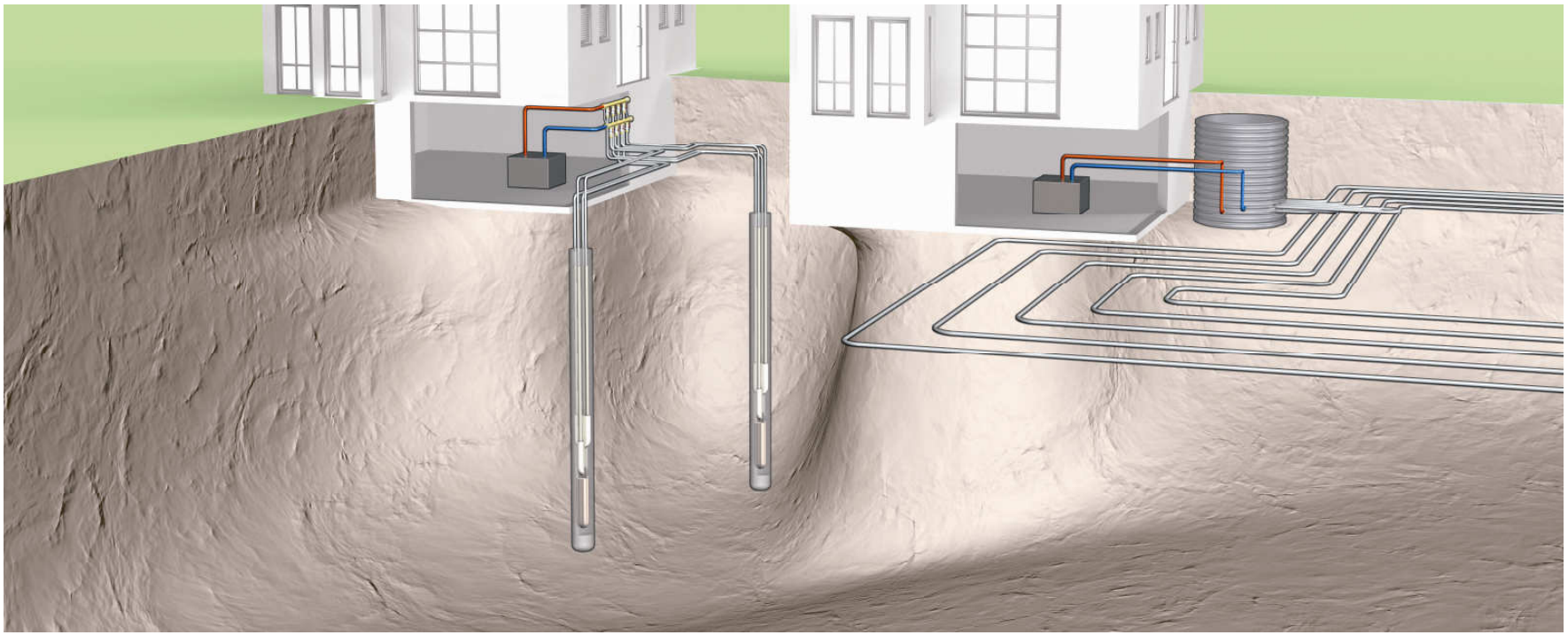
REHAU
Unlimited Polymer Solutions



RAUGEO™ GROUND LOOP HEAT EXCHANGE SYSTEM

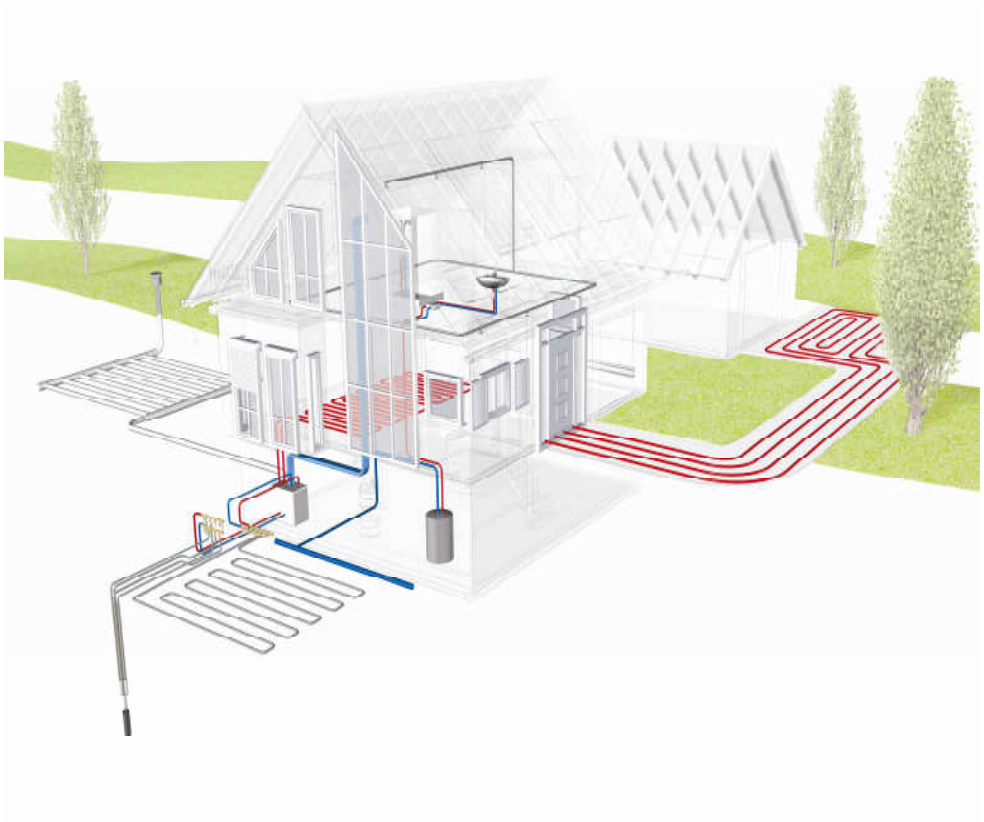
AN ENGINEERED GEOTHERMAL SOLUTION FOR QUALITY INSTALLATIONS
PRESENTATION TO THE COG ENERGY ADVISORY COMMITTEE – MAY 17, 2012

Construction
Automotive
Industry

SUSTAINABLE HEATING/COOLING GEOTHERMAL SYSTEMS

OUTLINE

- Who is REHAU ?
- Ground source geothermal overview
- Advantages of geothermal heat pump systems
- Geothermal system components
  - Heat pump technology
  - Ground loop pipes
  - Fittings
  - Manifolds
- Reference Projects



