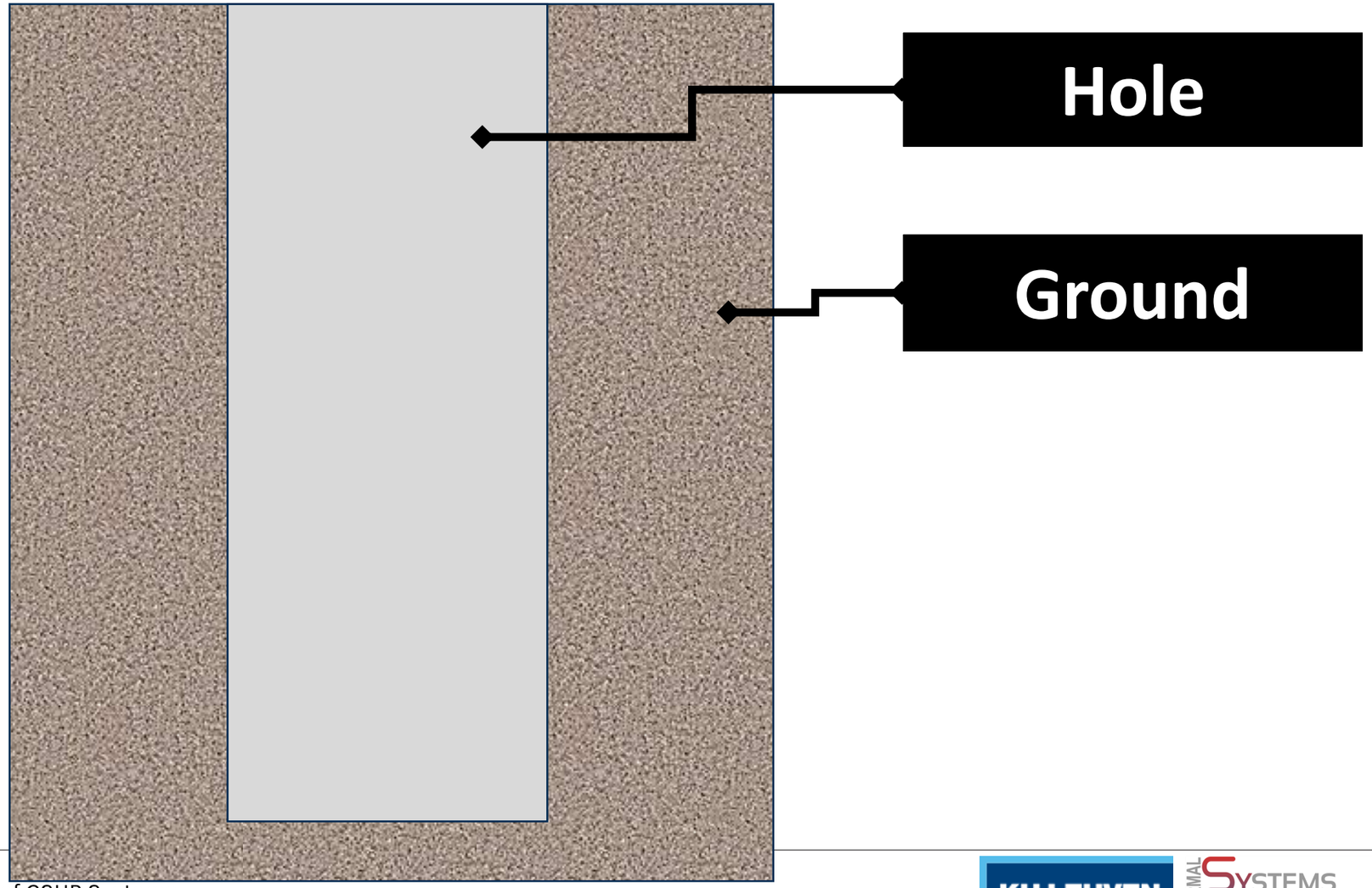
NO ON SITE EMISSIONS

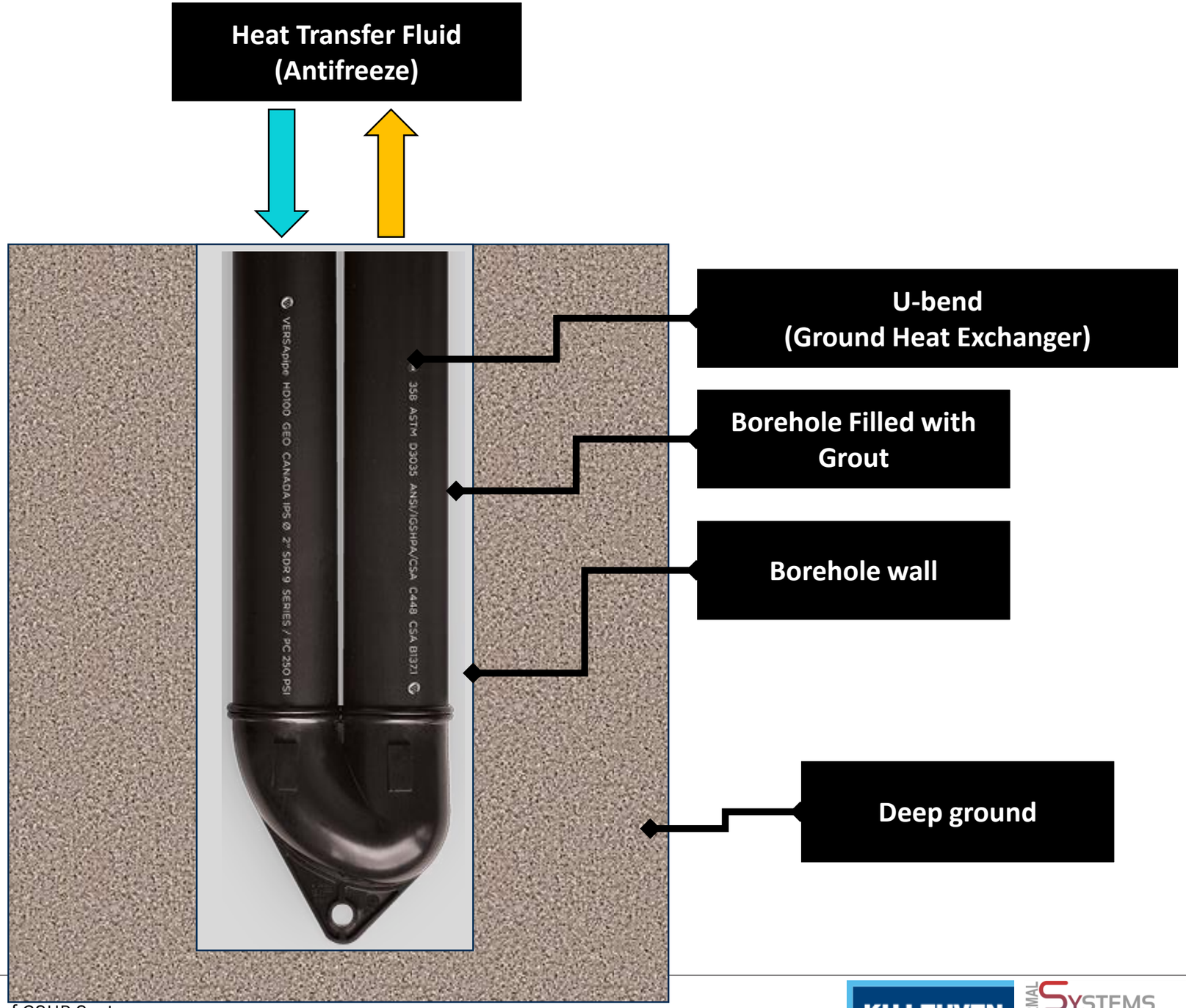
NO WATER CONSUMPTION

NO SITE ACOUSTICS

LASTS FOREVER

THE HUMBLE TECHNOLOGY




Heat Transfer Fluid
(Antifreeze)
U-bend
(Ground Heat Exchanger)
Borehole Filled with
Grout
Borehole wall
Deep ground
VERSAPIPE HDPE 100 GEO CANADA IPS Ø 2" SDR 9 SERIES / PC 250 PSI
358 ASTM D3035 ANSI/IGSHPA/CSA C448 CSA B137.1

How do you stay (GSH)PUMPED UP?

- Financial Incentive Stacking
- Sustainability Goals
- Resiliency Analysis

How do you stay (GSH)PUMPED UP?

- Financial Incentive Stacking > 50% OFF ON YOUR G$HP YTEM!
- Sustainability Goals > LEED, NET ZERO
- Resiliency Analysis > EXTREME WEATHER

GEOSYSTEMS ARE MULTI-DOMAIN

FIRST….

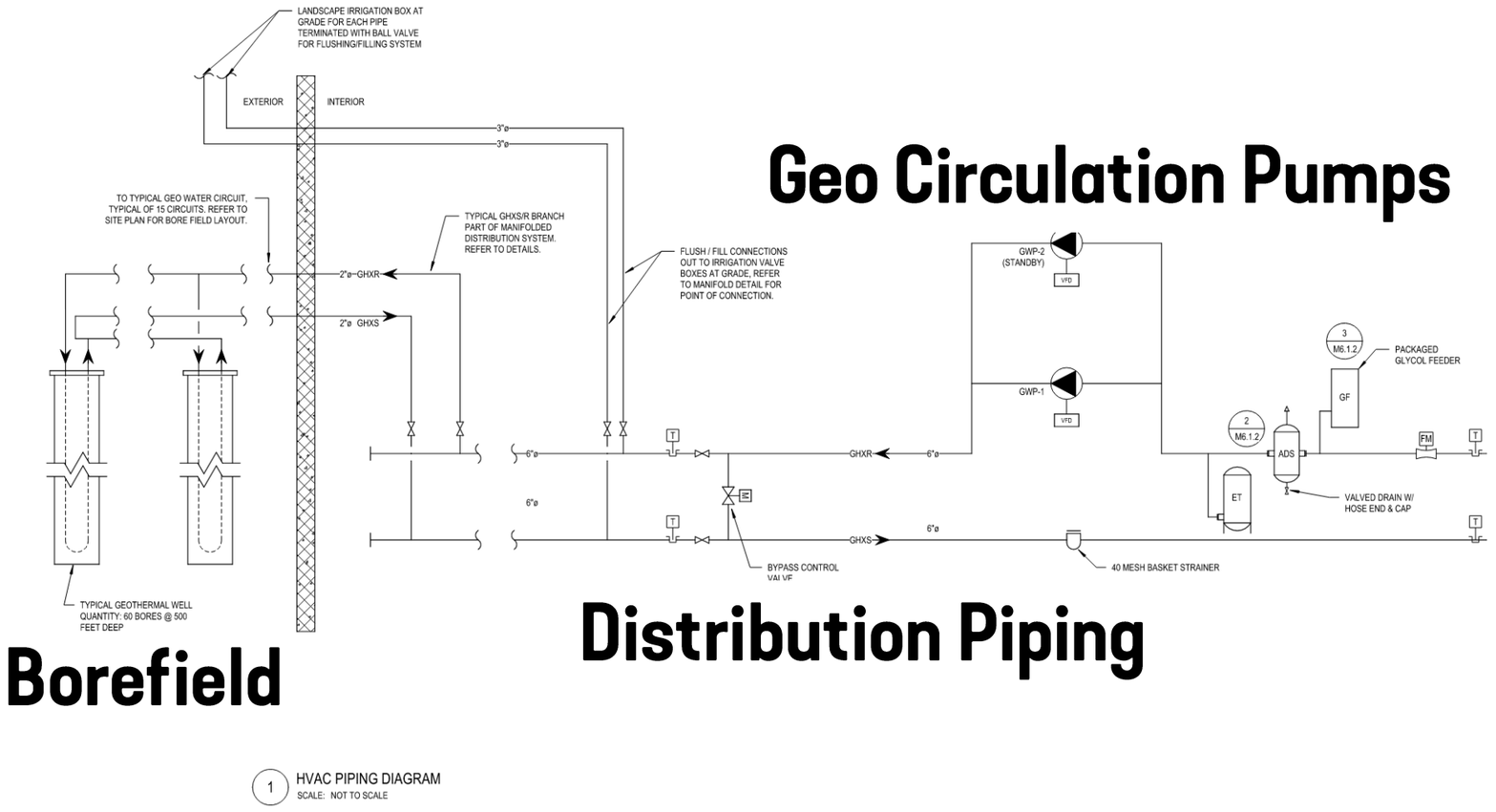
THERMAL (BUILDING LOADS + BOREFIELD SIZING)

BUT DON’T FORGET….

HYDRAULICS + CONTROLS + ELECTRICAL

SCOPE: MECHANICAL SCHEMATIC

Geo System Volume
10,000 gal



Geo Circulation Pumps

Ground Source Heat Pumps

Distribution Piping

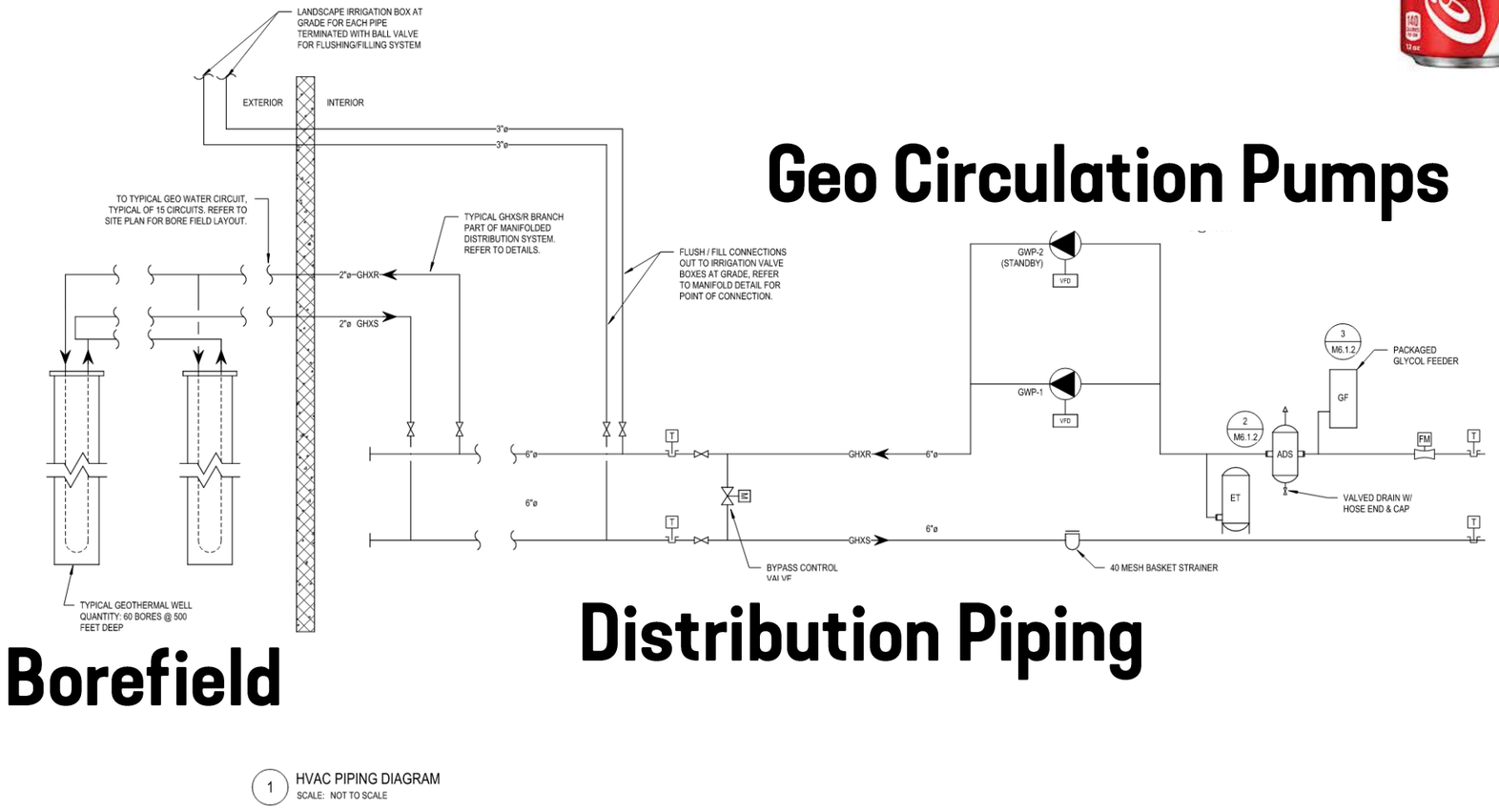
Borefield

SCOPE: MECHANICAL SCHEMATIC

Geo System Volume

100,000 cans





Geo Circulation Pumps

Ground Source Heat Pumps

Borefield

Distribution Piping

LEGACY DESIGN SILOS

Tool #1 – Building Load Modeling (Thermal Only)

Tool #2 – Simple Geo Sizing (Thermal Only)

Tool #3 – System Pressure Drop (Hydraulic Only)

Tool #4 – Annual Energy Modeling (Thermal Only)

Tool #5 – Controls Verification???

LEGACY DESIGN SILOS

Tool #1, 2 ,3, 4, 5, etc.

Missing Capability: Multi-Domain Integration

How do individual domain decisions impact the interconnected system?

DEVELOPMENT TOOLKIT

MODELING LANGUAGE



MODELING ENVIRONMENTS



Modelon Impact



LIBRARIES

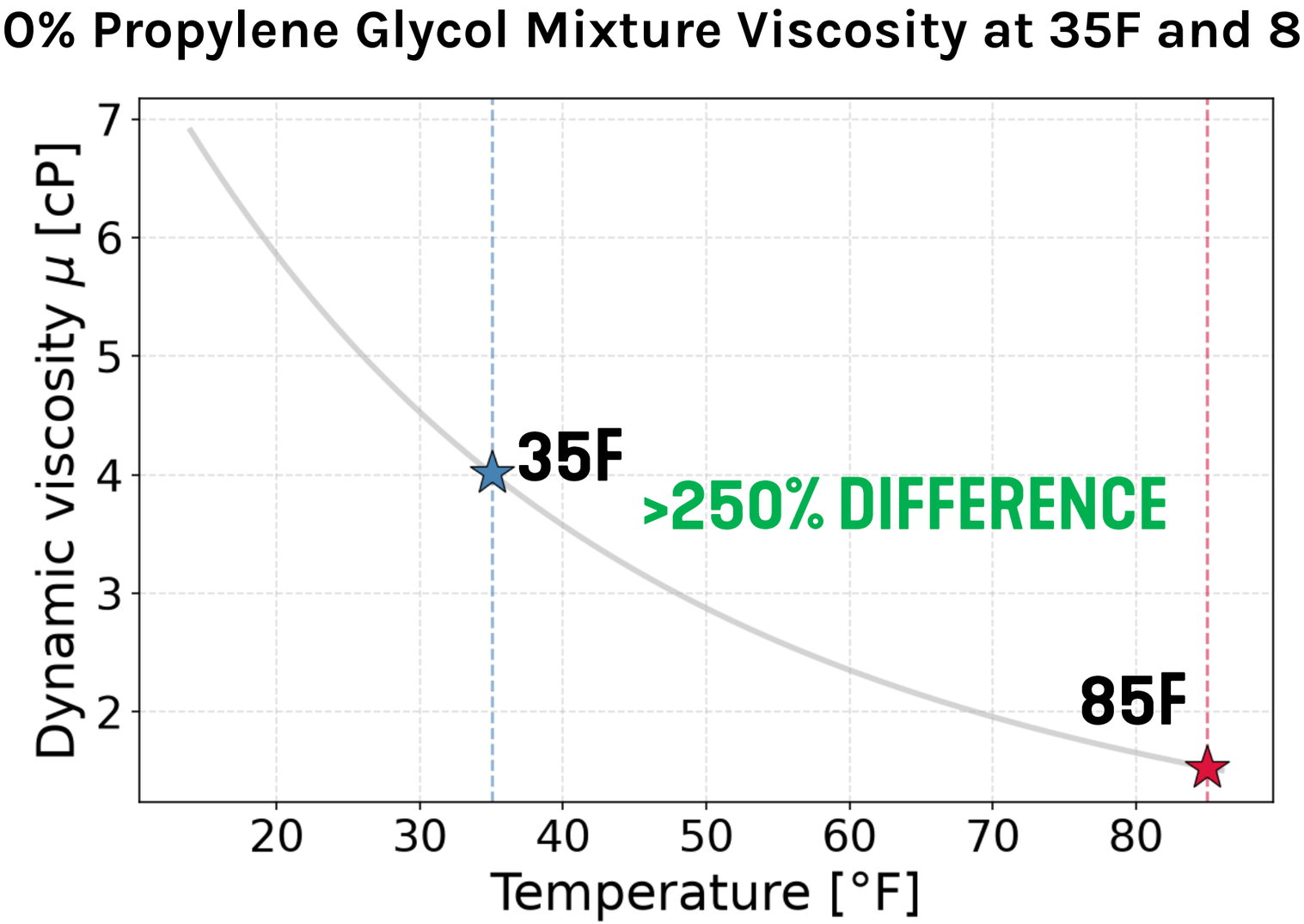


DEV: MODELICA BUILDINGS LIBRARY

Goals

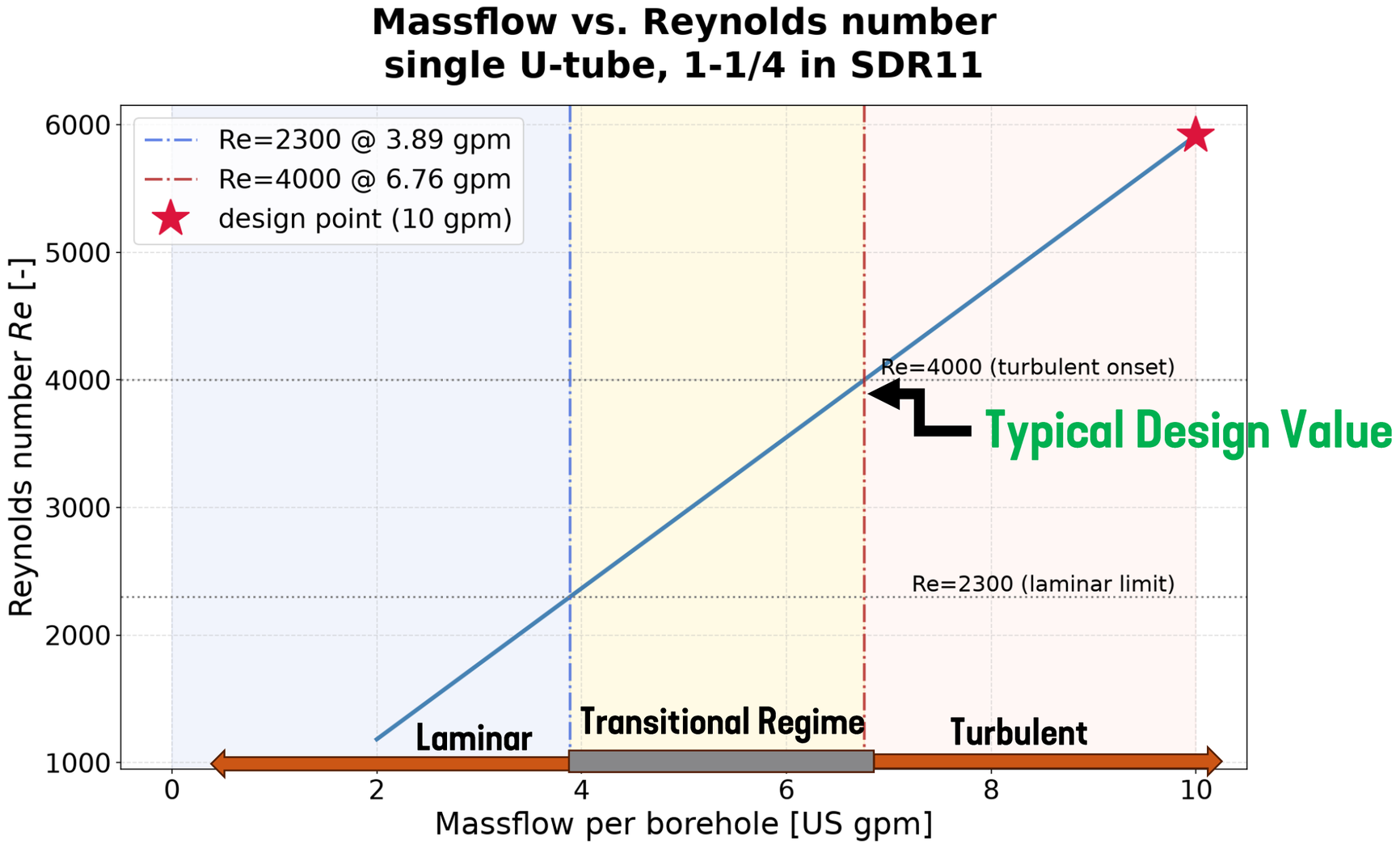
1. Increase geo bore depth >> pressure drop (PD) increases
2. Change from water to glycol >> Viscosity increases >> PD increases
3. Fluid temperature reduces >> Viscosity increases >> PD increases

EXAMPLE: ANTIFREEZE FLUID PROPERTIES



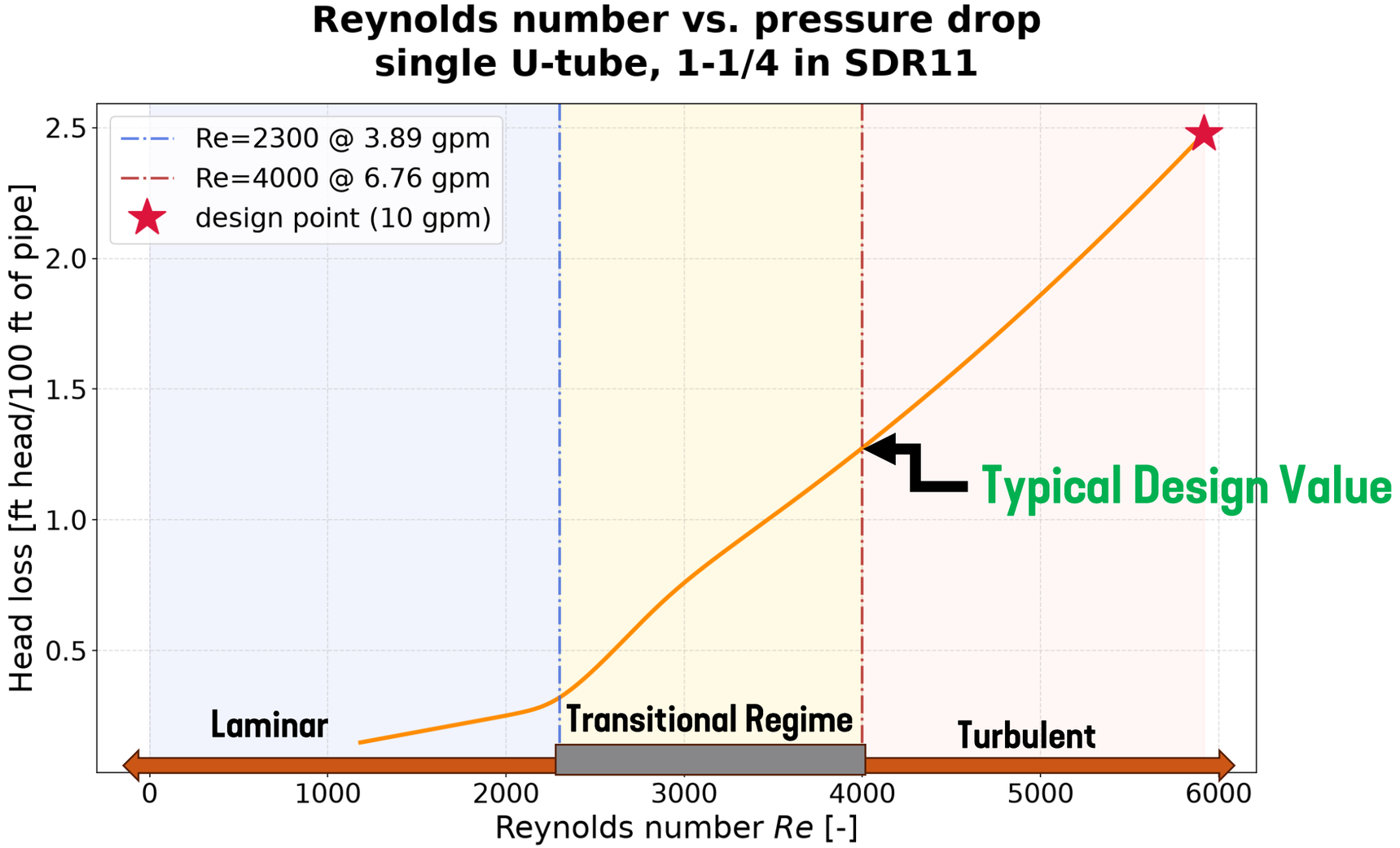
FLOW RATE VS FLOW REGIME





GROUND HEAT EXCHANGER PRESSURE DROP VS FLOW REGIME

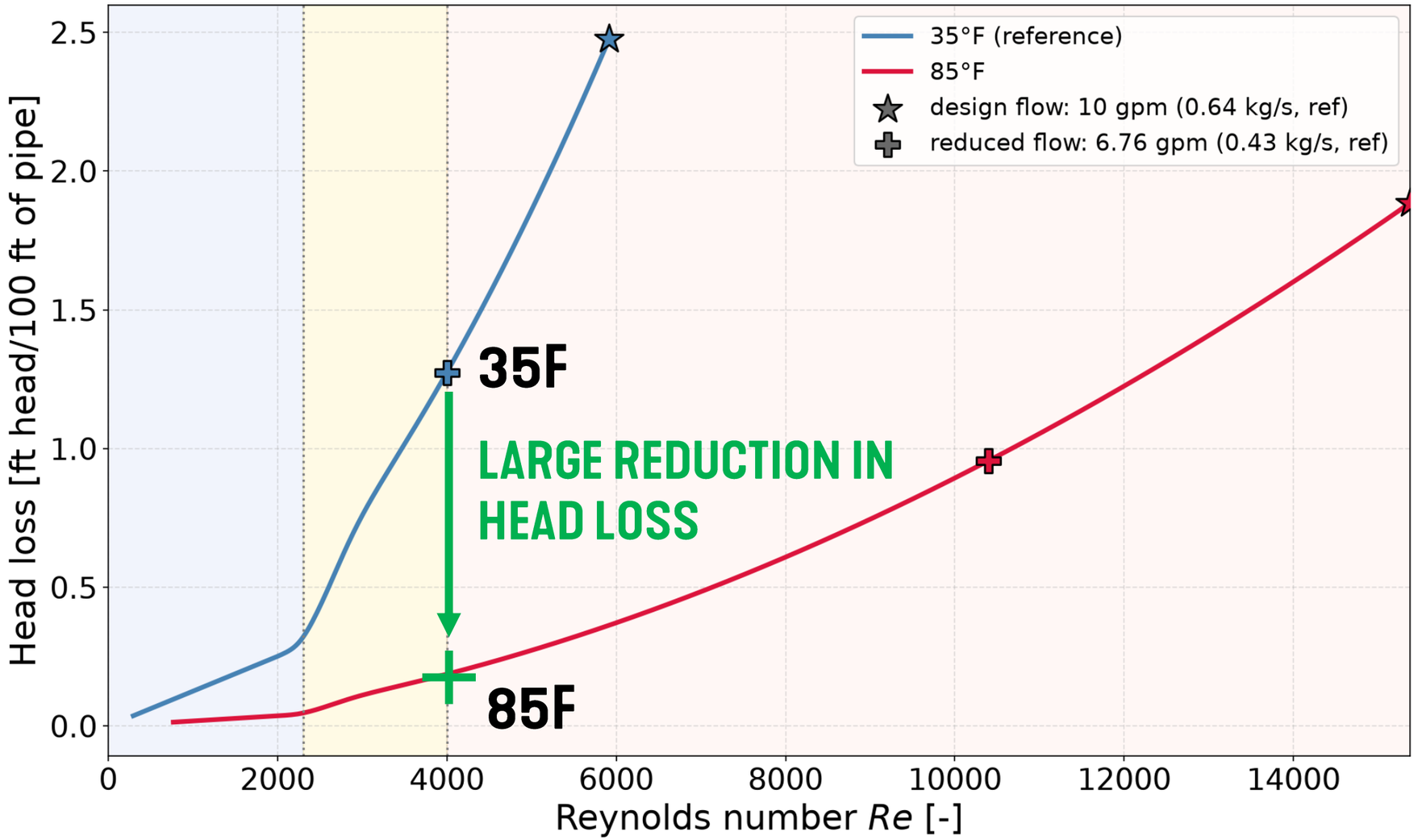




EXAMPLE: PRESSURE DROP VS TEMPERATURE



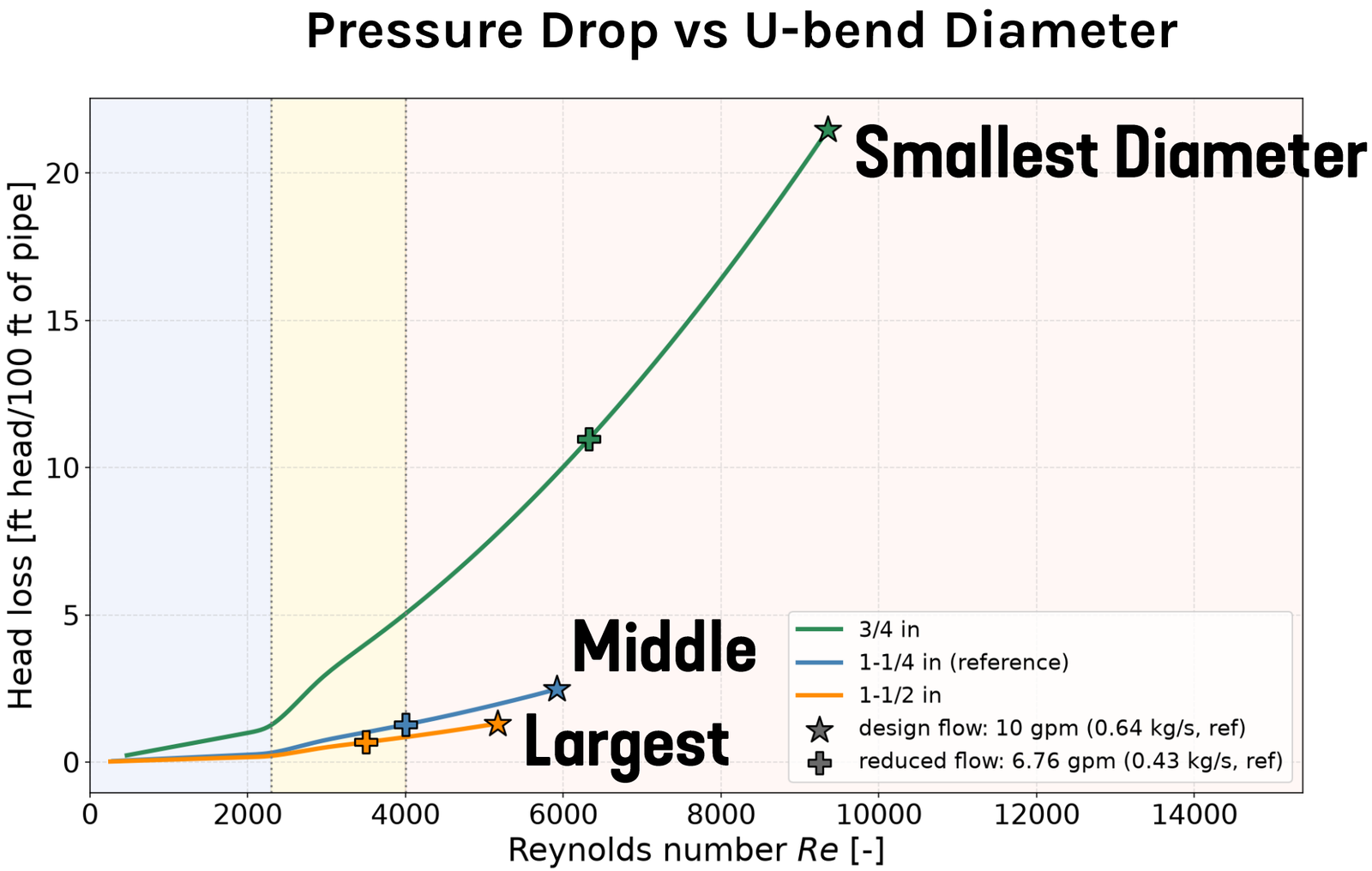
20% Propylene Glycol Mixture Pressure Drop at 35F and 85F



KU LEUVEN THERMAL SYSTEMS SIMULATION SMITHGROUP

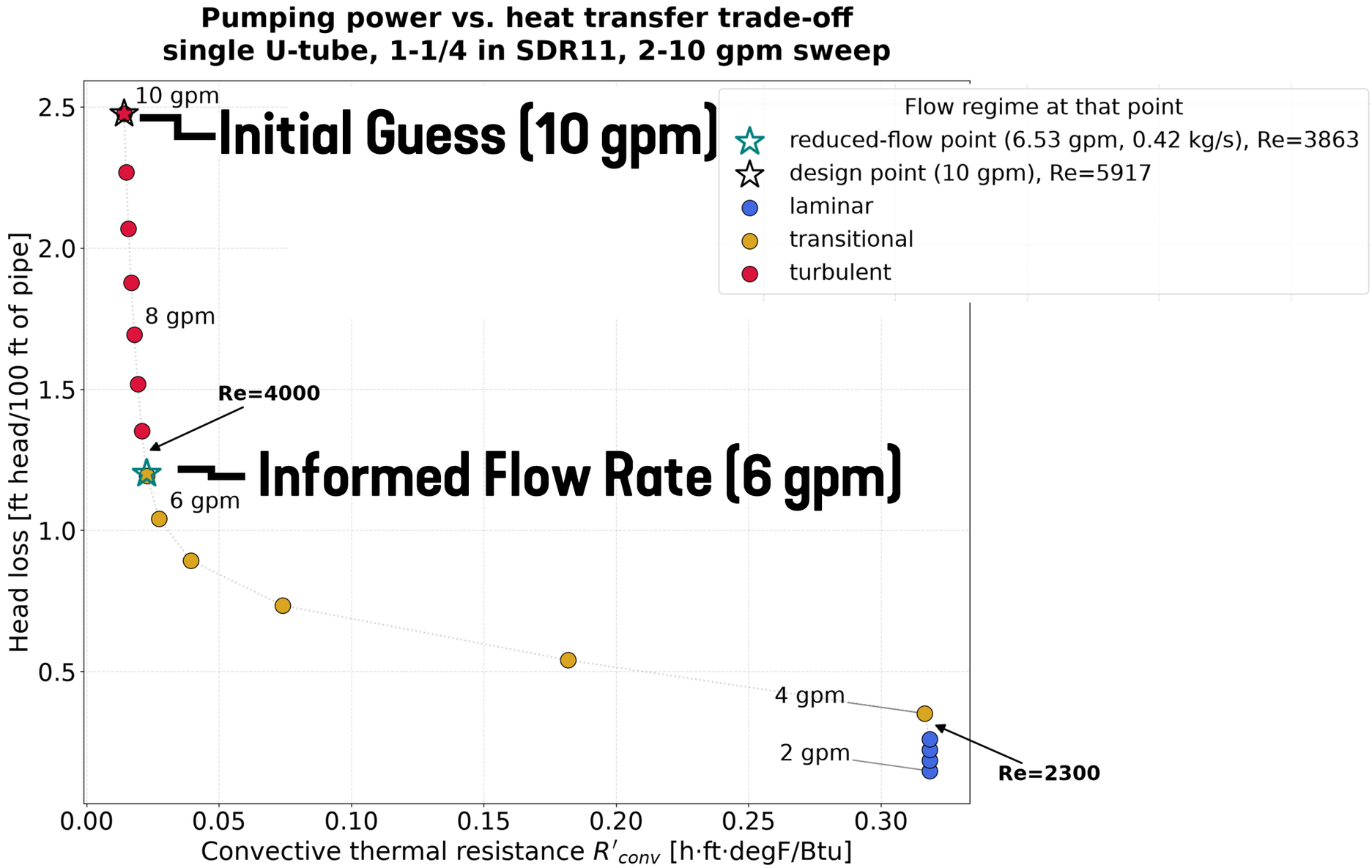
EXAMPLE: PRESSURE DROP VS PIPE DIAMETER





TRADEOFF: PRESSURE DROP VS CONVECTIVE THERMAL RESISTANCE





CITY OF RACINE

DR. MARTIN LUTHER KING JR. COMMUNITY CENTER & INTEGRATED HEALTH CLINIC

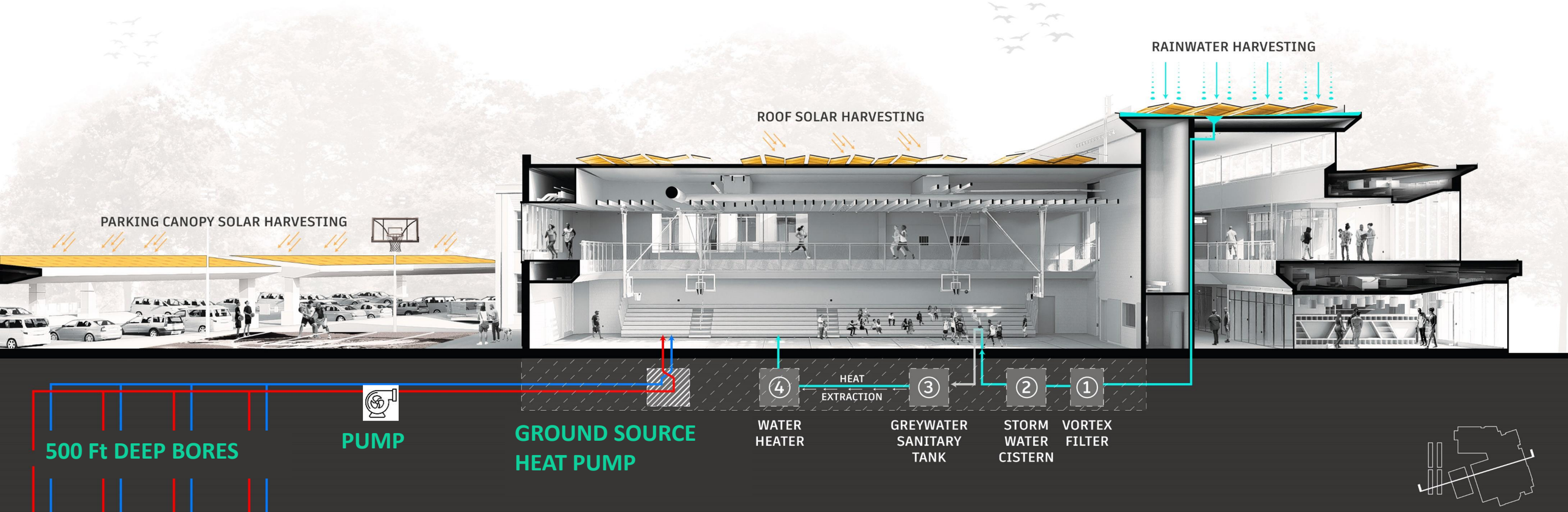


PROJECT OVERVIEW

Net Zero Energy + LEED Platinum

Tax Credit Stacking: New Market Tax Credits + Investment Tax Credit

Design: 100% Geo (No Boiler or Cooling Tower)