ABOUT REHAU

THE REHAU GROUP:
POLYMER MANUFACTURER, PEX PIONEER

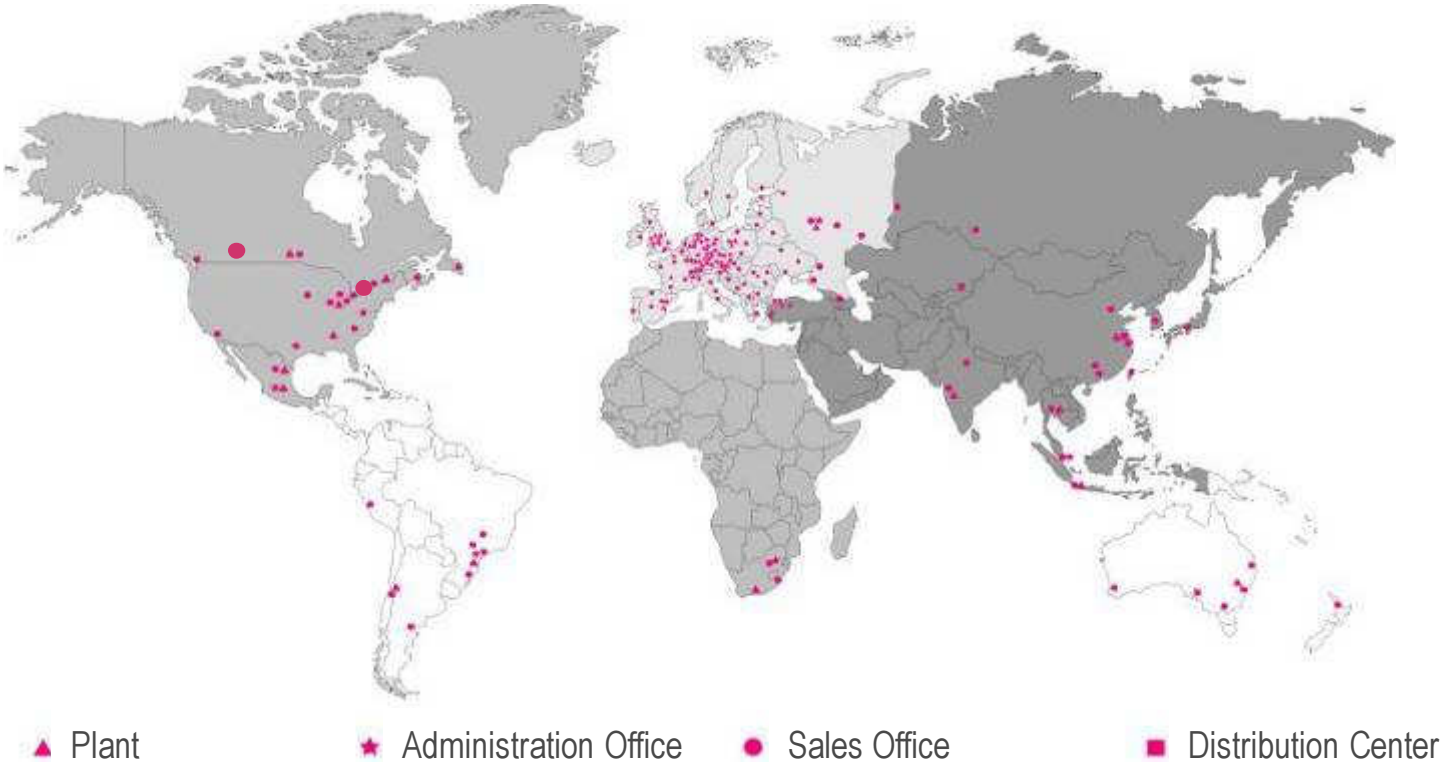
- Founded over 60 years ago in 1948 in the town of Rehau, Germany
- Independent, privately held company
  - Still family-owned
  - Started as “REHAU”, still ”REHAU”
- Approximately 15,000 employees at more than 170 locations around the world
- Pioneer of PEX piping systems starting in 1968
- More than one billion feet of PEX pipes installed worldwide
  - Five PEX plants globally, including NA’s plant in Alabama

REHAU NA Headquarters, Leesburg, VA

ALL AROUND THE WORLD

EFFECTIVE WORLDWIDE NETWORK

The worldwide network of REHAU locations together with suppliers, customers, research institutes and universities provides optimum results.



ALL AROUND THE WORLD

RIGHT AROUND THE CORNER

- Detroit
- Greensboro
- Chicago
- Minneapolis
- Dallas
- Grand Rapids
- Los Angeles

- St. John’s
- Winnipeg
- Montreal
- Toronto
- Moncton
- Vancouver

- Celaya
- Monterrey

THE REHAU GROUP

“UNLIMITED POLYMER SOLUTIONS”

The performance capability of REHAU is unmatched with regard to its breadth and quality. Many of our polymer-based products and services in the areas of construction, automotive and industry are today’s world leaders.

CONSTRUCTION

- Building Technology
- Windows and Doors
- Civil Engineering and Infrastructure
- Renewable Energy

AUTOMOTIVE

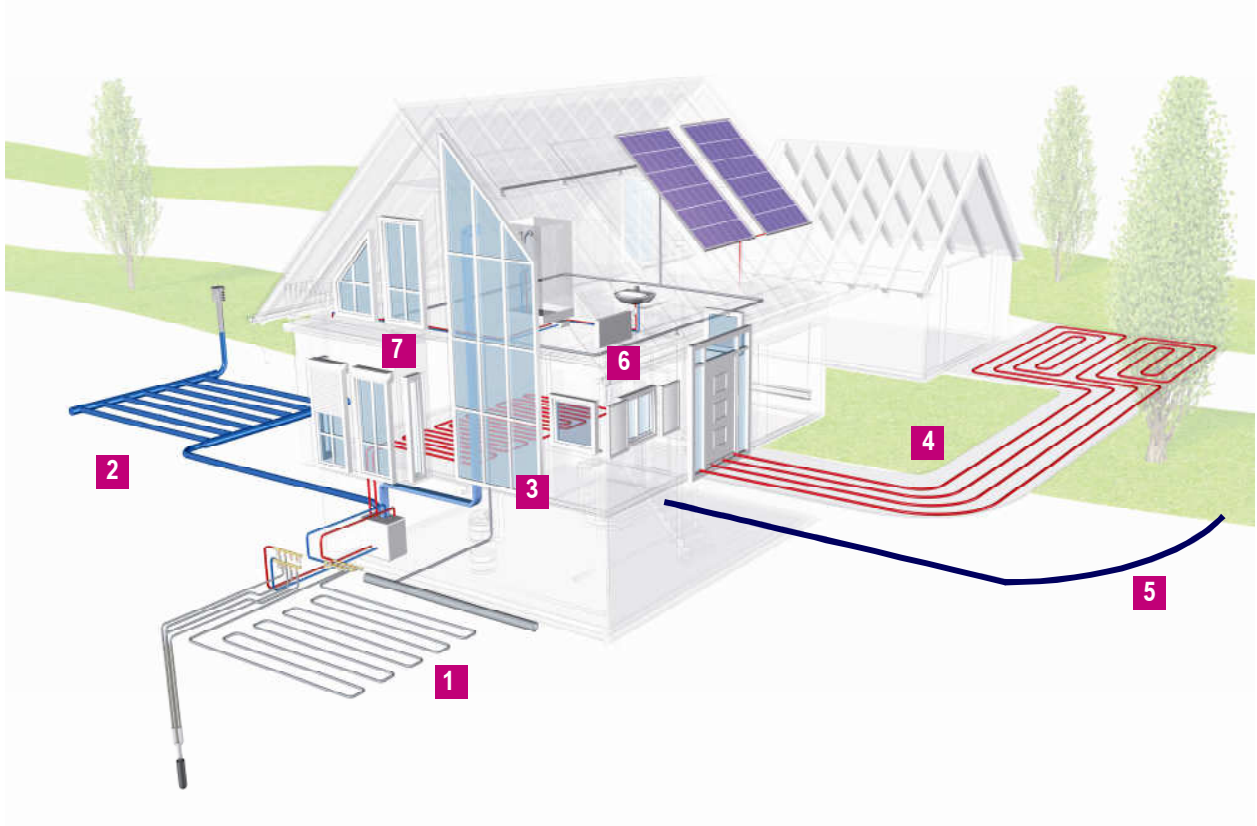
- Exterior
- Sealing
- Aftermarket
- Water and Air Management