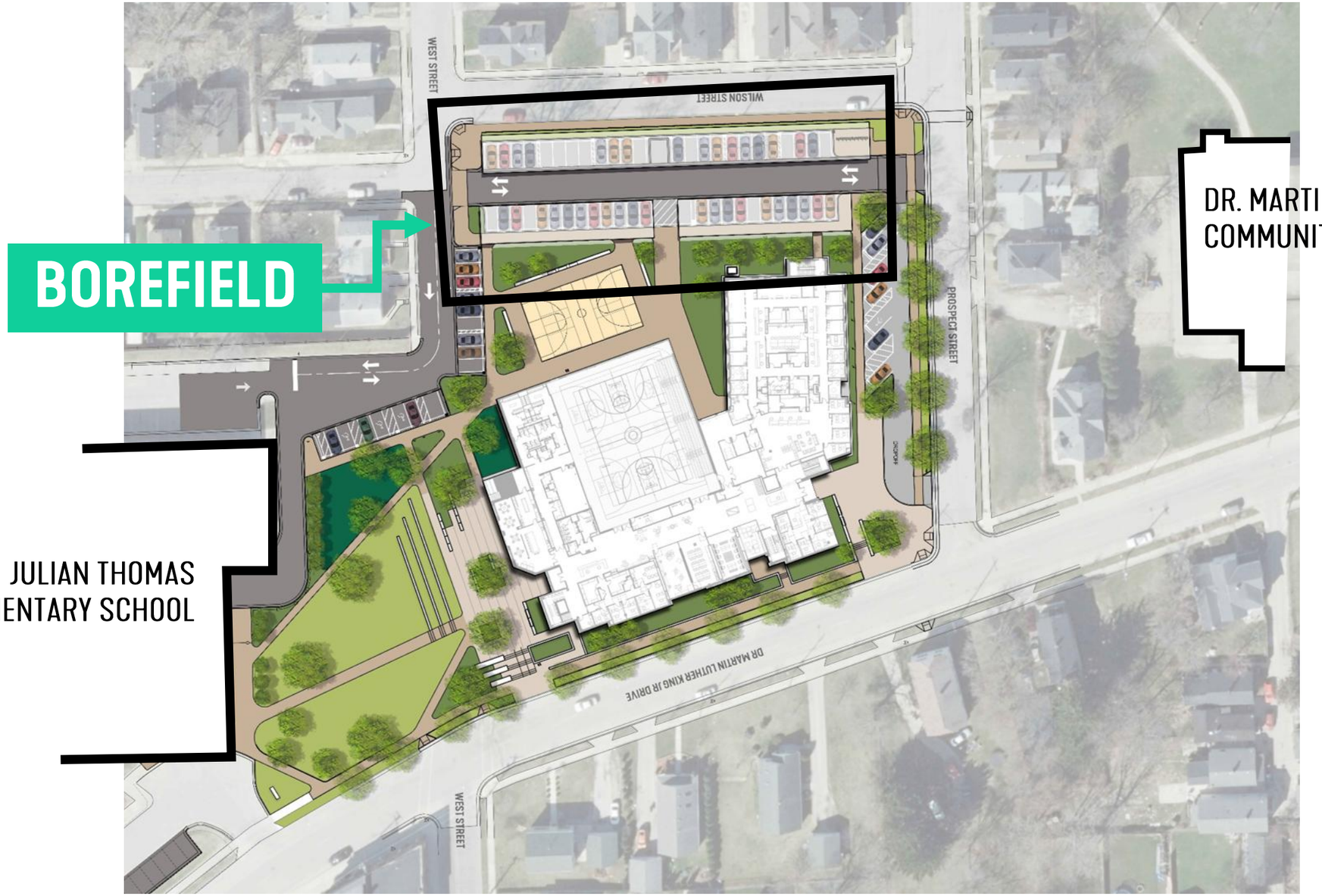


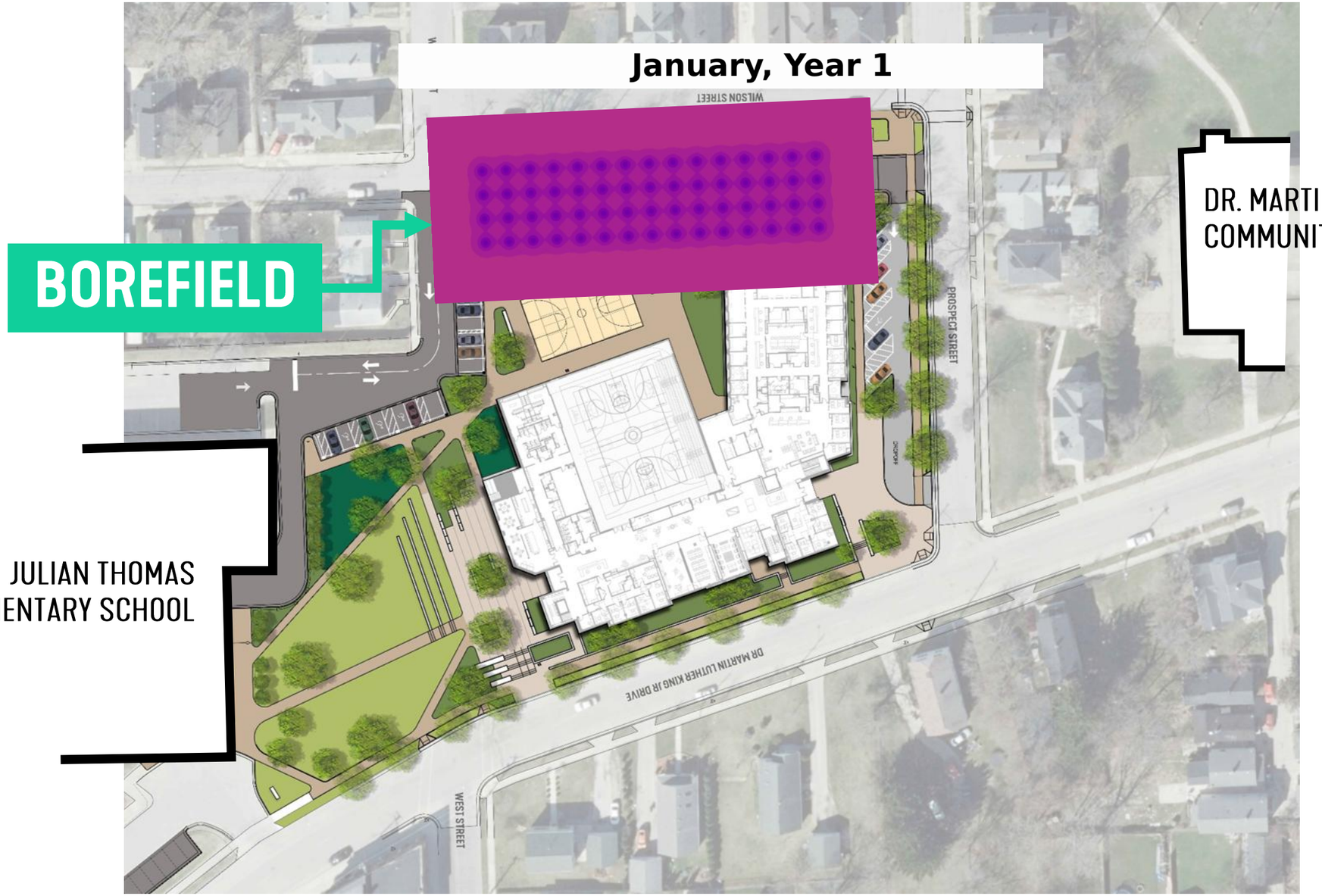
DREAM BIGGER!



BUT NOT THAT BIG…




BOREFIELD
JULIAN THOMAS
ELEMENTARY SCHOOL
DR. MARTIN LUTHER KING JR
COMMUNITY CENTER
WEST STREET
WILSON STREET
PROSPECT STREET
DR MARTIN LUTHER KING JR DRIVE
WEST STREET
N


January, Year 1
BOREFIELD
DR. MARTIN LUTHER KING JR
COMMUNITY CENTER
JULIAN THOMAS
ELEMENTARY SCHOOL
WILSON STREET
PROSPECT STREET
DR MARTIN LUTHER KING JR DRIVE
WEST STREET
N

OBJECTIVES

- **External**: Racine Community > increase resilience, net zero energy
- **Internal**: Design Team > deliver (derisked) project

Apply Multi-Domain Derisking

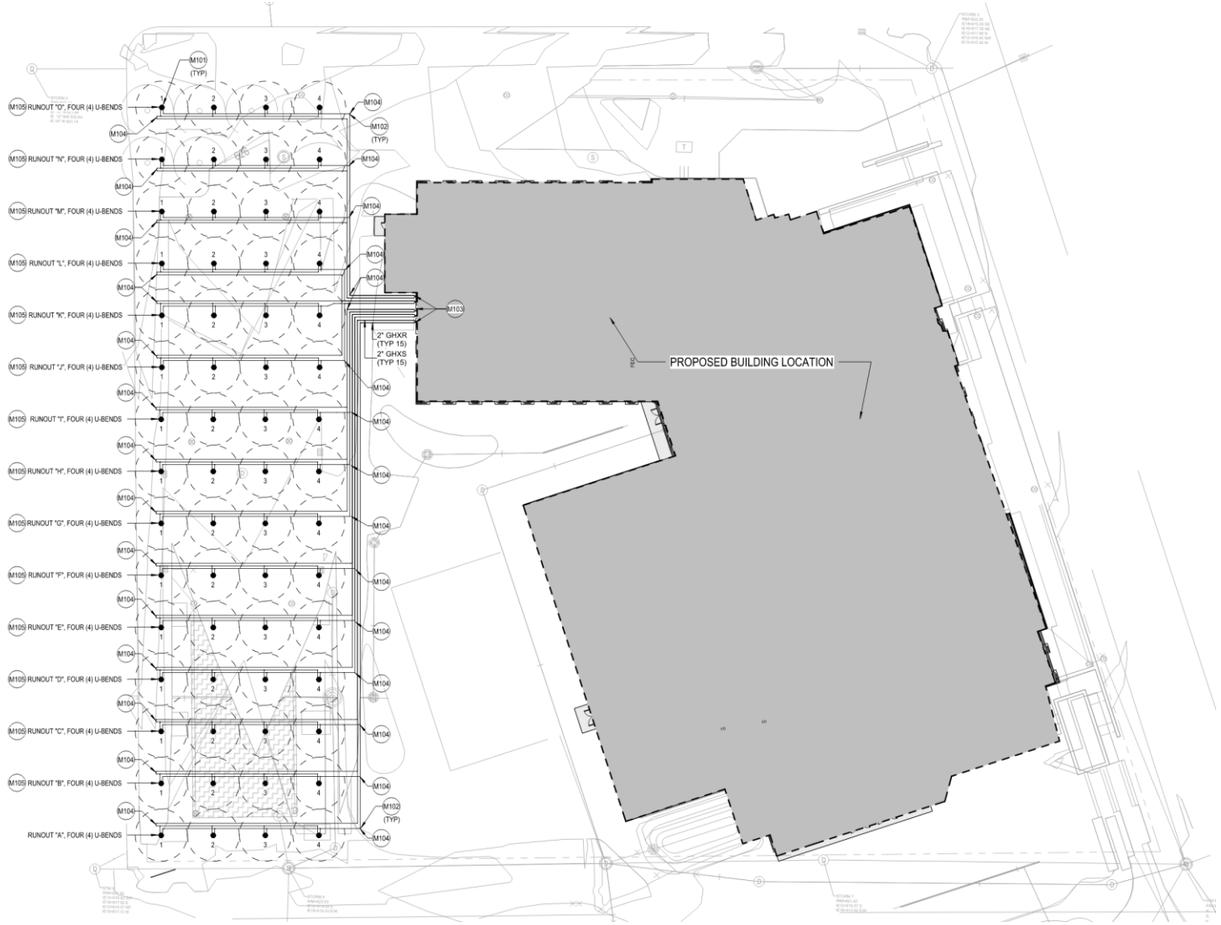
#1 – Geo Circuiting Resiliency

#2 – Energy Use (vs Hydraulic and Control Decisions)