INDUSTRY

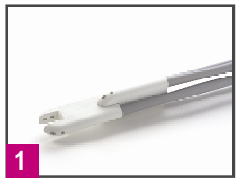
- Furniture
- Appliance
- Industrial Developments

REHAU CONSTRUCTION

SMART SOLUTIONS FOR SUSTAINABLE DESIGN



RAUGEO™ Geothermal System



REHAU ECOAIR™ GAHE System

Radiant Heating & Cooling

Snow and Ice Melting

REHAU QUALITY ENERGY EFFICIENCY

Window and Door Designs

PEX Plumbing Pipe

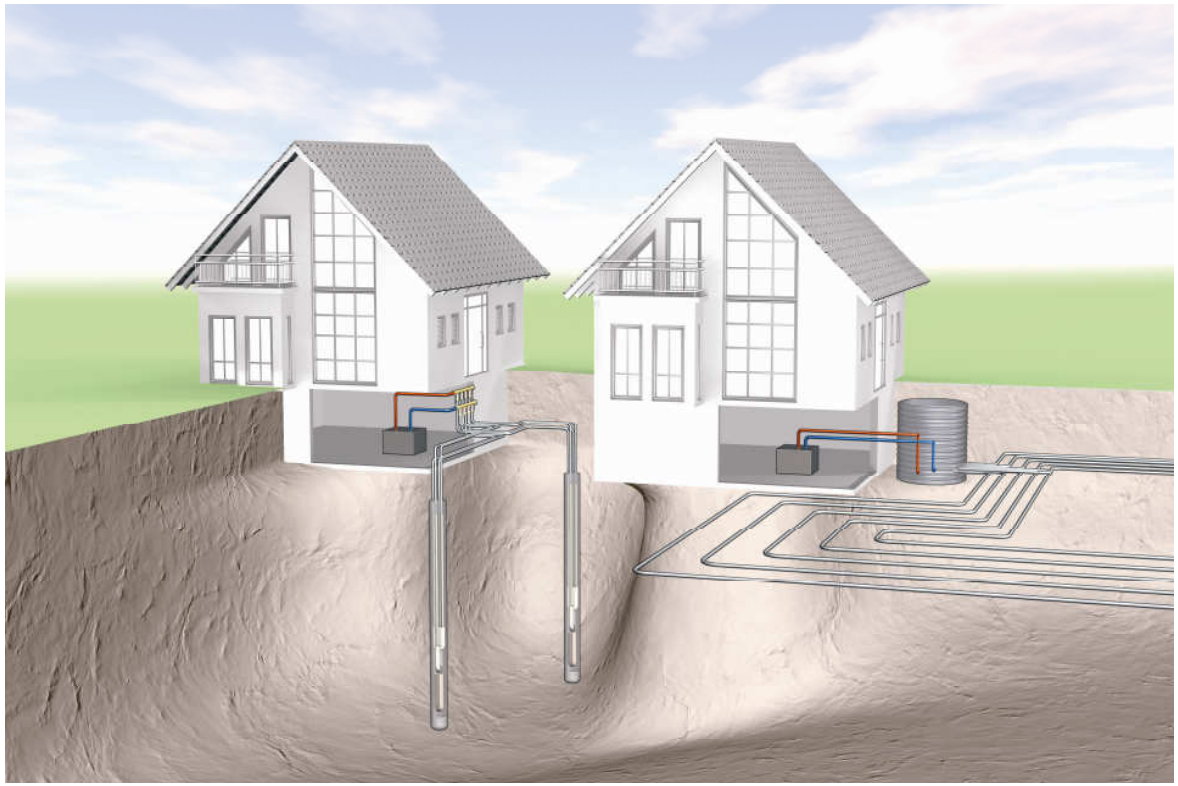
MUNICIPEX Water Service Line

GEOTHERMAL OVERVIEW

TERMINOLOGY

Ground source heat pump system includes:

- Ground loops
- Heat pump and controls
- Pumping systems
- Indoor distribution

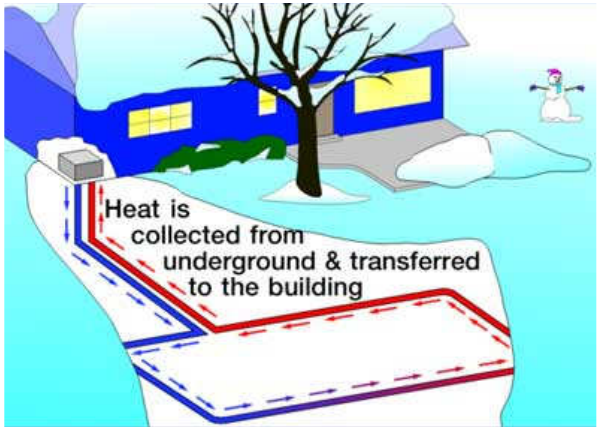


GEOTHERMAL OVERVIEW

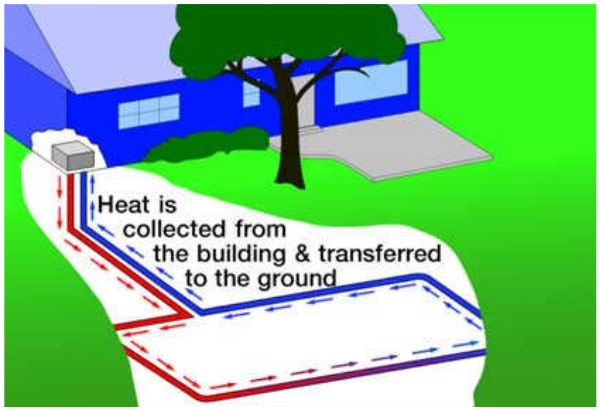
TAPPING THE EARTH'S STORED ENERGY

PRINCIPLES

- A geothermal system does not directly burn fossil fuel; electricity is used for pumps
- A geothermal system can be used to heat or cool a space
- When heating, a geothermal system collects and concentrates heat from the ground and delivers it to the building
- When cooling, a geothermal system collects and concentrates heat from the building and delivers it to the ground
- **The ground acts like a "heat battery"**
  - The piping ground loop is like the battery cables