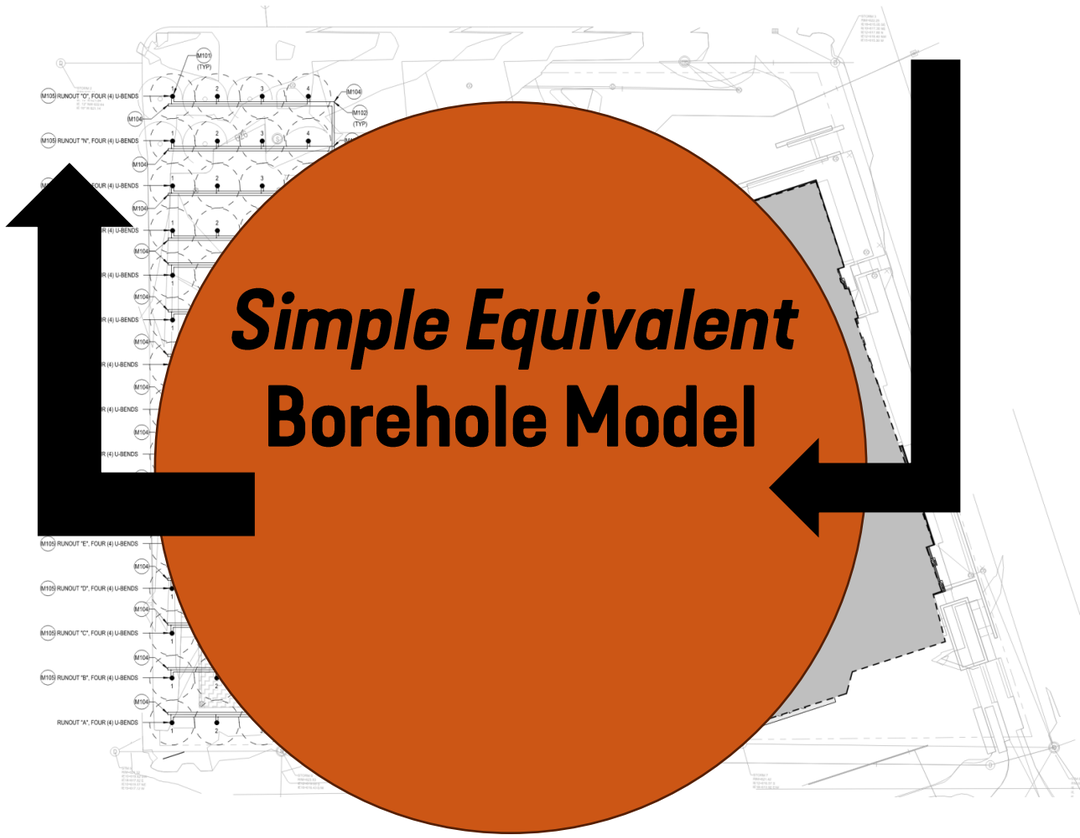
#3 – Borefield Long-Term Health

LEGACY GEO ANALYSIS WASN'T GOOD ENOUGH…

60 Bores
15 Rows x 4 bores

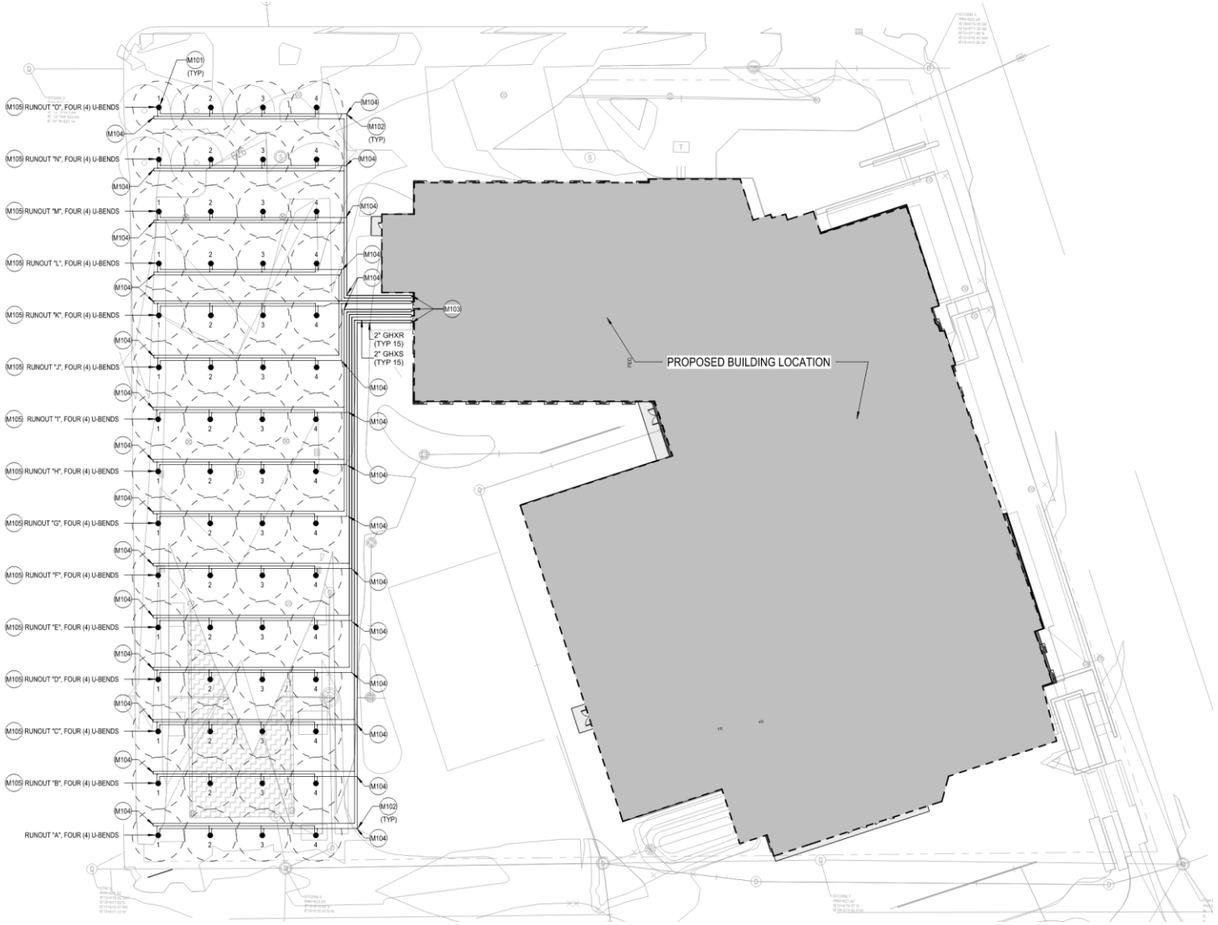


60 Bores
15 Rows x 4 bores



SEARCH FOR NEW ANALYSIS APPROACH

60 Bores
15 Rows x 4 bores

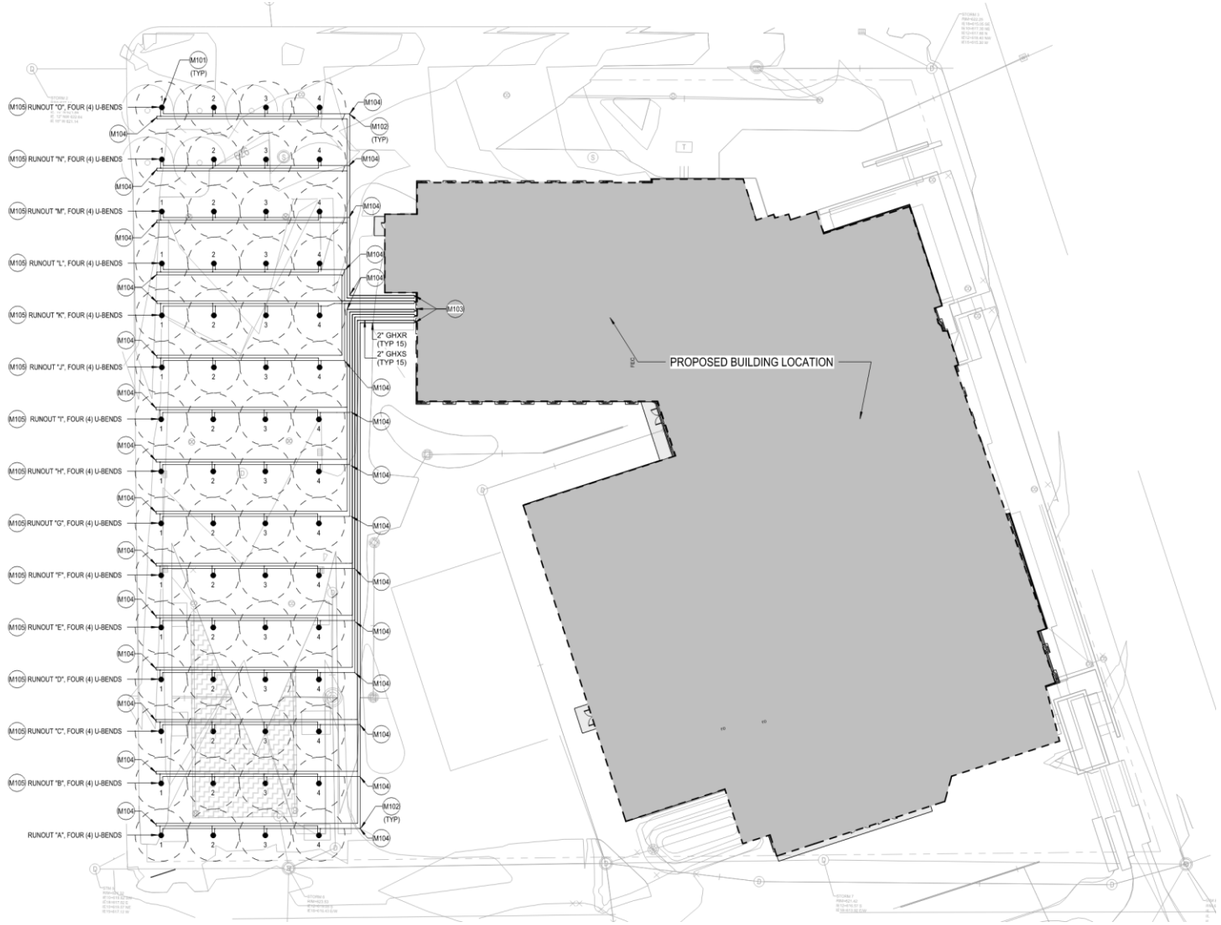


60 Bores
15 Rows x 4 bores

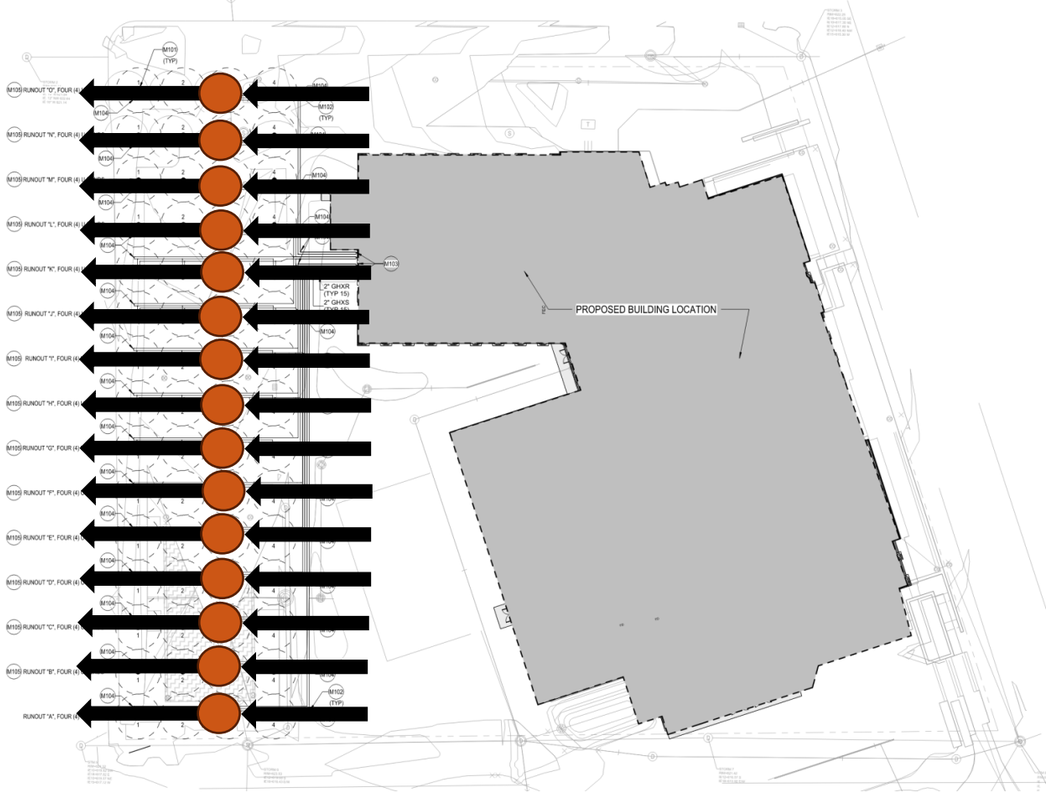


NEW GEO ANALYSIS APPROACH: ZONED BOREFIELD

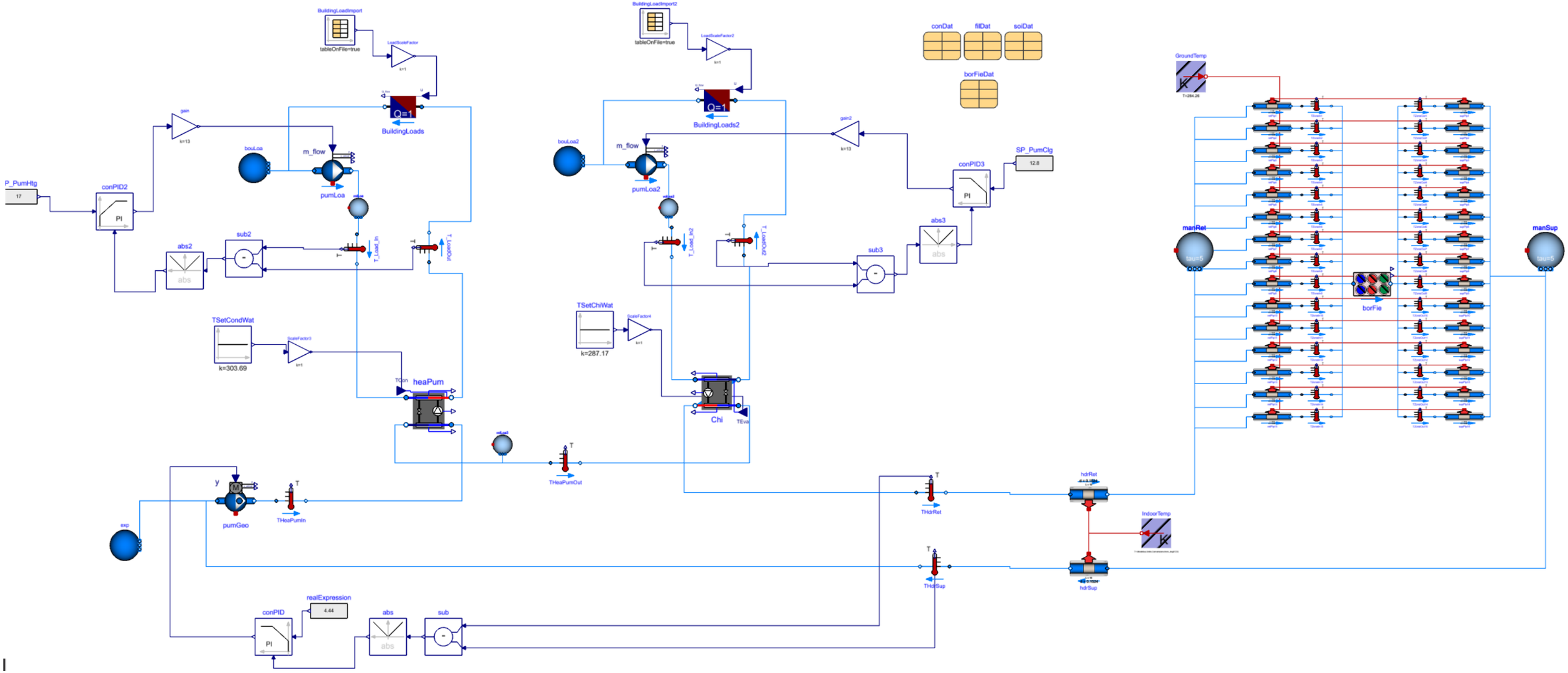
60 Bores
15 Rows x 4 bores



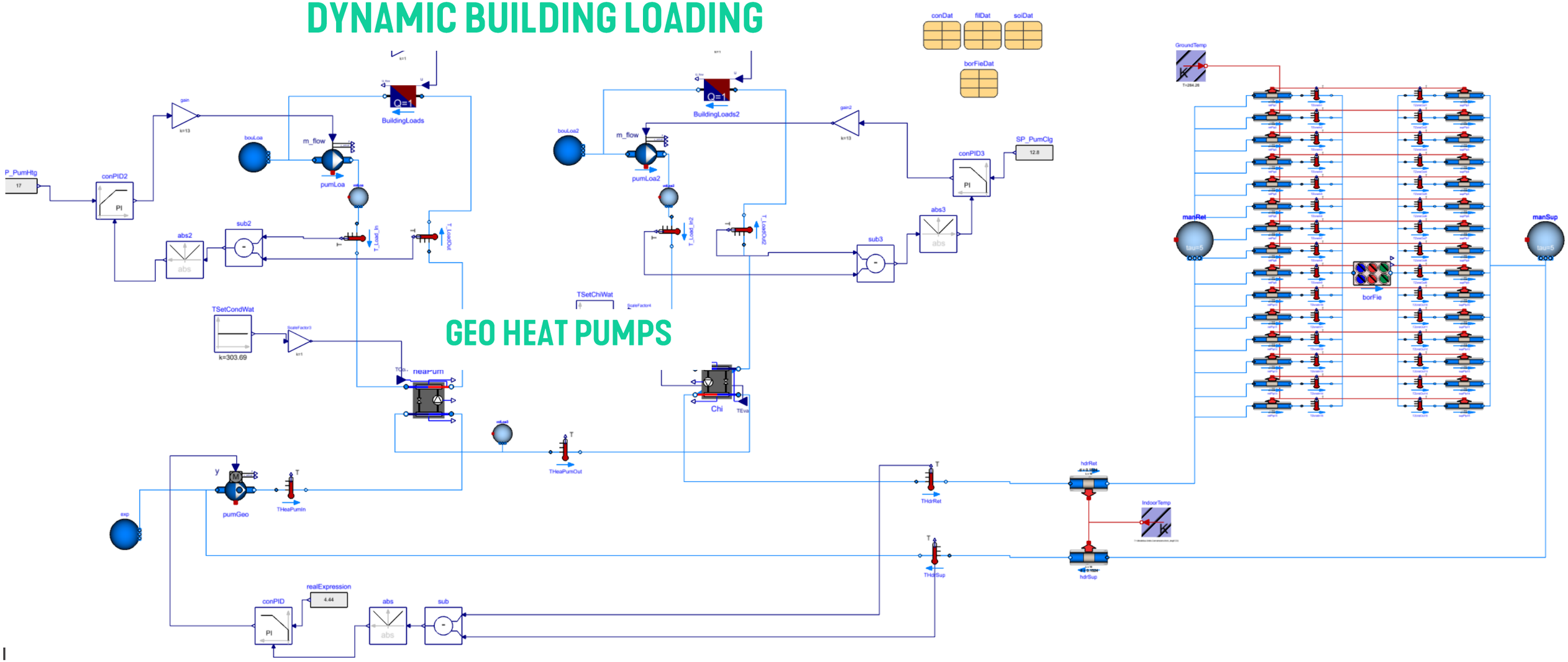
60 Bores
15 Rows x 4 bores
Independent Hydraulic Control