Heat pump in winter



Heat pump in summer

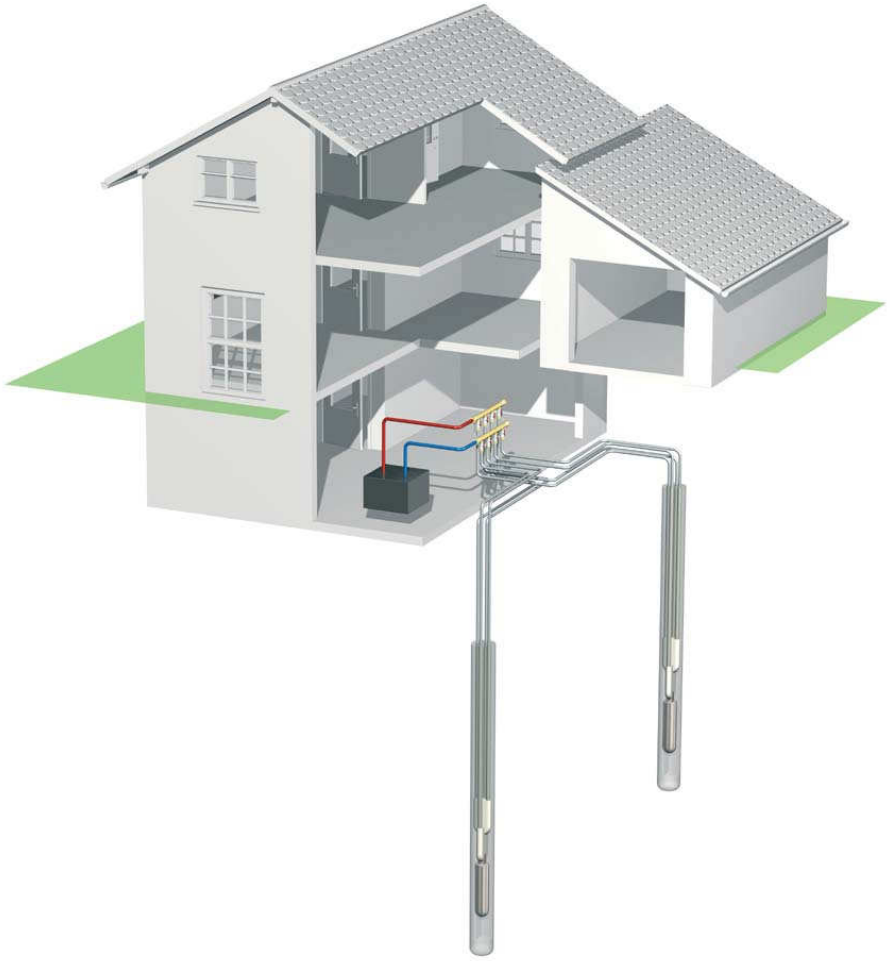
ADVANTAGES OF GEOTHERMAL HEAT PUMP SYSTEMS

ENERGY SAVINGS, COST SAVINGS, REDUCED EMISSIONS, RECOGNITION

- Geothermal systems are “the most energy-efficient, environmentally clean and cost-effective space conditioning systems available today.”
  - U.S. Department of Energy

In addition:

- Energy savings
- Cost savings
  - Operating costs
  - Reduced maintenance costs
  - No external fuel tanks
  - No external venting
- Reduced emissions
  - Reduced “carbon footprint”
- Green status or recognition



ADVANTAGES OF GEOTHERMAL HEAT PUMP SYSTEMS

ENERGY SAVINGS, COST SAVINGS, REDUCED EMISSIONS, RECOGNITION

ENERGY SAVINGS

Heating

30% - 70% energy savings*

Cooling

20% - 50% energy savings*

*According to the EPA, and versus standard electric resistance heating and air-to-air heat pump cooling. Actual cost savings may be even higher

ADVANTAGES OF GEOTHERMAL HEAT PUMP SYSTEMS

ENERGY SAVINGS

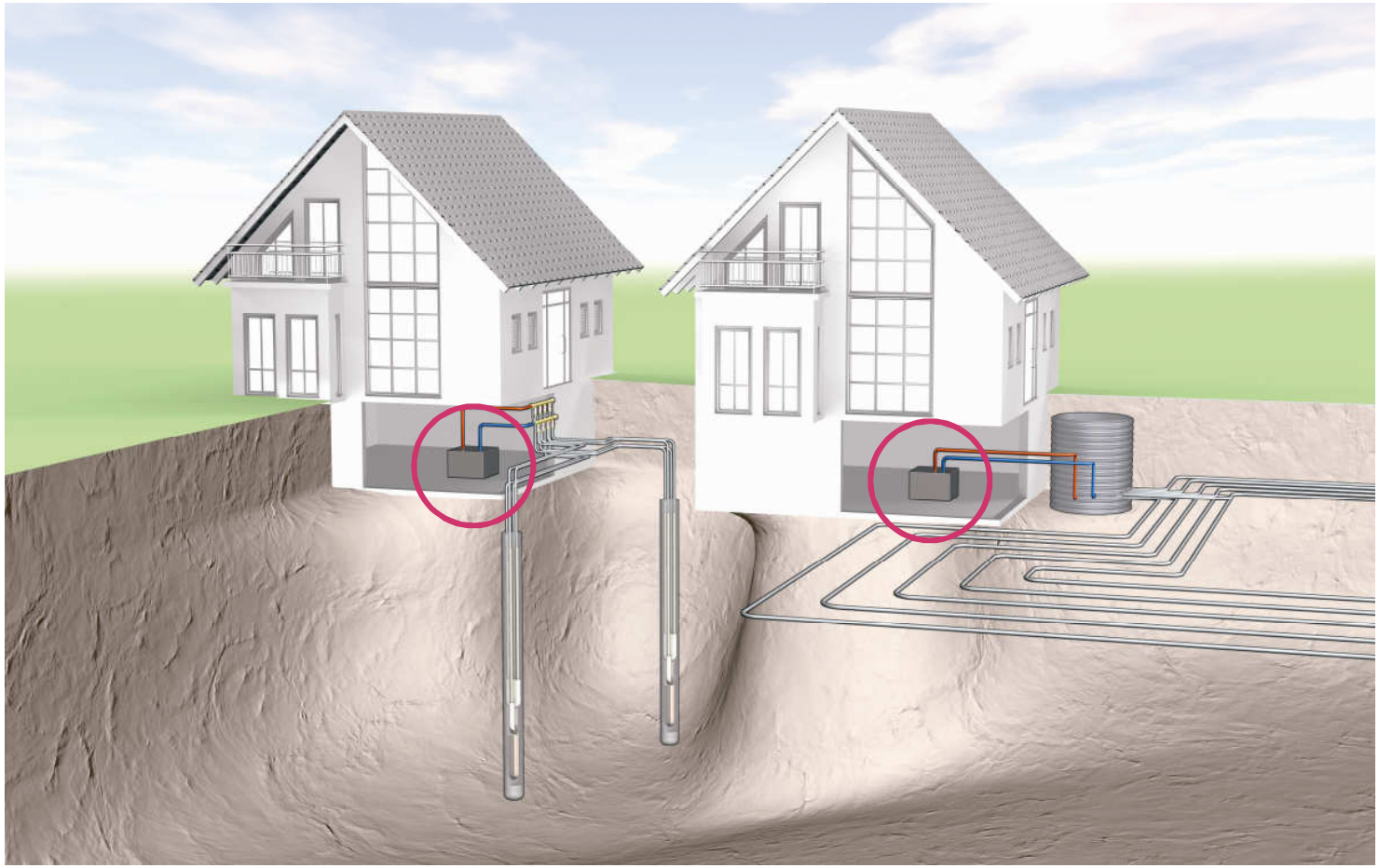
COST SAVINGS: $USD/ 1 MILLION BTU. SAMPLE COSTS, YOUR COST MAY VARY

Energy Source	Cost / Energy Unit (Efficiency)	Net Cost (USD) $/1,000,000 BTU
Electrical Resistance	$0.08/kWh (@ 100%)	$23.40
Propane (boiler)	$2.75/Gal (@ 88%)	$34.00
Fuel Oil (boiler)	$2.50/Gal (@ 85%)	$21.00
Natural Gas (condensing boiler)	$1.30/Therm (@ 93%)	$14.00
Geothermal (heat pump)	$0.08/kWh @ 4.0 COP (@ 400%)	$5.69

Net energy cost for 4.0 COP geothermal heat pump = 59% savings vs. natural gas

GEOTHERMAL SYSTEM COMPONENTS

CLOSED LOOP PIPING SYSTEMS



Vertical Wells *Horizontal Trenches*

GEOTHERMAL SYSTEM COMPONENTS

GROUND SOURCE HEAT PUMP

TYPE: WATER-TO-AIR

- Most common heat pump type
- Residential and commercial
- Heating and cooling are provided through air coil
  - Works with forced air distribution
- A desuperheater coil may be included to extract additional heat to produce domestic hot water
- COP of 4.5 or more (depending on the model)
- EER of 16 to 22 (depending on the model)

GEOTHERMAL SYSTEM COMPONENTS

GROUND SOURCE HEAT PUMP

TYPE: COMBINATION

- Residential or commercial
- Works ideally with hydronic radiant heating distribution
  - Water-to-air for cooling and water-to-water for radiant heating
- A desuperheater coil may be included to extract additional heat to produce domestic hot water
- COP of 4.5 or more (depending on the model)
- EER of 16 to 22 (depending on the model)

GROUND LOOP PIPES

POLYETHYLENE PIPES & CROSS-LINKED POLYETHYLENE PIPES

- Background
- U-bend fabrication
- Connection technique
- Headering concept

GROUND LOOP PIPES

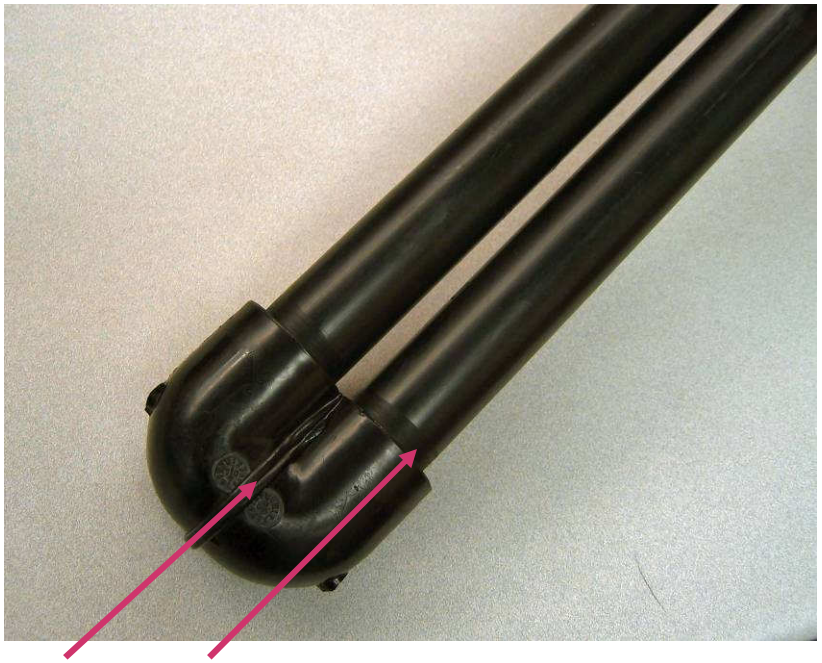
POLYETHYLENE PIPES

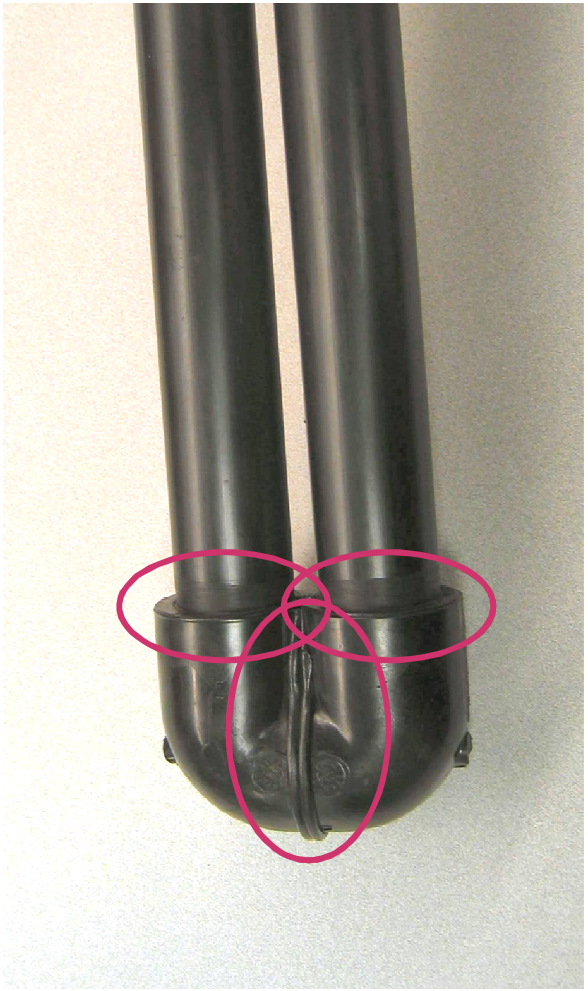
GROUND LOOP PIPES

POLYETHYLENE PIPES WITH FUSED U-BEND

Fusion-welded HDPE single U-bend:

- Joints may be butt-fused (fitting-to-fitting) or socket-fused (pipes-to-fittings)





Butt and socket fusion HDPE U-bend connection

GROUND LOOP PIPES

HDPE BUTT FUSION TECHNOLOGY

EXCERPT FROM PPI TR-33: “GENERIC BUTT FUSION JOINING PROCEDURE…”

“The principle of heat fusion is to heat two surfaces to a designated temperature, then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion.”

- “Field-site butt fusions may be made readily by trained operators using butt-fusion machines that secure and precisely align the pipe ends for the fusion process.“
- The six steps involved in making a butt fusion joint are:
    1. Securely fasten the components to be joined
    2. Face the pipe ends
    3. Align the pipe profile
    4. Melt the pipe interfaces
    5. Join the two profiles together
    6. Hold under pressure

Socket fusion HDPE connection

GROUND LOOP PIPES

HDPE BUTT FUSION TECHNOLOGY

How to join these pipes?