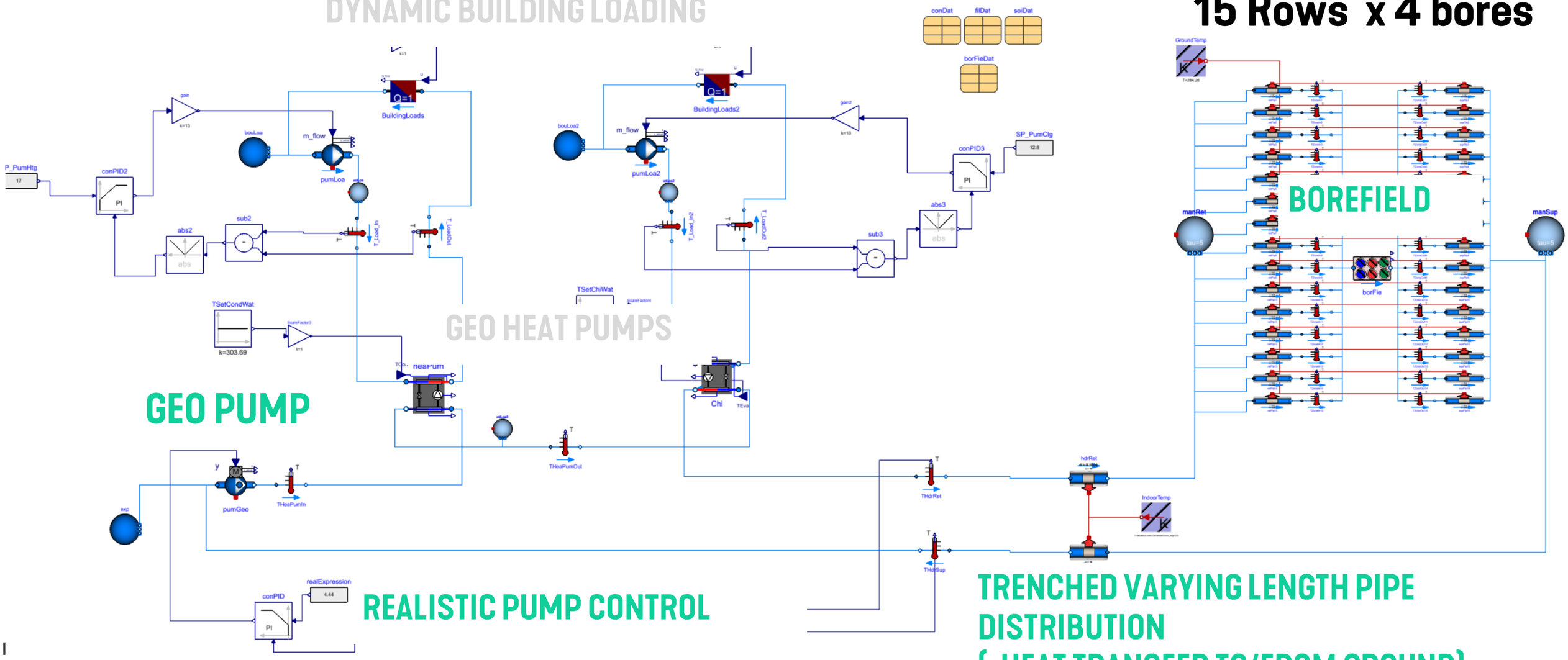
MULTIDOMAIN DESIGN:
DERISK BEFORE CONSTRUCTION



MULTIDOMAIN DESIGN:
DERISK BEFORE CONSTRUCTION

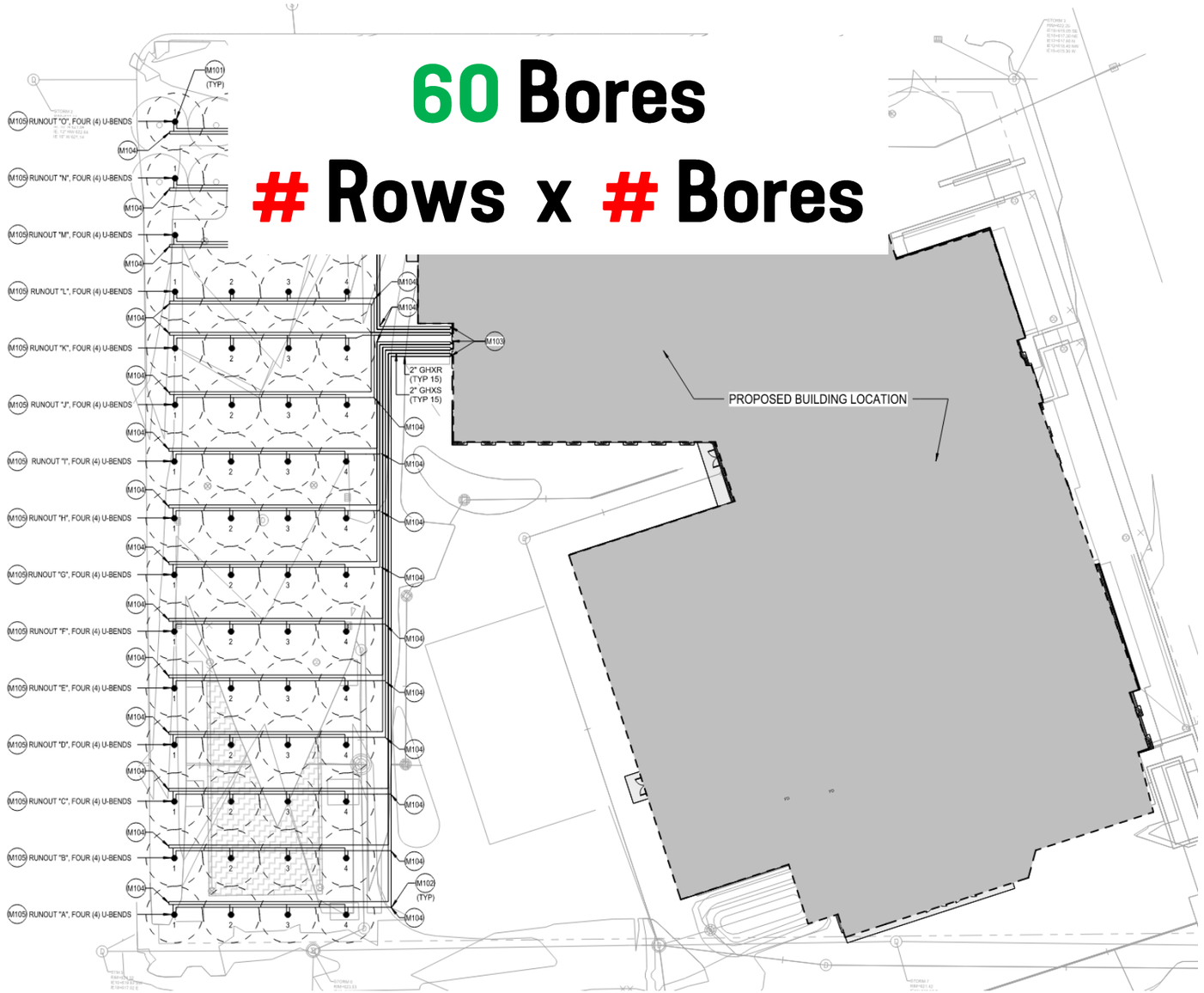


MULTIDOMAIN DESIGN:
DERISK BEFORE CONSTRUCTION



Derisk Operation…
in the Design Phase

GEO PIPING NETWORK

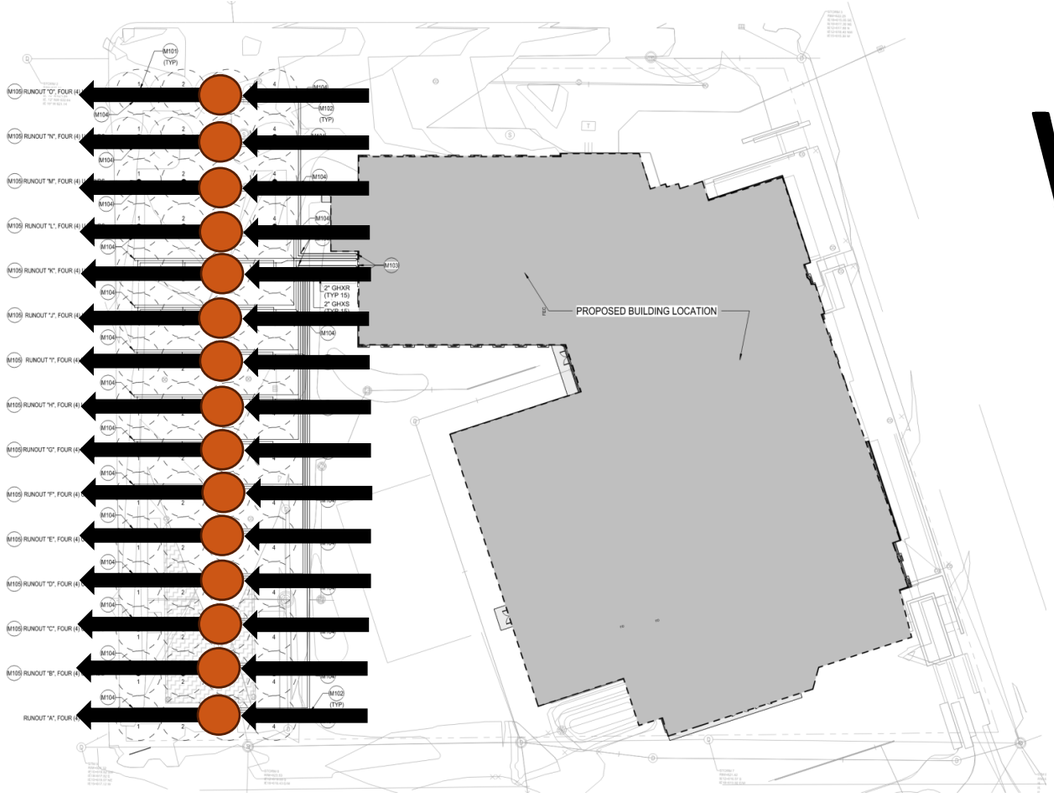


KU LEUVEN THERMAL SYSTEMS SIMULATION SMITHGROUP

RESILIENCY: GEO CIRCUITING

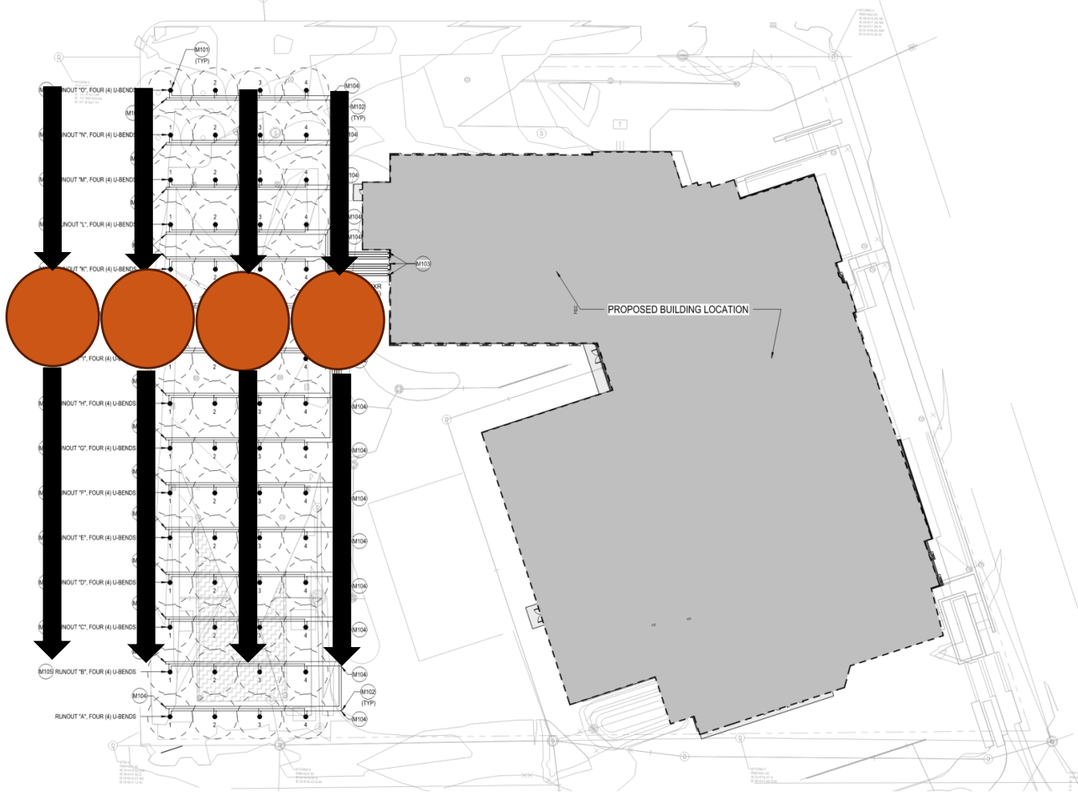
How to connect 60 Bores…

15 Rows x 4 bores



VS

4 Rows x 15 bores



RESILIENCY: GEO CIRCUITING

How to connect 60 Bores…

15 Rows x 4 bores

More Resilient

1 Row Down = 7% Loss

VS

4 Rows x 15 bores

Les Resilient

1 Row Down = 25% Loss

RESILIENCY: GEO CIRCUITING

How to connect 60 Bores…

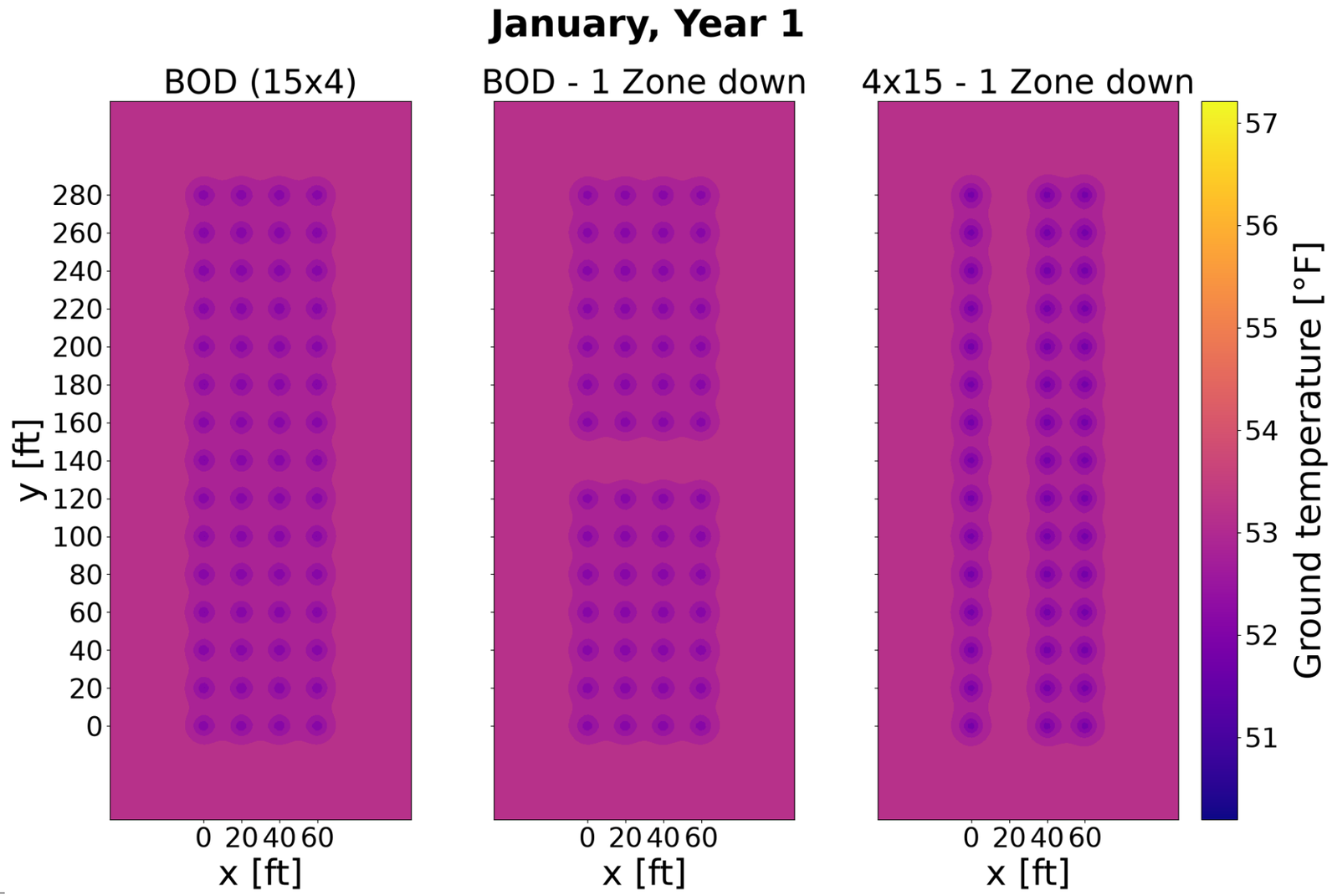
15 Rows x 4 bores

More Resilient

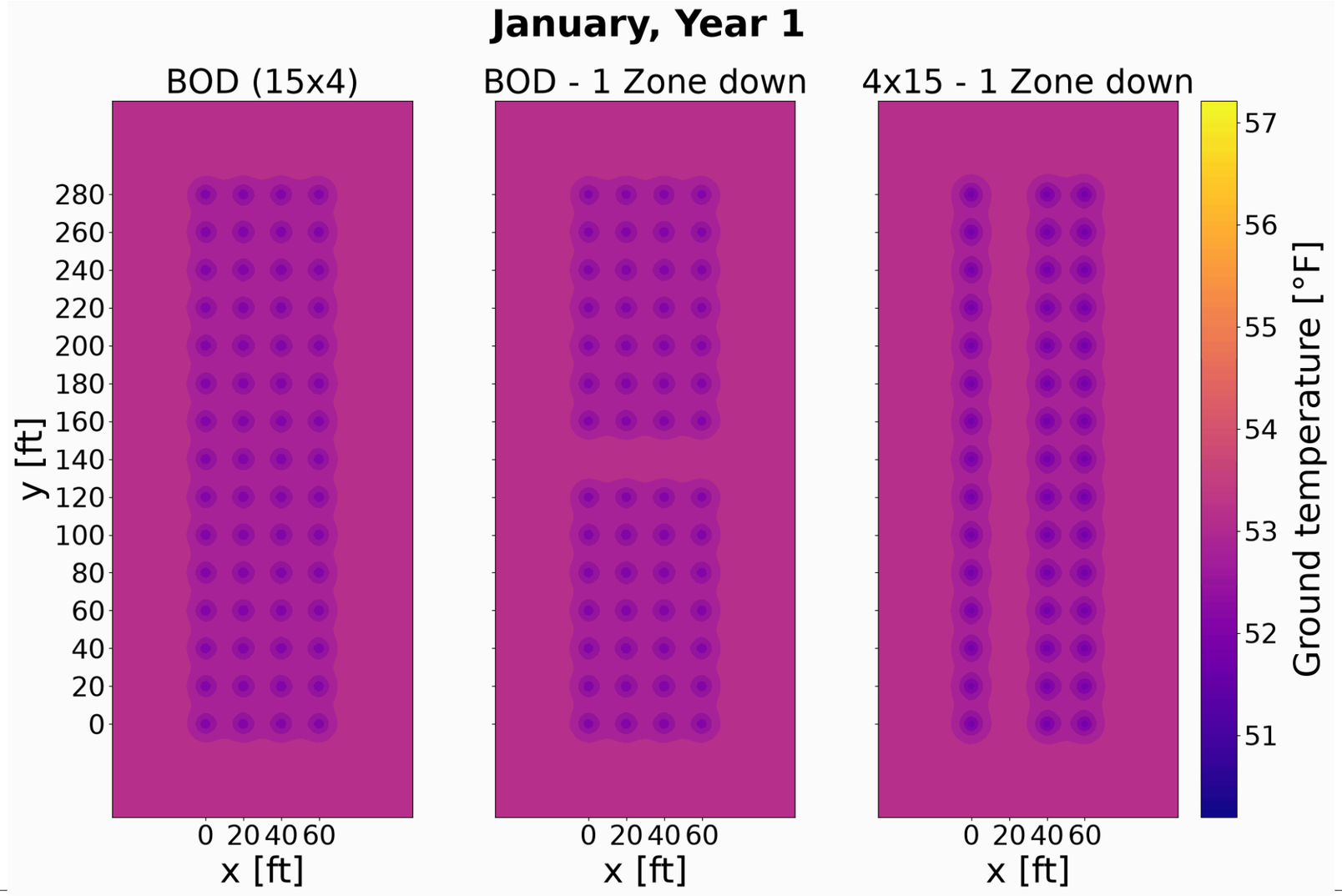
1 Row Down = 7% Loss



RESILIENCY: GEO CIRCUITING

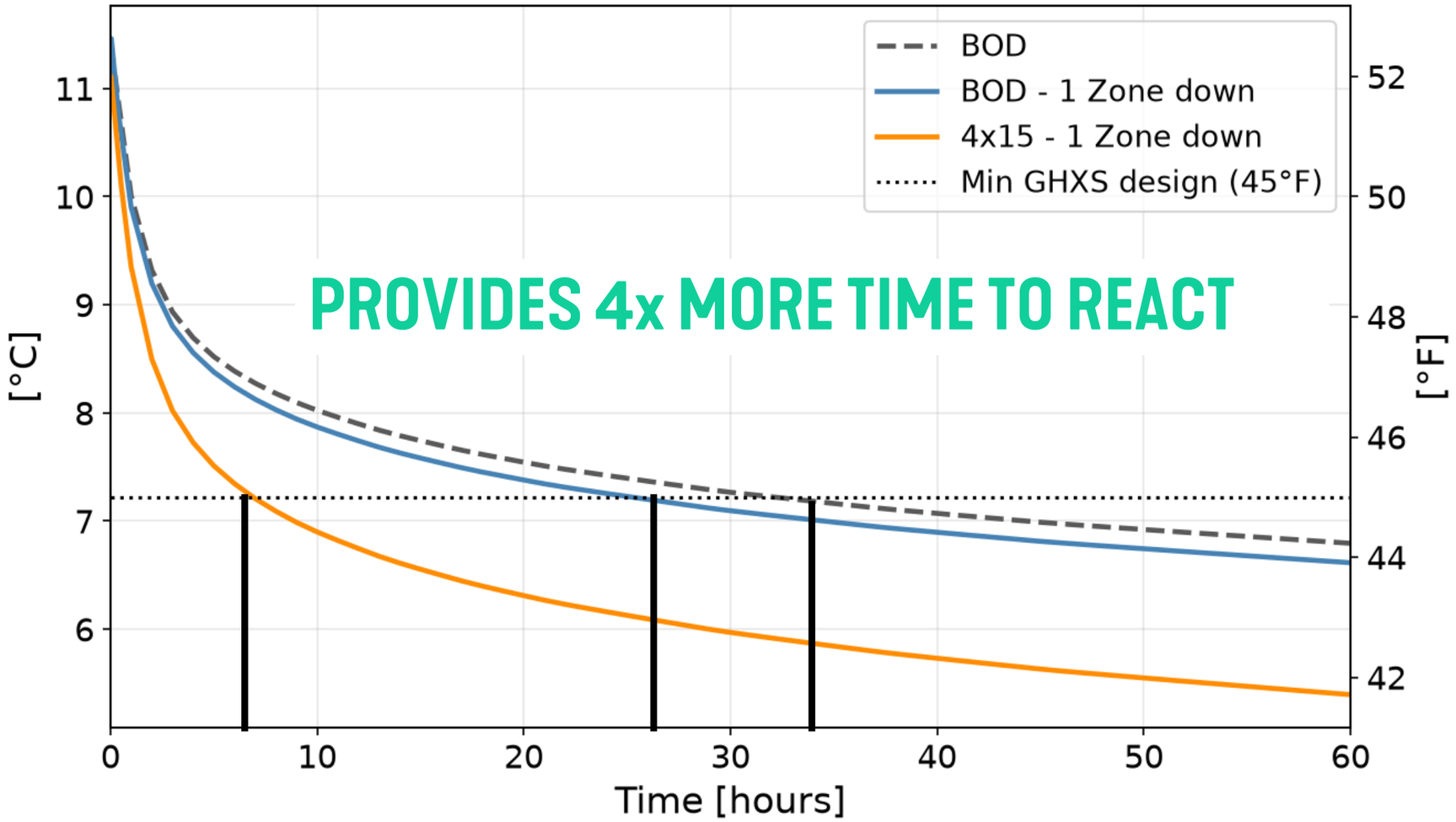


RESILIENCY: GEO CIRCUITING



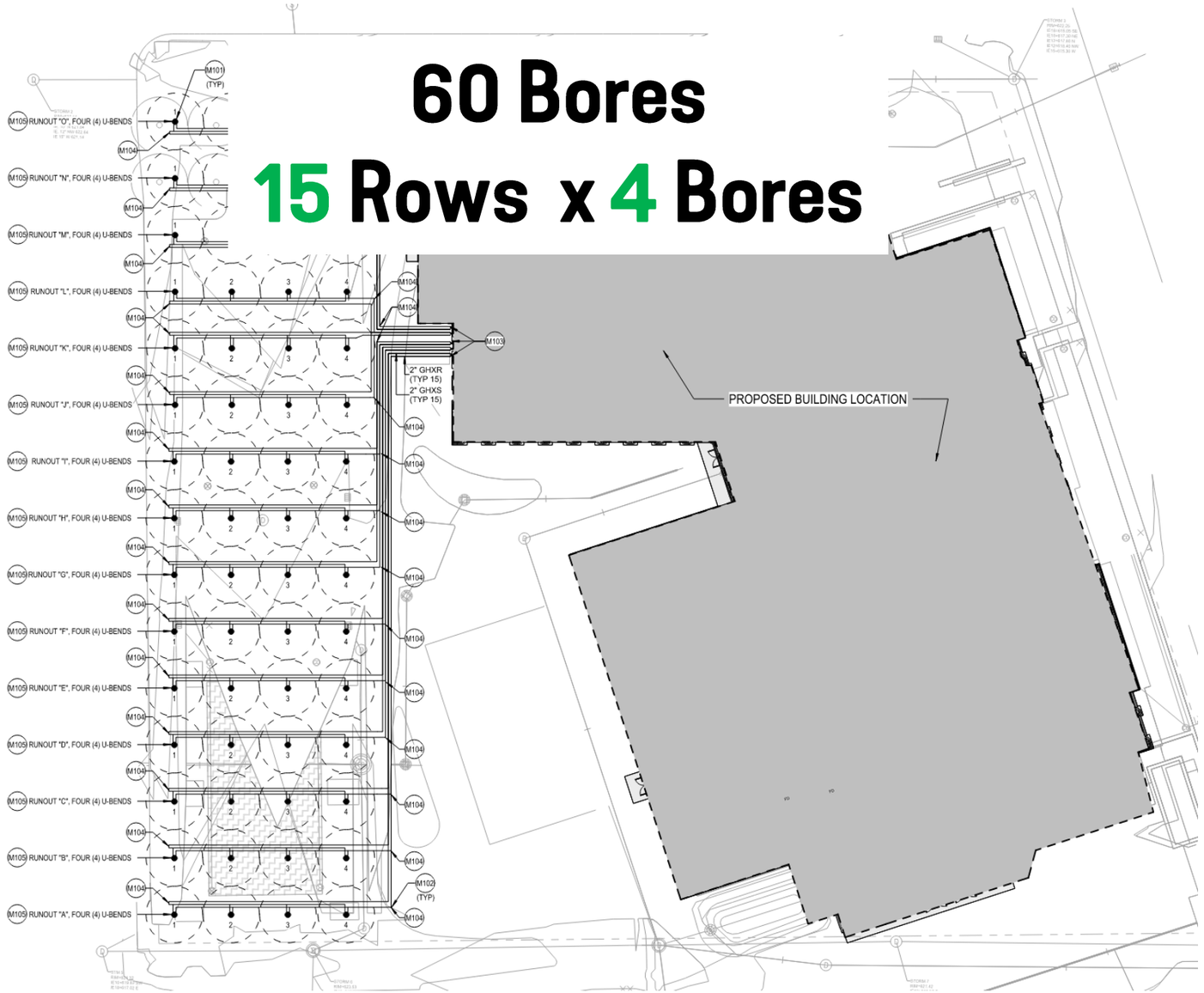
RESILIENCE: UNDER PEAK HEATING CONDITIONS

GHXS (Entering HP) Temperatures: Under Continuous Peak Heating Load



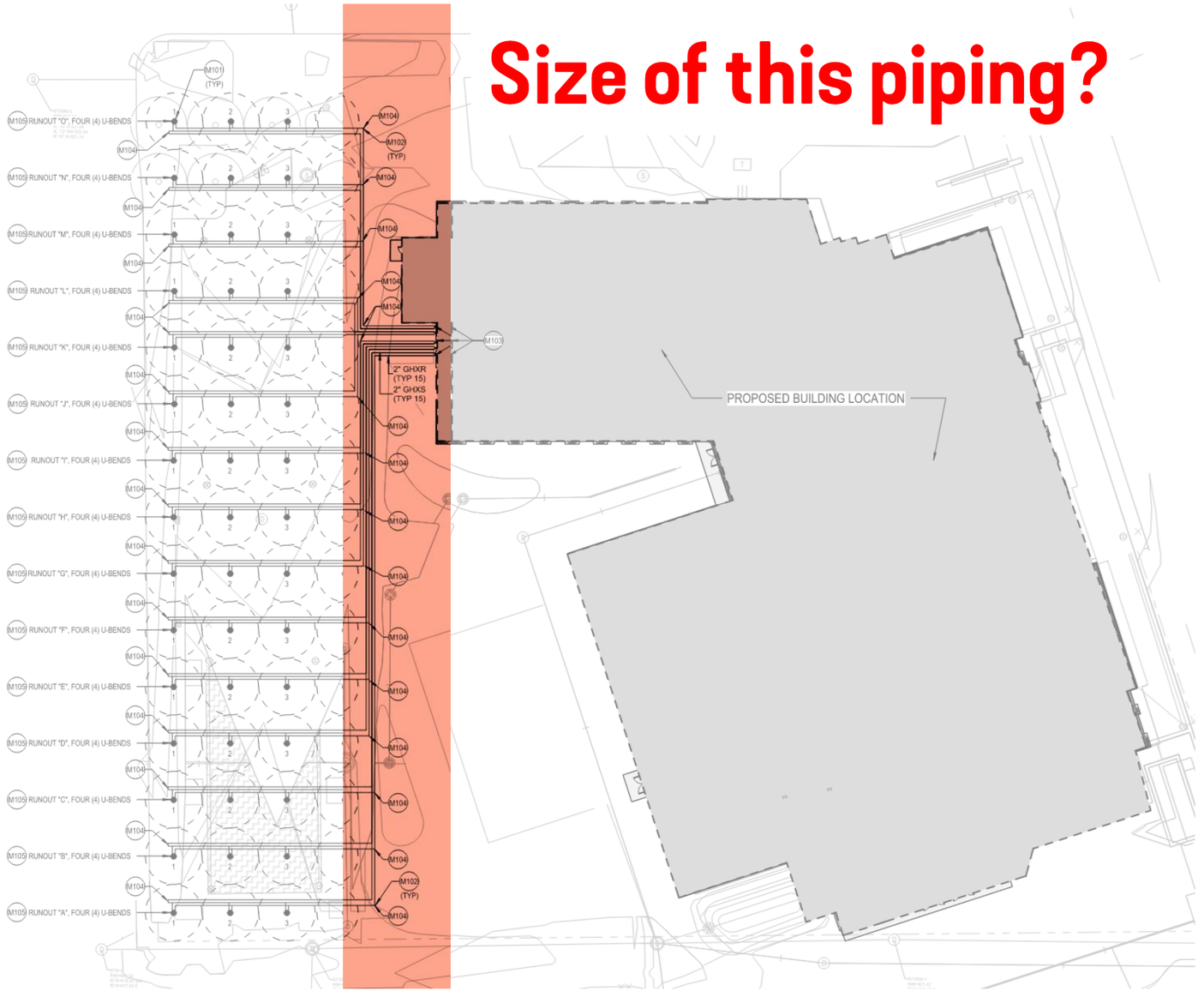
KU LEUVEN THERMAL SYSTEMS SIMULATION SMITHGROUP

GEO PIPING NETWORK



KU LEUVEN THERMAL SYSTEMS SIMULATION SMITHGROUP

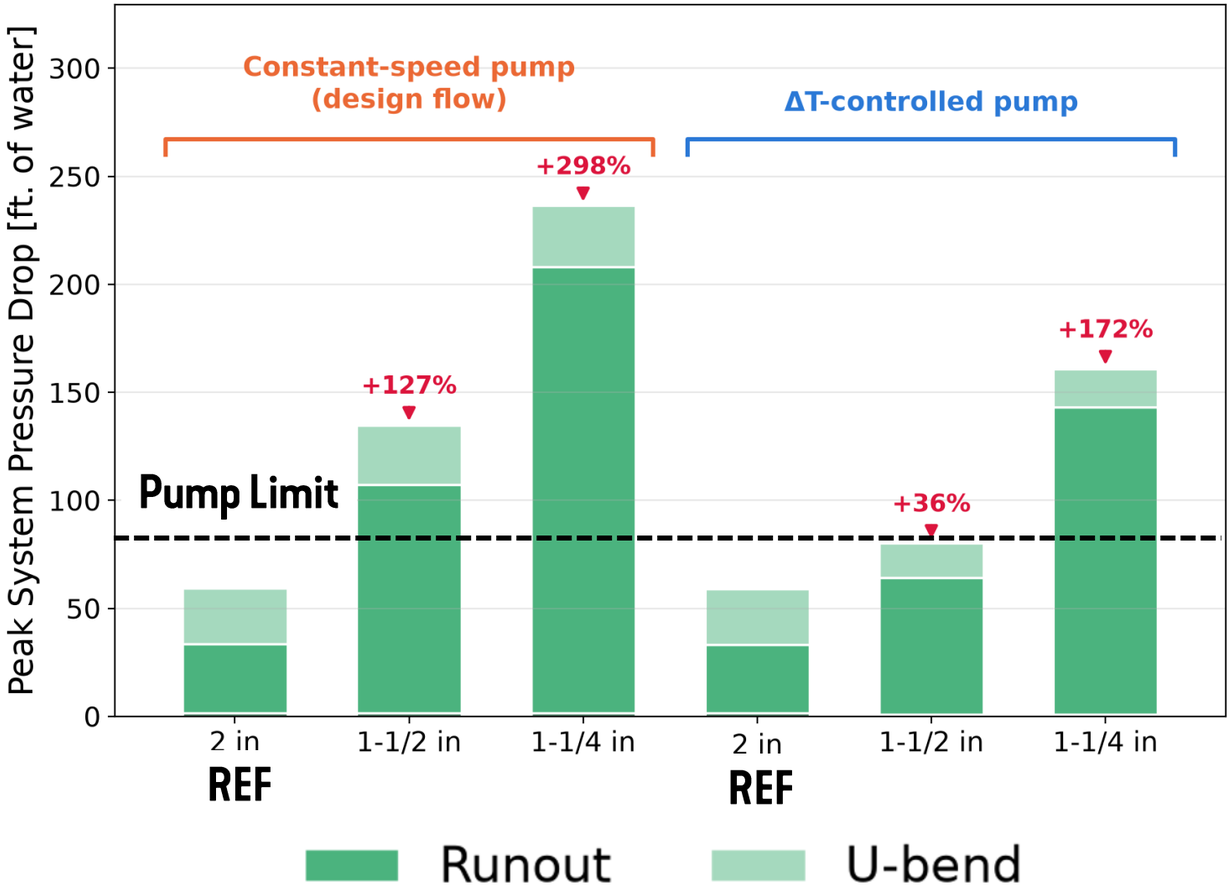
GEO RUNOUT PIPING



ENERGY USE VS HYDRAULIC AND CONTROL DECISIONS

KEY CONCEPT **Pipe distribution size impacts pump head pressure required**

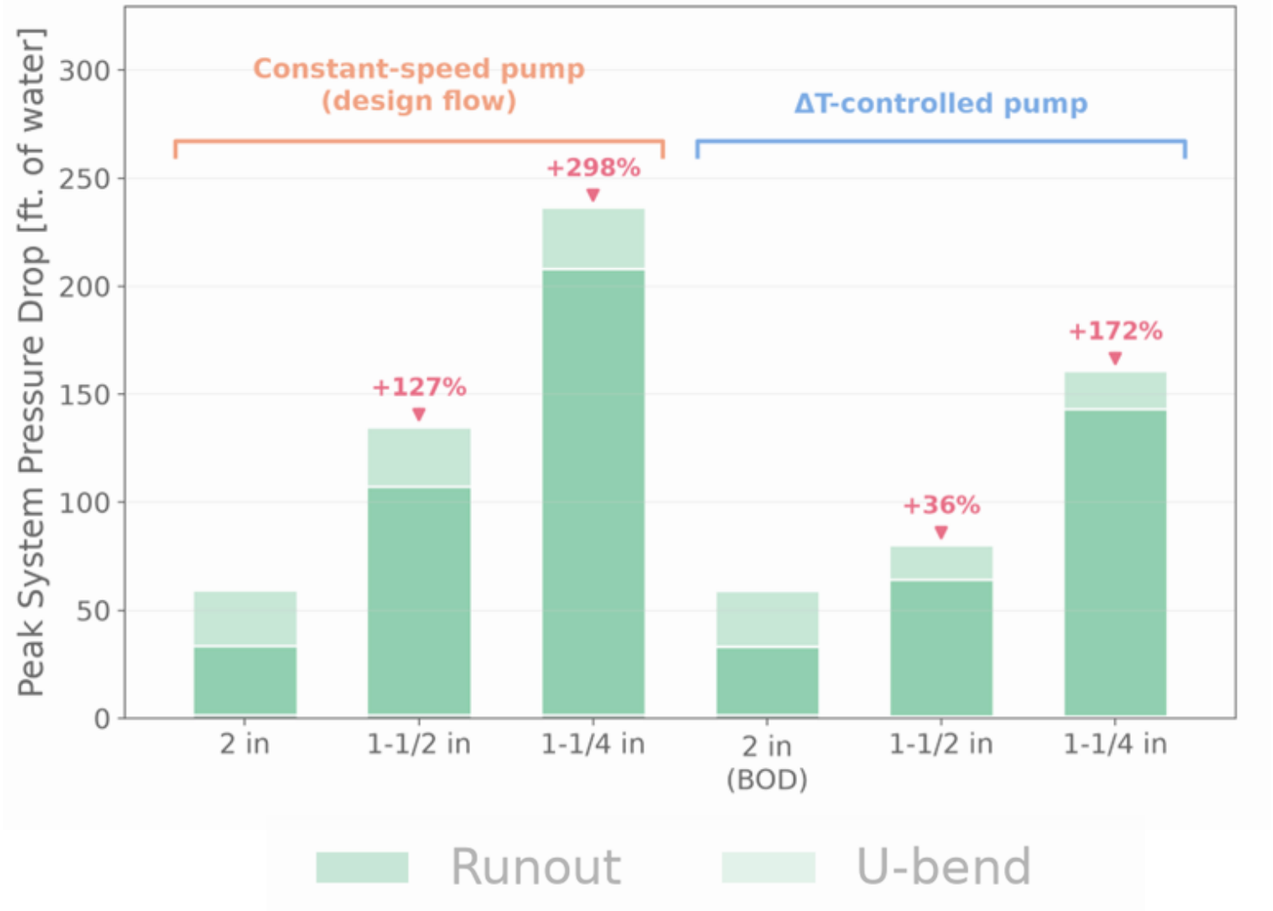
Impact of Geo Runout Pipe Diameter & Pump Control

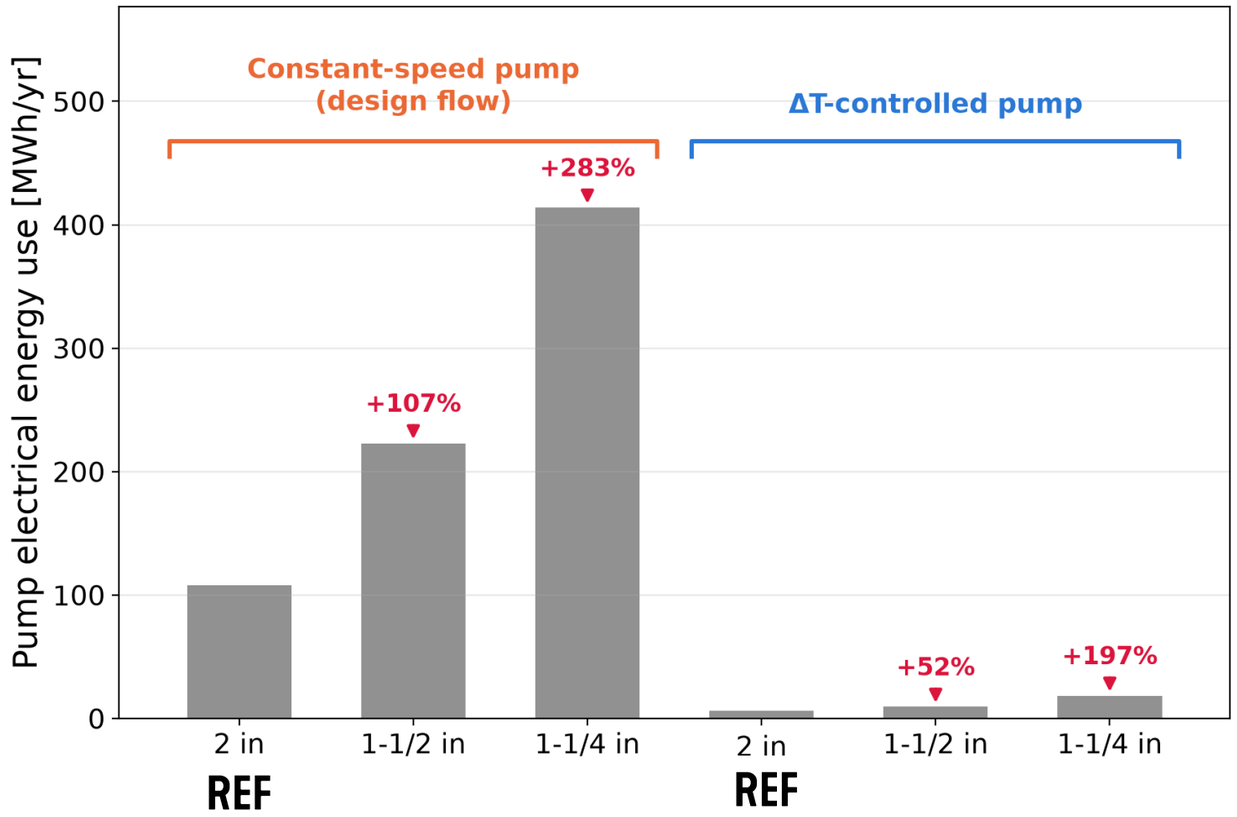


ENERGY USE VS HYDRAULIC AND CONTROL DECISIONS

KEY CONCEPT **Pipe distribution size impacts pumping energy**

Impact of Geo Runout Pipe Diameter & Pump Control

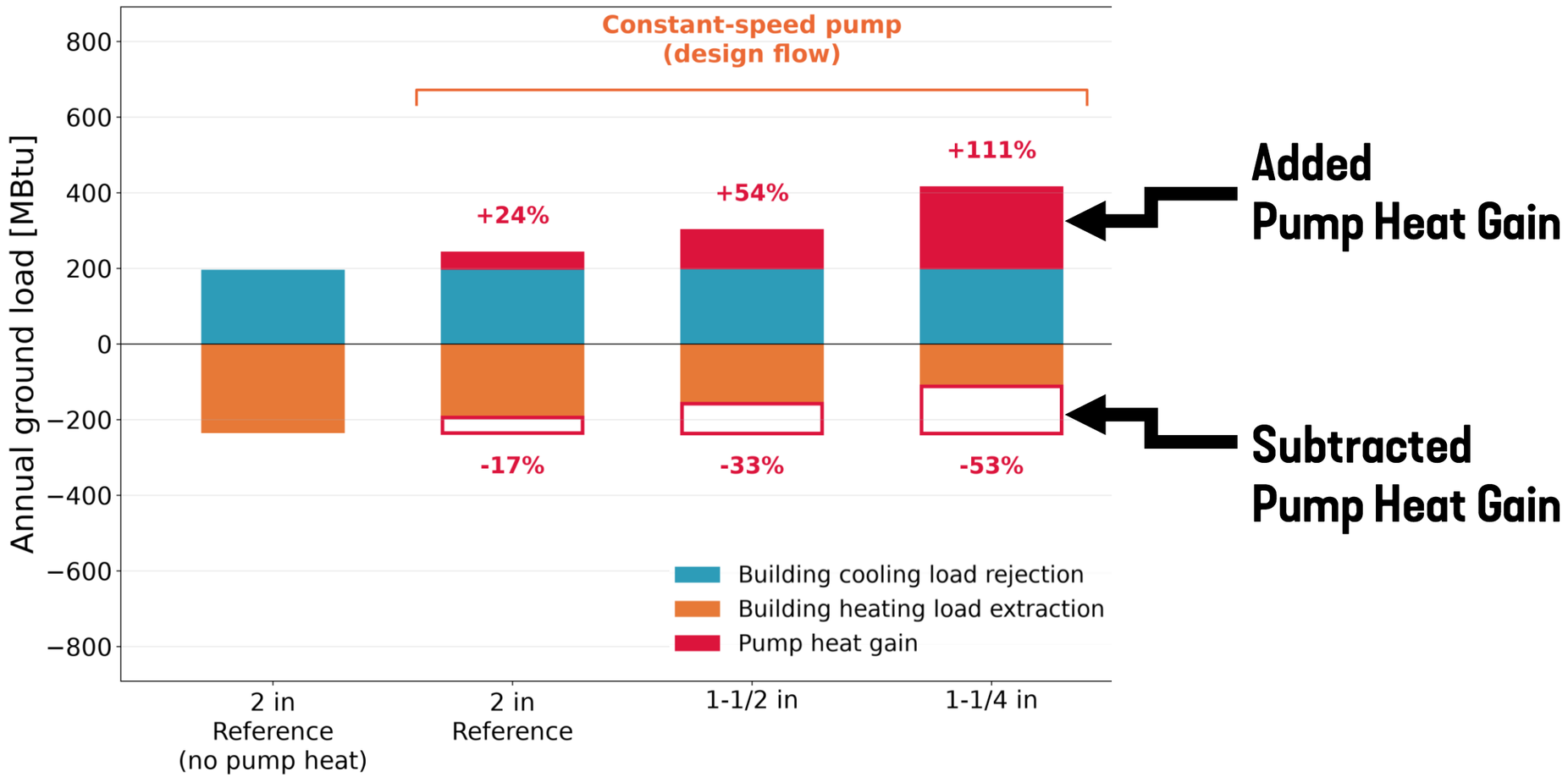




INTEGRATED HYDRAULICS + HEAT GAIN TO GROUND

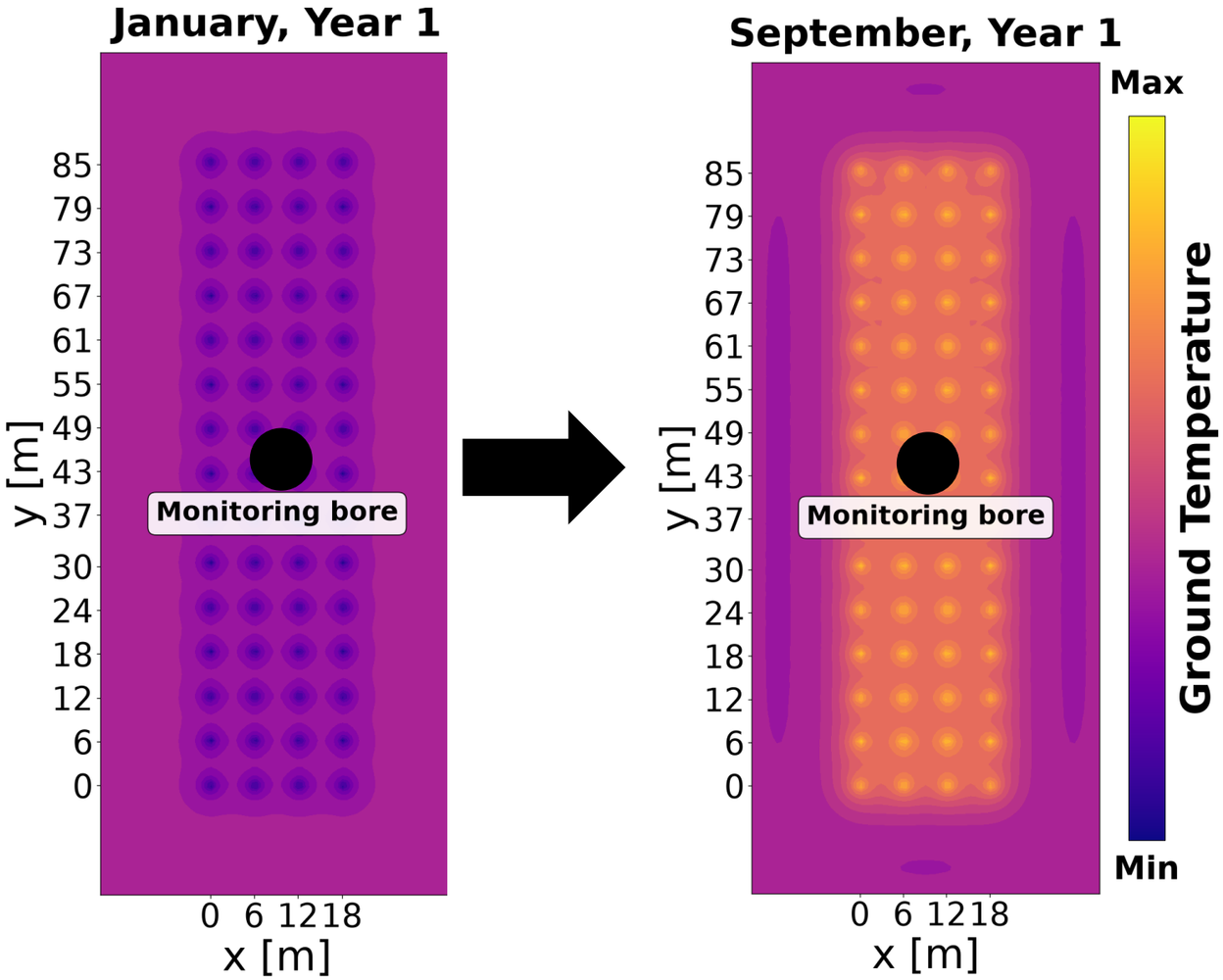
KEY CONCEPT **Hydraulic distribution and pump size impact heat gain to ground**

Geo Heat Rejection/Extraction: Effect of Pump Heat Gain



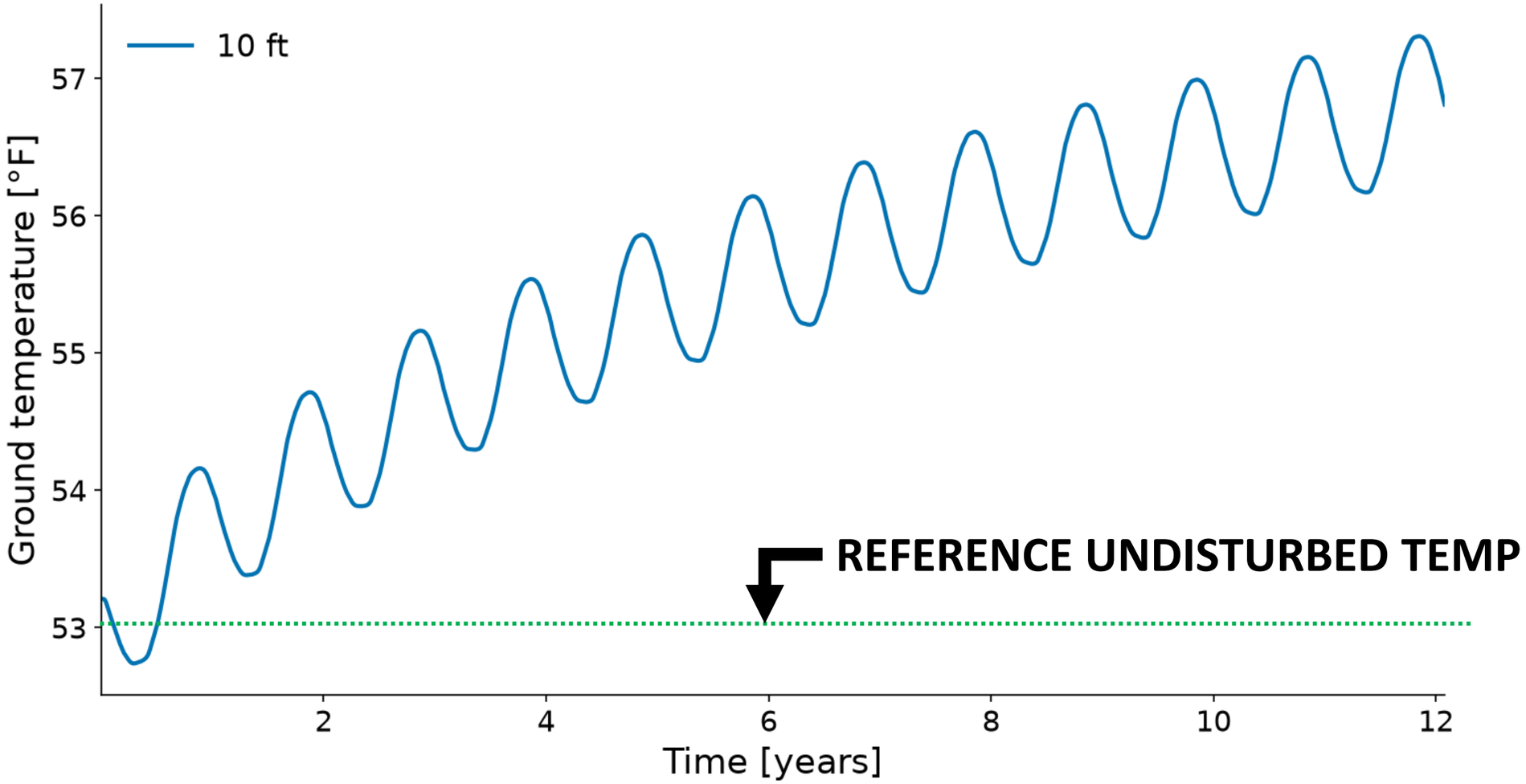
DERISKING: INTERNAL MONITORING BORE IN MODELICA

- **Internal Field Sensor**
  - Field Health
  - “Thermal battery charge” indicator
  - Long time scale control point