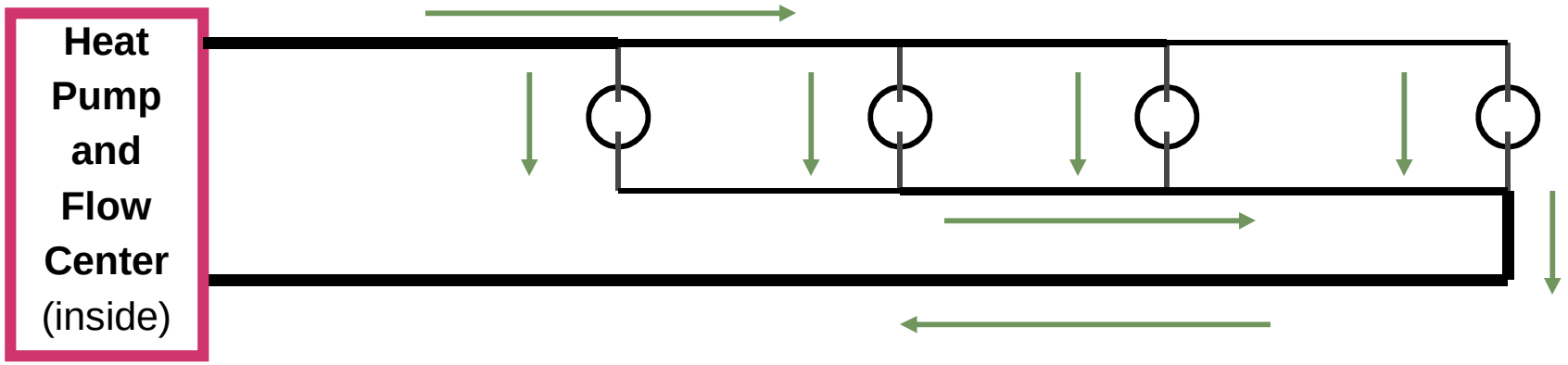
- Pipes must be connected in some sort of header
- Fusion becomes more of a challenge in wet, cold conditions
- Typical trench conditions following rain or reaching the water table

GROUND LOOP PIPES

TRADITIONAL HDPE HEADERS

Reverse-return piping arrangement:

- Goal: equal flow through all boreholes
- Field assembled manifolds of fused HDPE tees and pipes
- Headers need to step-up and step-down to “force” the fluid flow to be equal to all wells
    - Larger diameter header pipes are costly and require extra fusion equipment
- Purging is a challenge, requiring high velocity through purge carts, lots of water and time



Example of step-up, step-down reverse return header with a four-well vertical system flowing 12 GPM

GROUND LOOP PIPES

TRADITIONAL HDPE HEADERS

HDPE “Close Manifold”:

- Field assembled manifolds of fused HDPE tees
- Reducing tees need to “step-up” or “step-down”
- Each piped U-bend must be within 5% length of each other to avoid “short circuits”
- Purging is a challenge, requiring high velocity through purge carts, lots of water and time

GROUND LOOP PIPES

CROSSLINKED POLYETHYLENE (PEXa) PIPES

WHAT IS CROSSLINKED POLYETHYLENE?

ENHANCED POLYETHYLENE

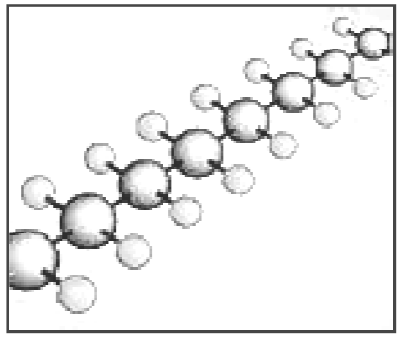
- **PEX** is **P**oly **E**thylene that has been chemically or physically modified – crosslinked (**X**) to cause the molecules to link together, permanently

- Once PE is crosslinked into PEX, it becomes a thermo-set plastic, meaning that it cannot be melted and reshaped

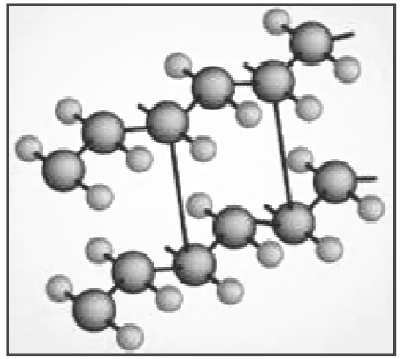
- Compared to standard PE pipes, PEX has desirable high temperature strength, reduced sensitivity to notching, improved chemical resistance, and high flexibility

- There are 3 commercial processes or methods:
  - PEXa: High-pressure peroxide
  - PEXb: Silane (“moisture cure”)
  - PEXc: Radiation (“electron beam” or “nuclear”)

- **PEXa** was pioneered by REHAU, with development beginning in 1968 and series production in 1972



PolyEthylene Molecule



PEXa “molecule”

GROUND LOOP PIPES

PEXa CAPABILITIES AND LIMITS

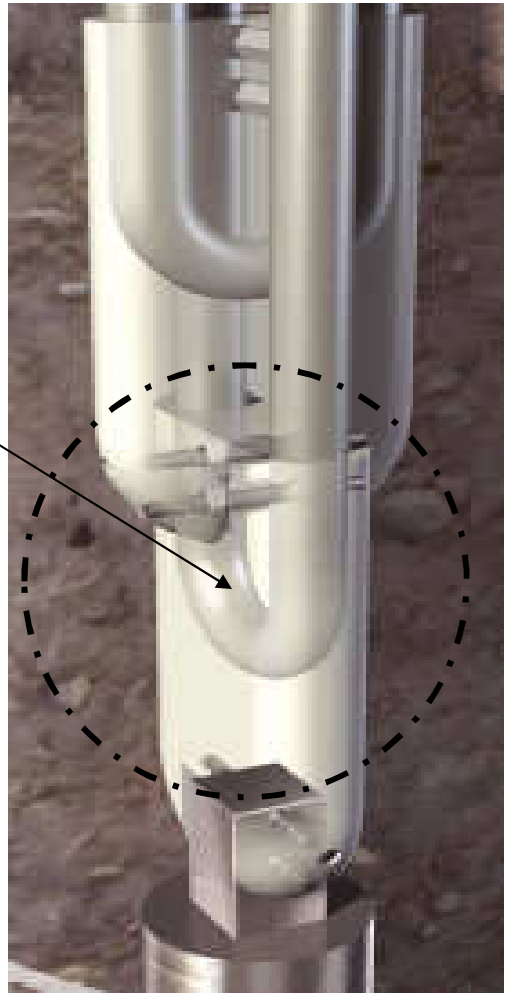
FLEXIBILITY AND KINKING RESISTANCE

Flexibility:

- PEXa is more flexible than other piping materials
- Pipes are less likely to kink when bending quickly or too tightly
- Flexible to below **-40℉ (-40℃)** ; will not become brittle or break at cold temperatures
- Bend radius as tight as **5x** the OD is possible without heating
- Bend radius as tight as **3x** the OD is possible *with* heating

PEXa U-bend:

- Continuous pipe using factory-made U-bend
- No joints/connections in the well
- No flow obstructions in connections
- No chance of failure due to fittings in the borehole



GROUND LOOP PIPES

PEXa DOUBLE U-BEND

CONTINUOUS U-BEND WITHOUT JOINTS

Two U-bends per hole is possible:

- Use of the double U-bend can increase borehole thermal conductivity
  - More energy per well
- Can reduce the amount of borehole footage by 20%*, or more
  - Lower drilling costs
  - More compact well field means faster installations with drill rigs