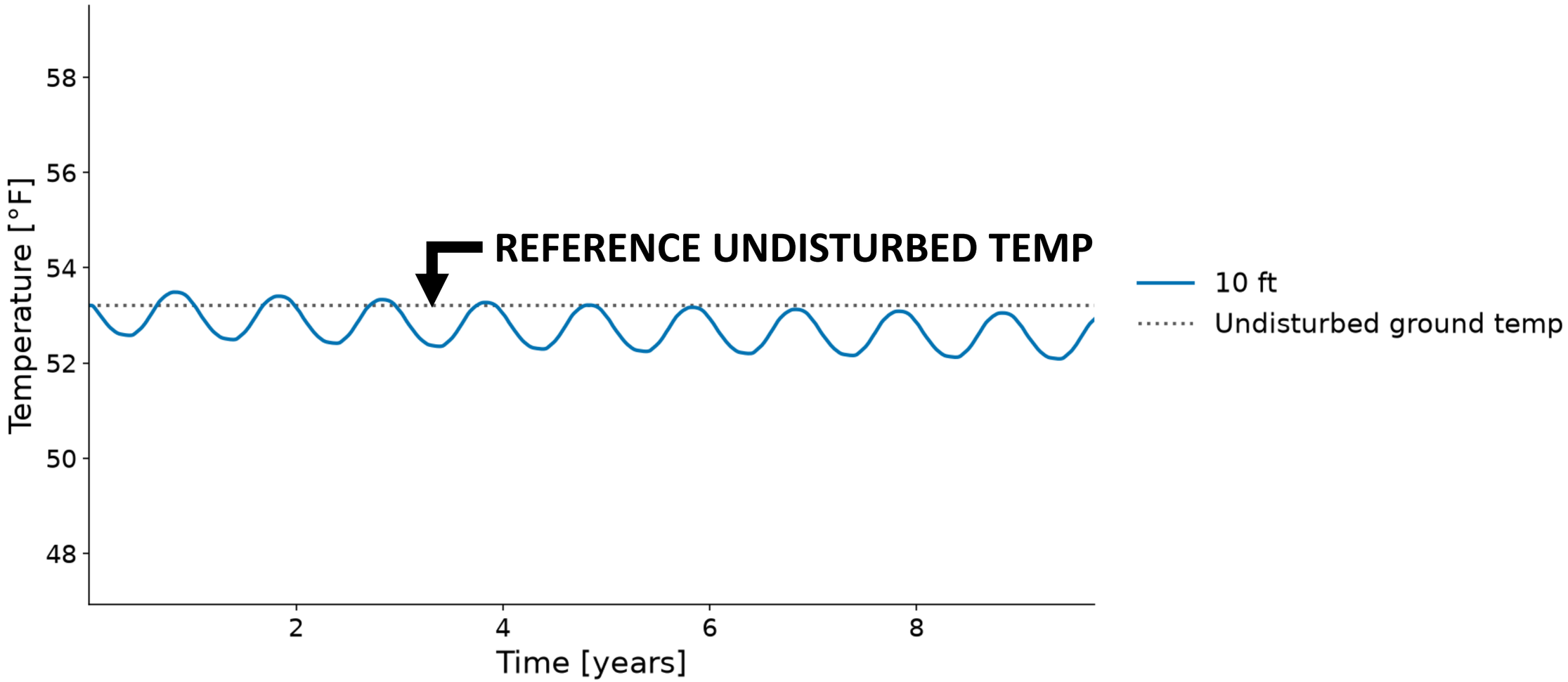
DERISKING: INTERNAL MONITORING BORE IN MODELICA

Increasing Ground Temperature Long Term Trend

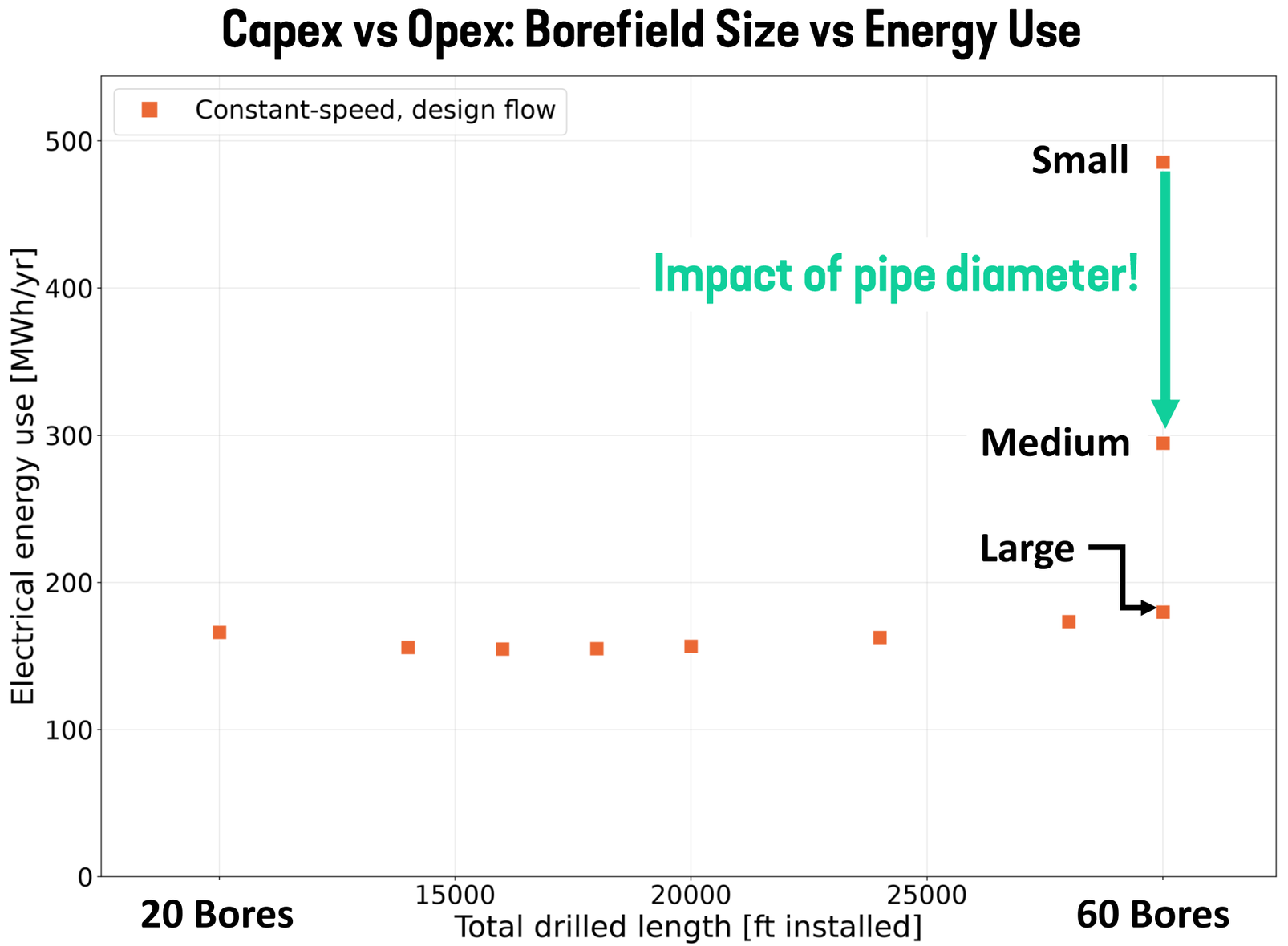


MONITORING BORE: AFTER IMPROVED PUMP CONTROL

Stable Ground Temperature Long Term Trend



NET ZERO DE-RISKING: ANNUAL ENERGY USE

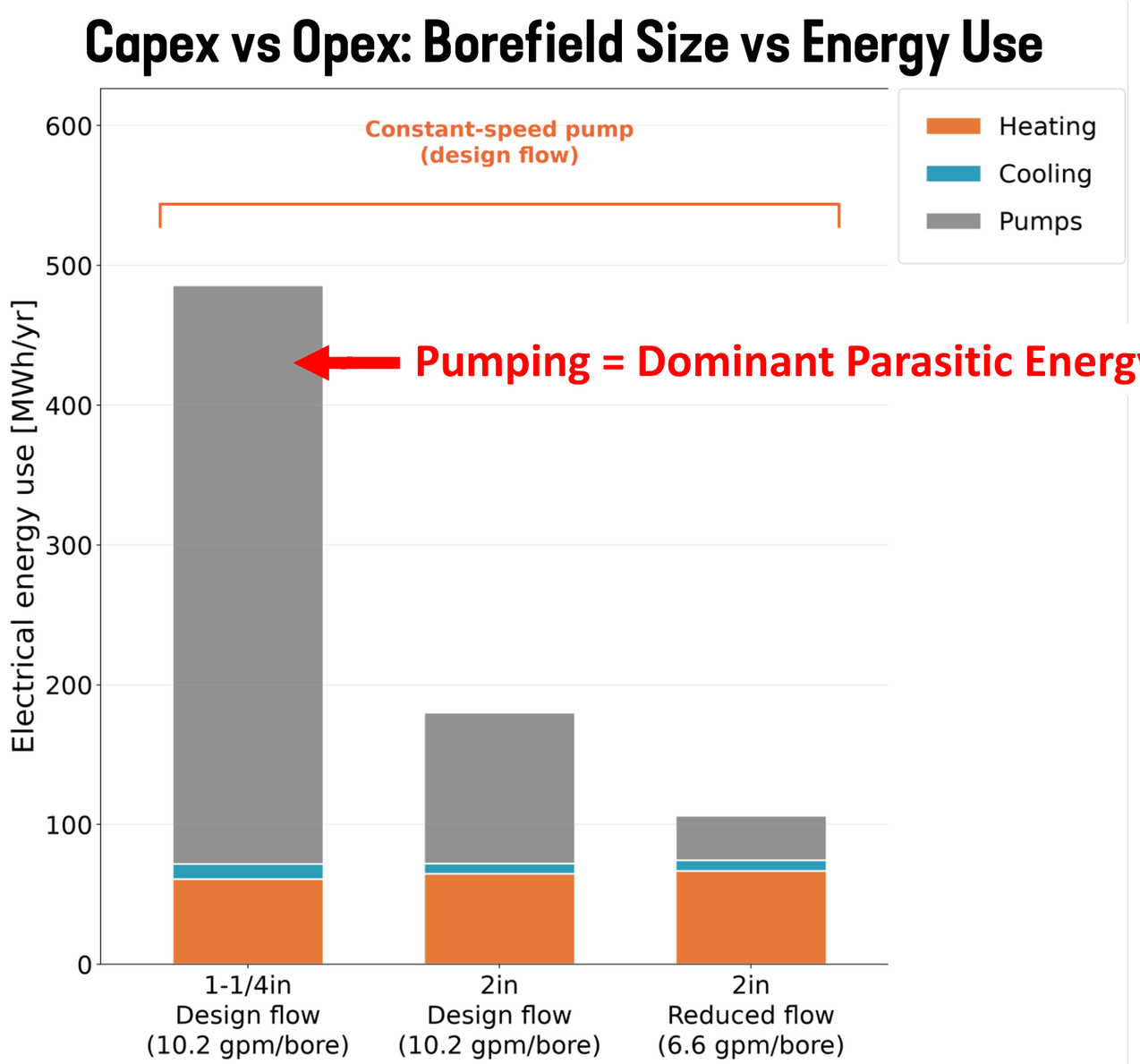


SMALL PIPE DIAMETER CASE
3x Energy Use

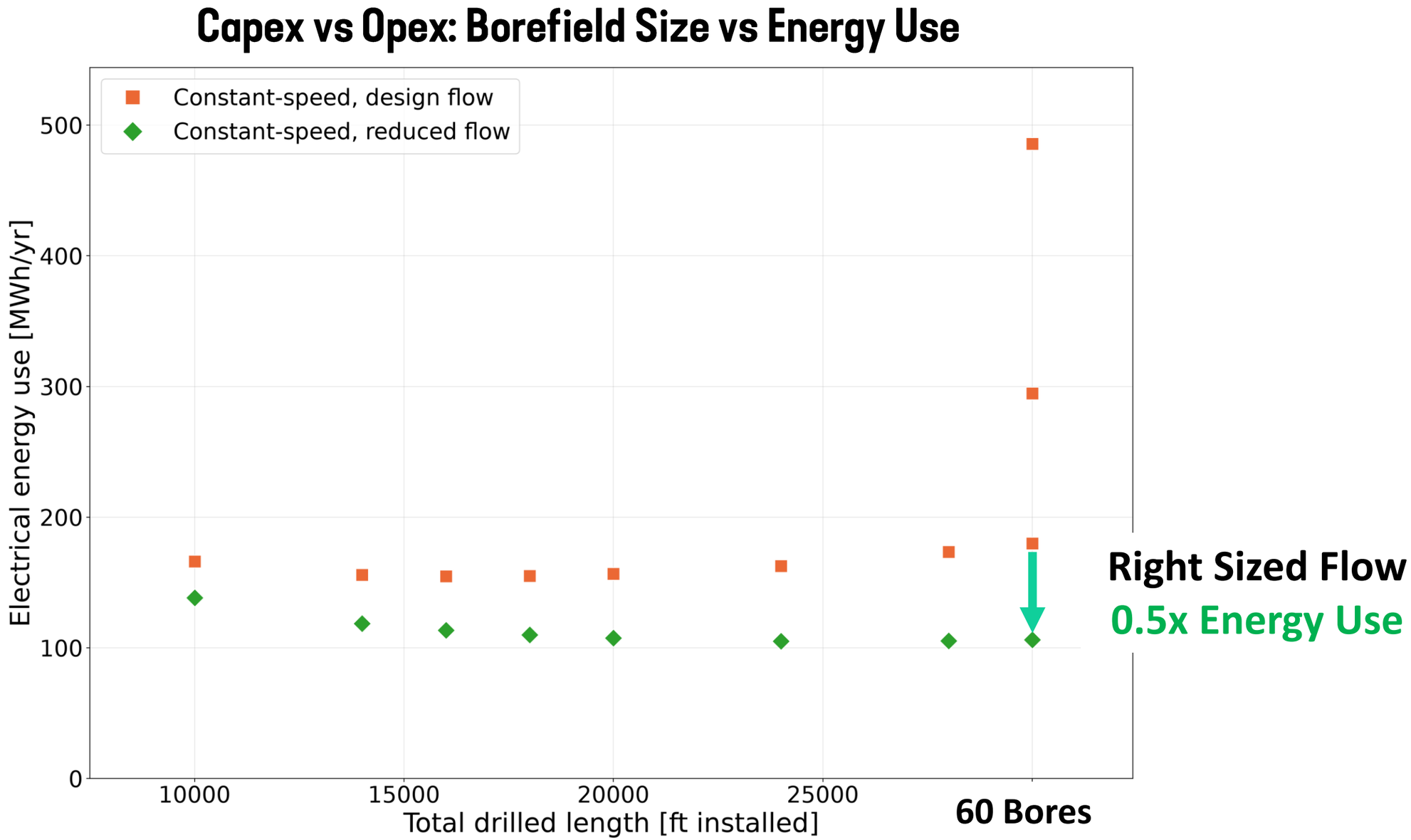
MEDIUM PIPE DIAMETER CASE
1.5x Energy Use

REFERENCE
60 Bore
Large Pipe

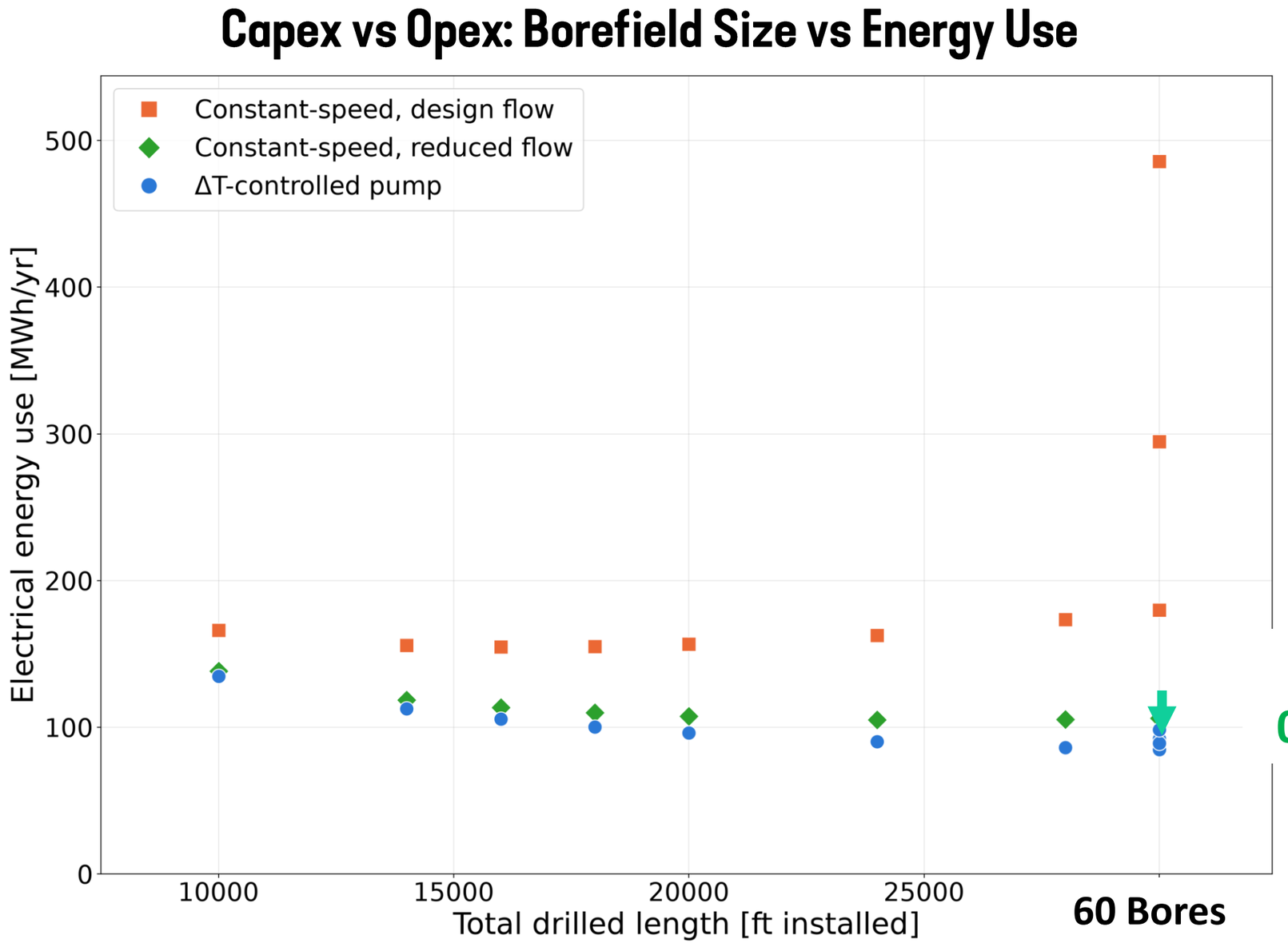
ANNUAL ENERGY USE BREAKDOWN: ISOLATE PROBLEMS



NET ZERO DE-RISKING: ANNUAL ENERGY USE



NET ZERO DE-RISKING: ANNUAL ENERGY USE

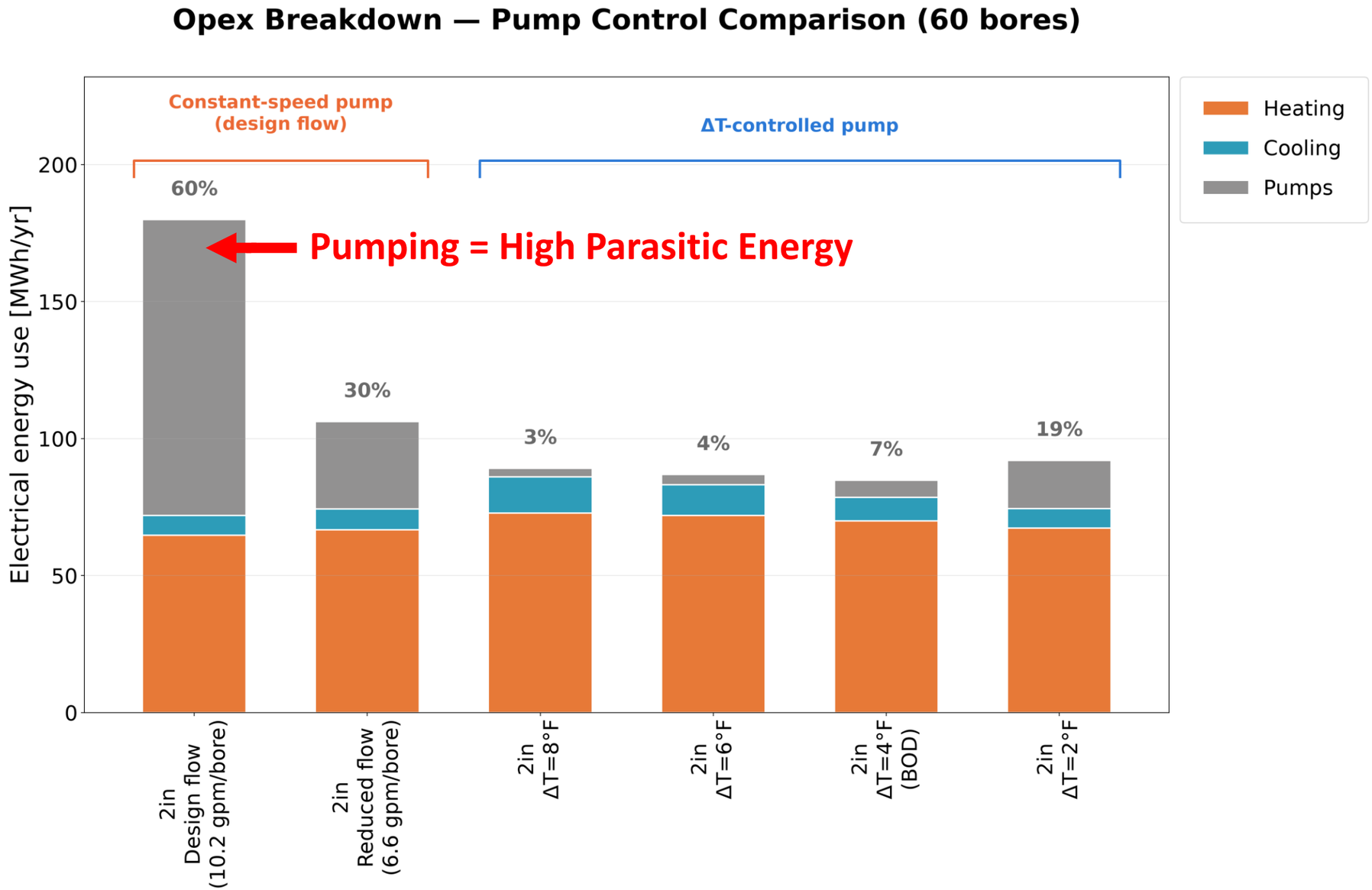


Better Control

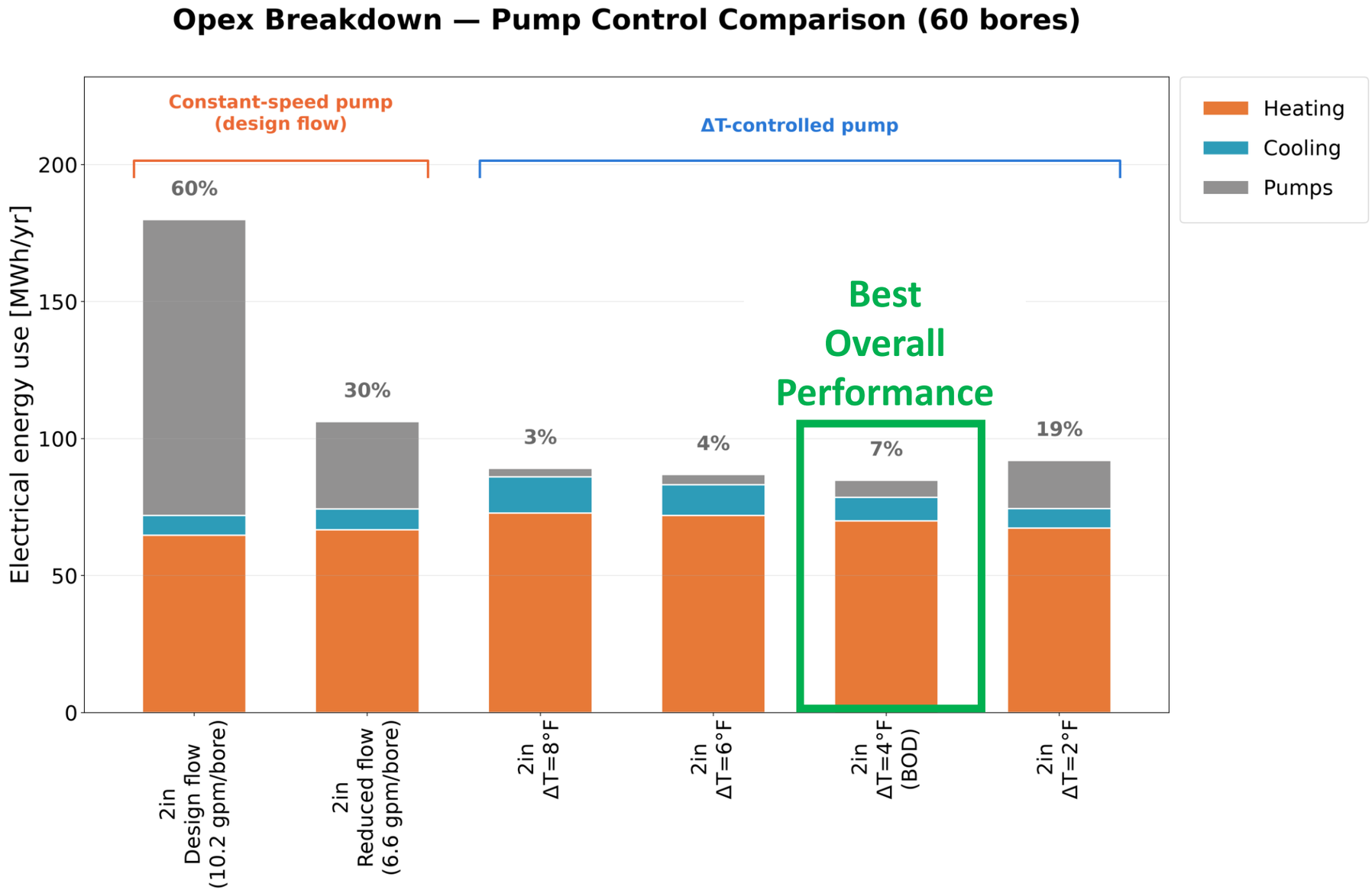
0.4x Energy Use

KU LEUVEN THERMAL SYSTEMS SIMULATION SMITHGROUP

ANNUAL ENERGY USE BREAKDOWN: CONTROLS



ANNUAL ENERGY USE BREAKDOWN: CONTROLS



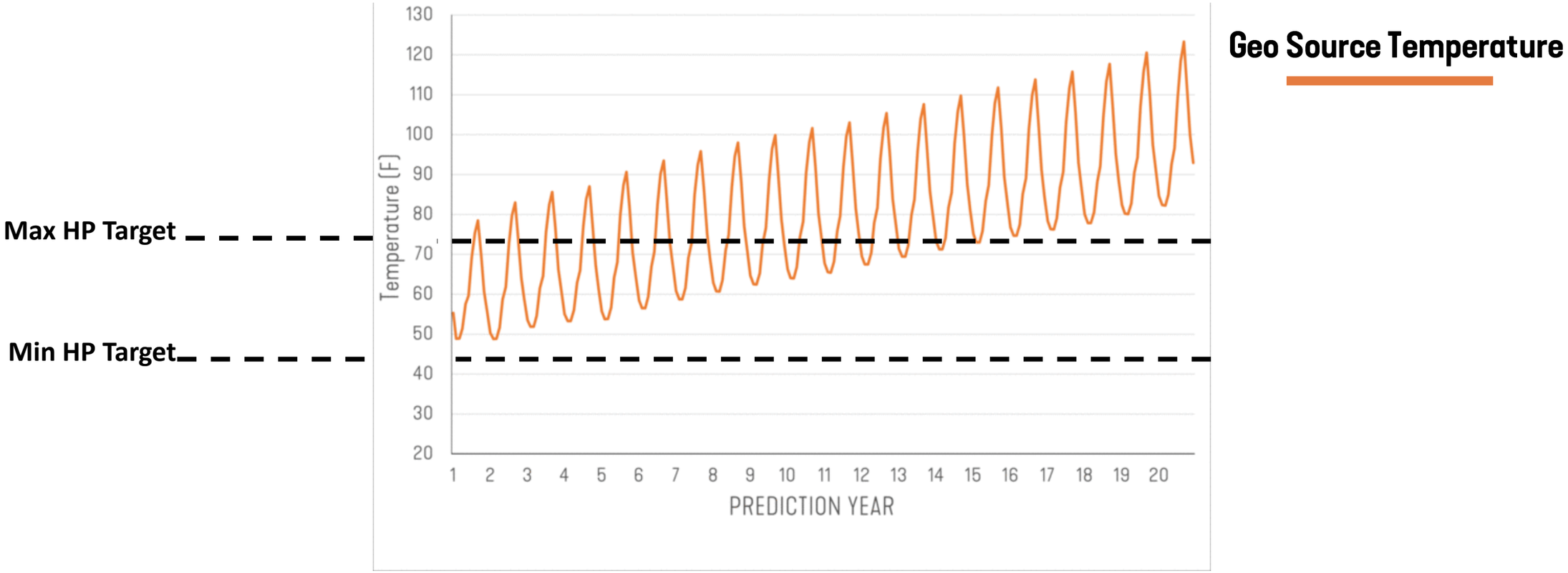
What value does modelica modeling provide?

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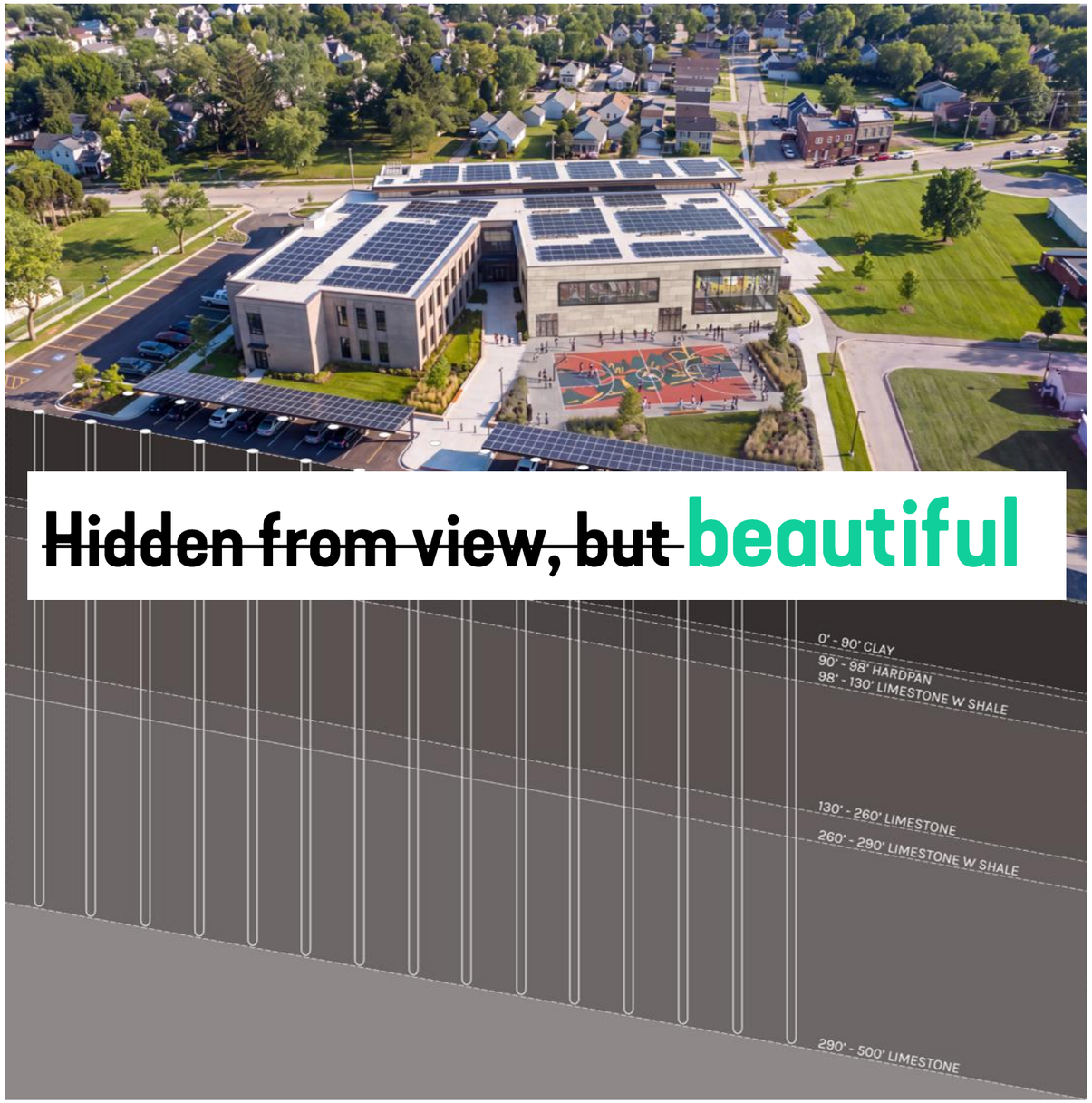
+ Multi-domain analysis is critical for de-risking
+ Multi-scale: ~~Buildings~~ District Scale
+ ~~Single~~ Multiple-developers
+ Future Proof

REMEMBER TO EXTRACT VALUE FROM MODELICA

GROUND HEAT EXCHANGER SOURCE TEMPERATURES (ENTERING HP)

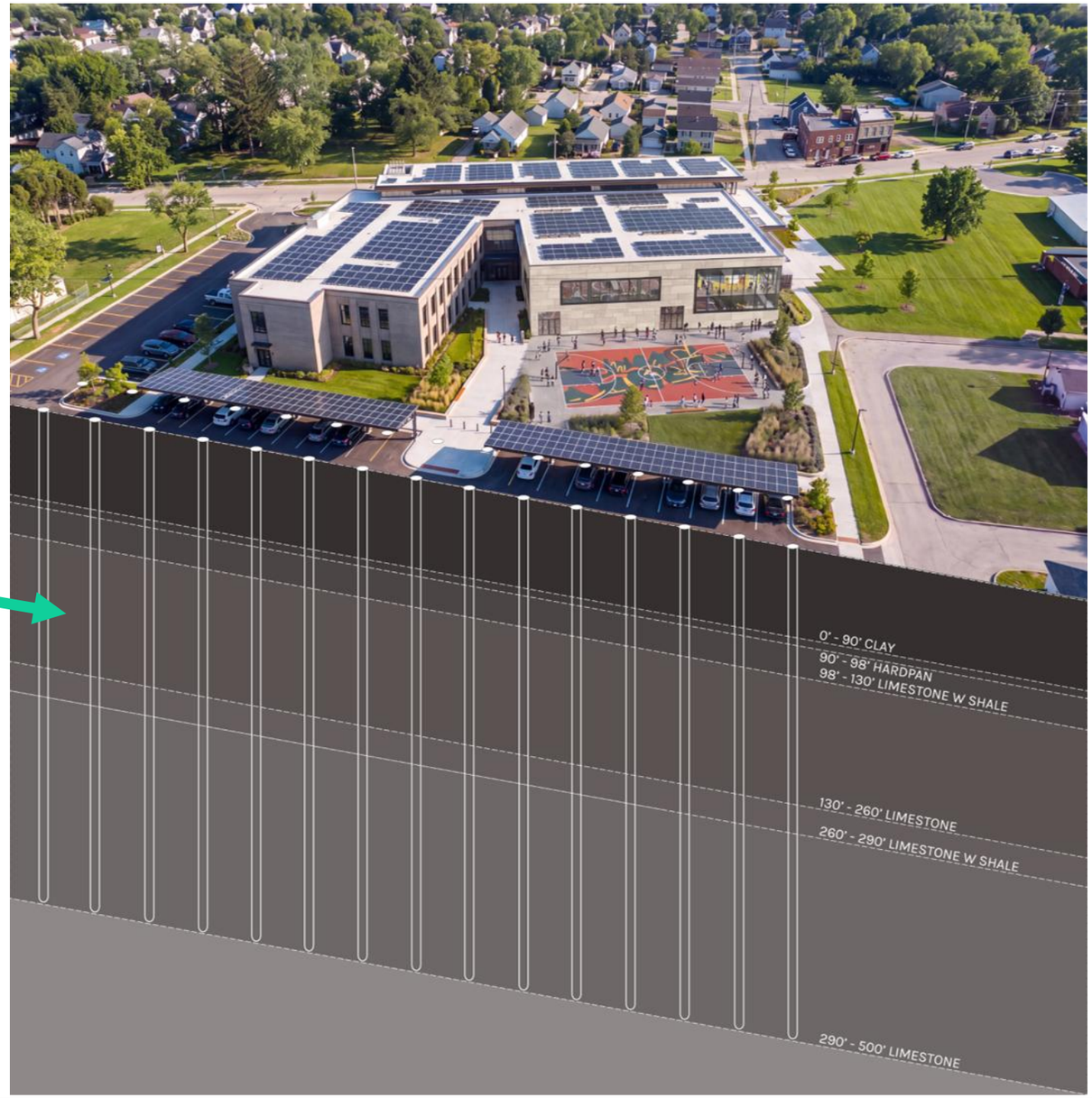


REMEMBER TO EXTRACT VALUE FROM MODELICA



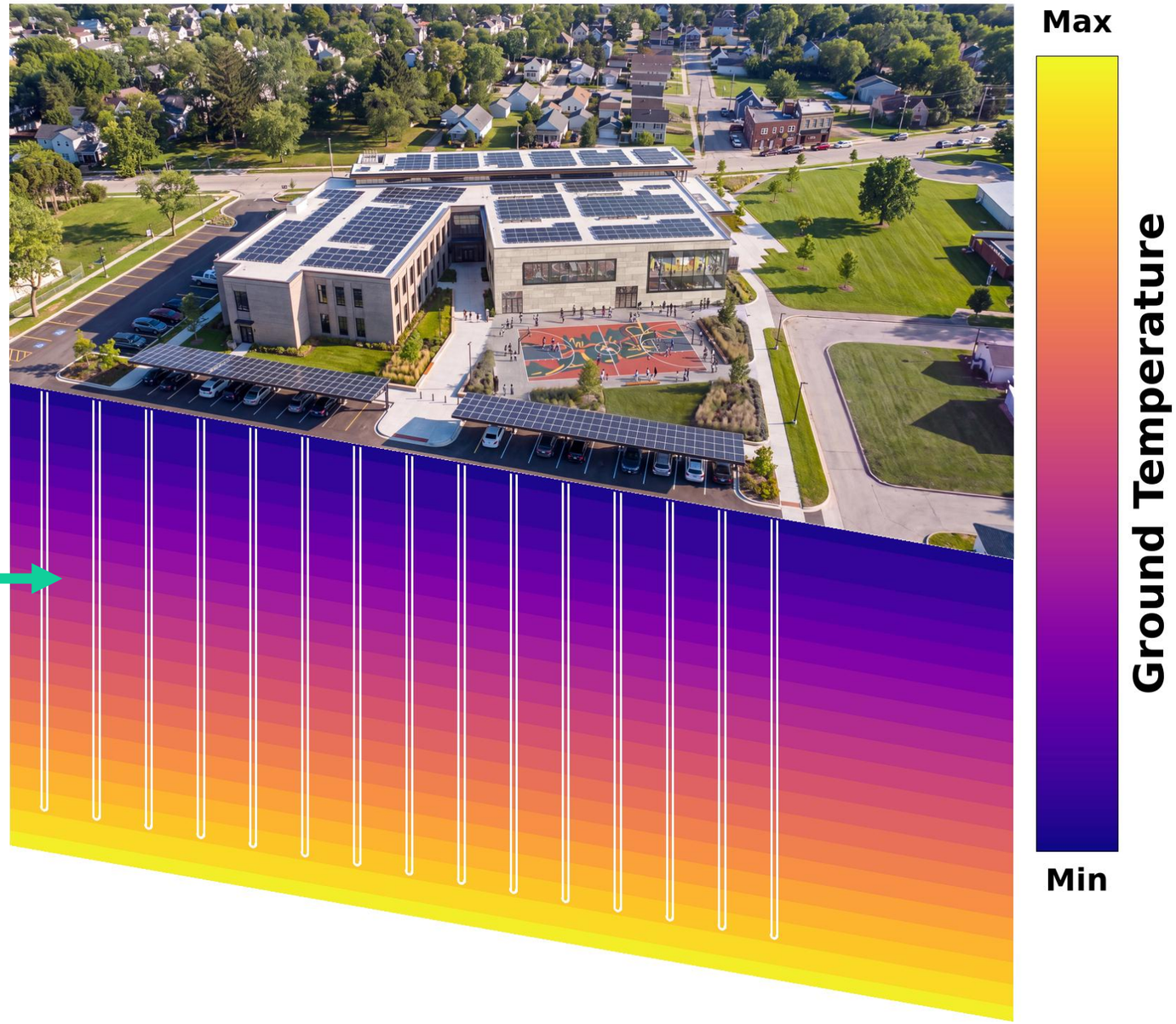
REMEMBER TO EXTRACT VALUE FROM MODELICA

CHECK OUT THE GROUND LAYERS!

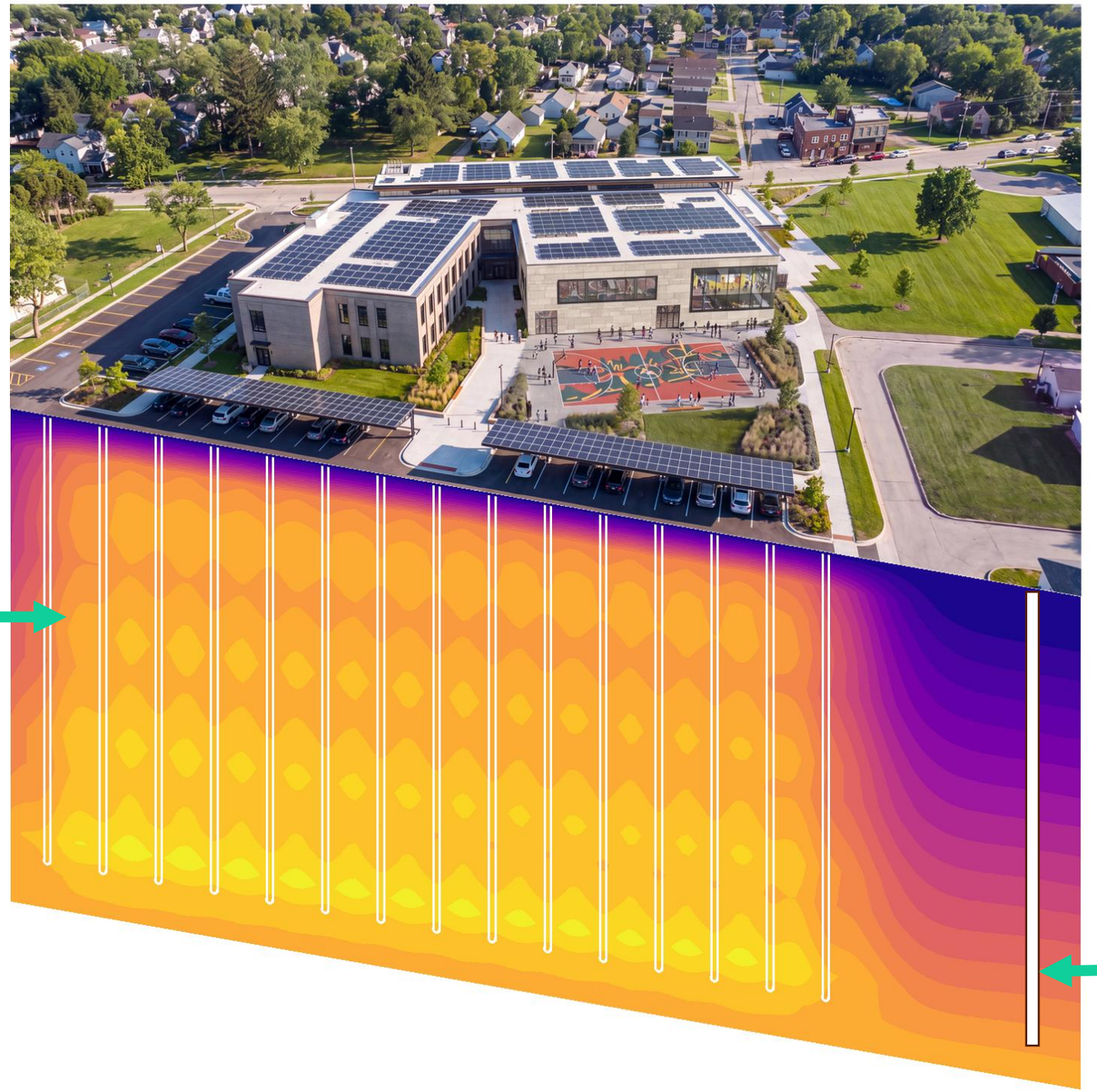


INITIAL GROUND CONDITIONS (BEFORE BUILDING LOADS)

CHECK OUT THE GROUND LAYERS NOW!



END OF YEAR GROUND CONDITIONS (AFTER BUILDING LOADS)

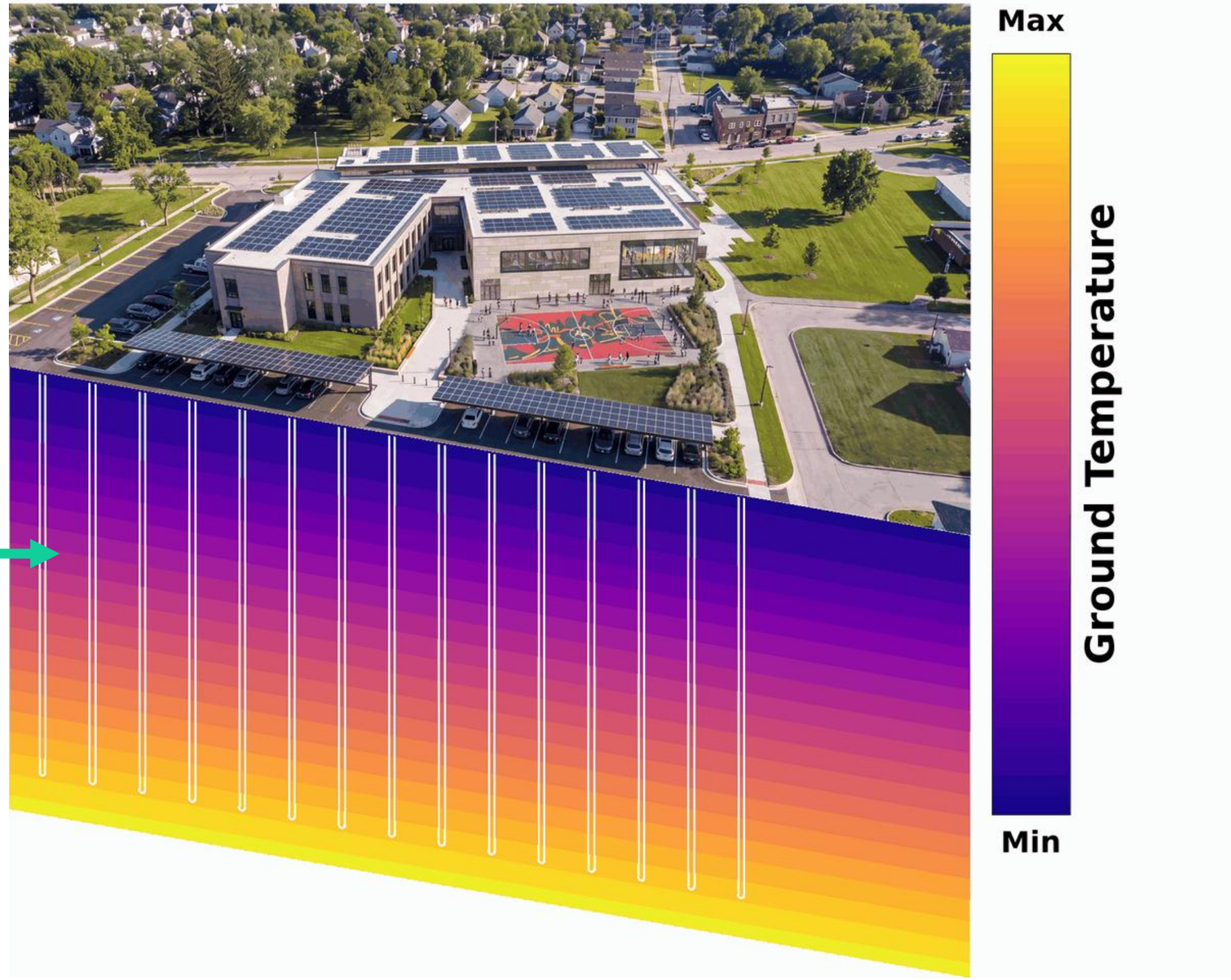


CHECK OUT THE GROUND LAYERS NOW!

MONITORING BORE

DYNAMIC GROUND CONDITIONS (AFTER BUILDING LOADS)

CHECK OUT THE GROUND LAYERS NOW!



Extracting Value from Modelica: De-Risking of GSHP Systems



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