**Depends on thermal conductivity of the well and soil conditions*

GROUND LOOP PIPES

PEXa ENVIRONMENTAL STRESS CRACK RESISTANCE

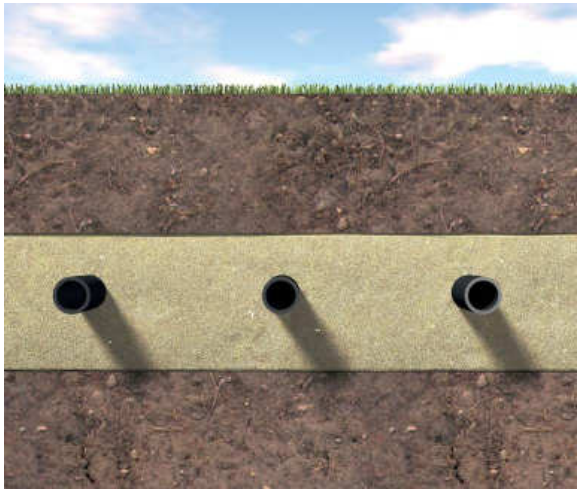
RESISTANT TO: IMPACT, SLOW CRACK GROWTH, ROCK IMPINGEMENT, SCRATCHES

HDPE requires special care:

- Pipes may be damaged from rocky soils and backfill
- Sand bedding may be required
- Sand may reduce thermal conductivity

PEXa has high impact resistance:

- Will not crush, kink or collapse when proper backfill techniques are used
- Superior notch resistance
- Will not dent or crush from typical impacts



HDPE: Sand bedding required

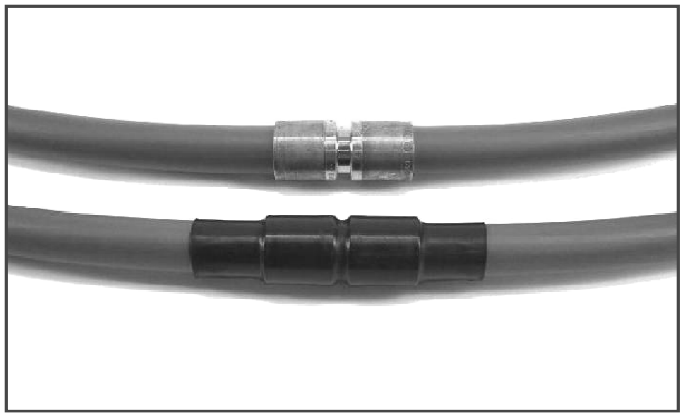
PEXa can usually use excavated material

GROUND LOOP PIPES

ASTM F2080 COLD-EXPANSION COMPRESSION-SLEEVE FITTING FOR PEXa PIPES

OVERVIEW

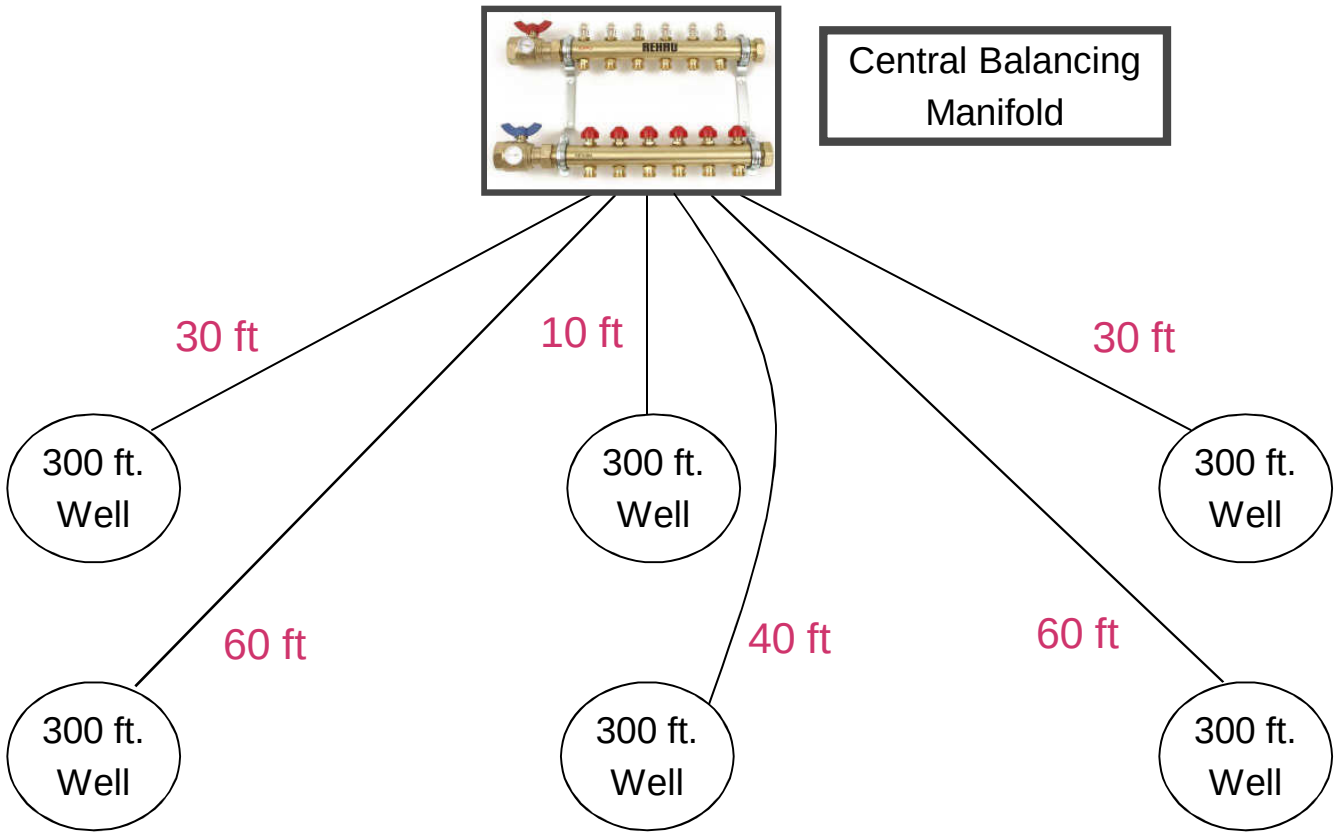
- Specifically for PEXa pipes
- Reliable, worry-free connection
  - Stronger than the pipe itself
- Large inside diameter
  - Excellent flow rates
- May be buried in concrete or ground
  - Heatshrink tubing or waterproof tape protects against corrosion
- Simple and safe to assemble:
  - No heat is required, no electricity
  - Installation is safe in the rain, in the cold
  - Ready for pressure test immediately
  - Assembly procedure and time are not sensitive to hot or cold, dry or wet conditions



F2080 coupling cutaway

GEOTHERMAL SYSTEM MANIFOLDS

CENTRAL BALANCING MANIFOLD CONFIGURATION
WELL DEPTHS MAY BE EQUAL



Note: Space between wells must be determined by designer

GEOTHERMAL SYSTEM MANIFOLDS

BALANCING MANIFOLDS

EXAMPLE

Balancing Manifold:

- 1 1/4" ID or greater
- Visual flow gauges
  - Measure flow to each borehole
- Flow control/balancing valves
  - Balance flow

- Access and control of each loop
- Only one borehole lost in the unlikely event of a leak (unlike reverse-return headers)
- Boreholes can be of different length

Up to 20 drops

GEOTHERMAL SYSTEM MANIFOLDS

WHERE TO INSTALL MANIFOLDS?

EITHER INDOORS, OR IN THE WELLFIELD INSIDE A BURIED VAULT

GEOTHERMAL SYSTEM MANIFOLDS

WHERE TO INSTALL MANIFOLDS?

EITHER INDOORS, OR IN THE WELLFIELD INSIDE A BURIED VAULT

ARCADIA UNIVERSITY

GLENDALE, PA

Project:

- The Commons is Philadelphia-area Arcadia University's 62,000 ft^2 addition to its Kuch Athletic and Recreation Center

System Used:

- Vertical boreholes with horizontal circuits using PEXa ground loop heat exchangers

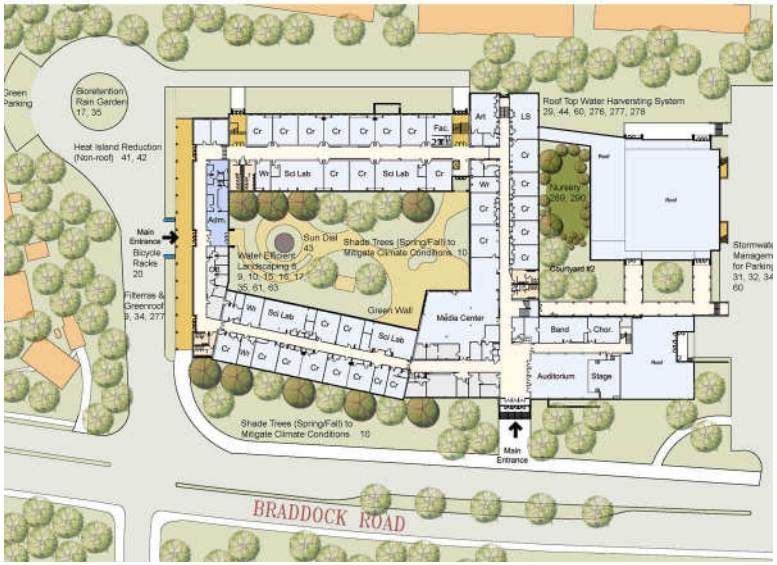
Description:

- 42 boreholes each approximately 396 ft deep
- More than 52,000 ft. of 1" RAUGEO PEXa, and 17,000 ft. of 1 1/4" RAUGEO PEXa
- 100% "Home-Run" from GSHP direct to the vault
- 100% PEXa continuous Double U-bend loop technique
- No buried joints in the wells or in trenches
- Very reliable and fast connections
- Easy to balance and purge each circuit
- 100% access and control to any individual circuit

MINNIE HOWARD ELEMENTARY SCHOOL

FOR THE ALEXANDRIA CITY PUBLIC SCHOOLS

ALEXANDRIA, VIRGINIA



Project:

- Minnie Howard Ninth Grade Center
- Alexandria, VA

System Used:

- PEXa Ground Loop Heat Exchanger

Description:

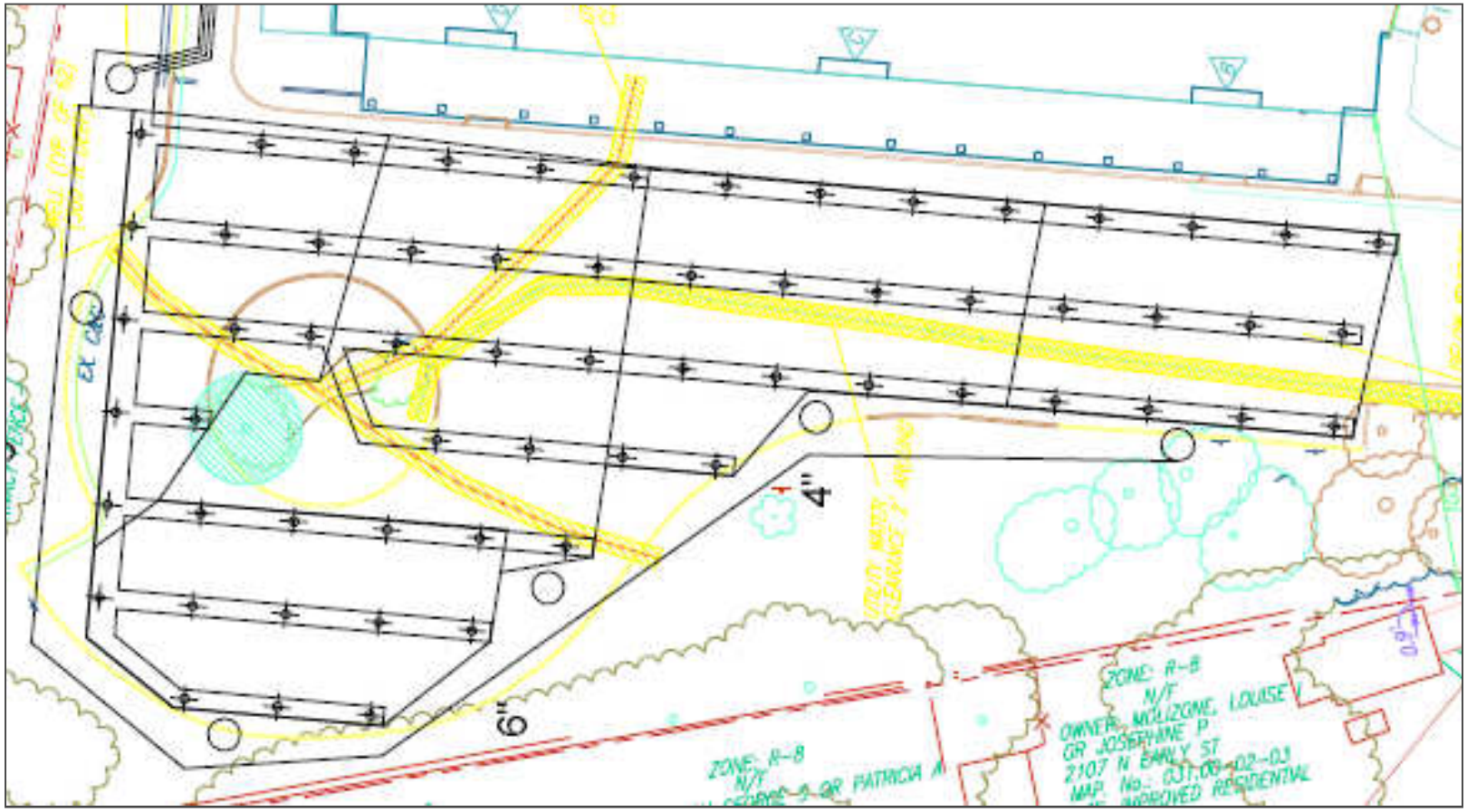
- 42 solar collector panels – 1,700 sq.ft. of collector area
- 65 boreholes each with 300 ft deep PEXa double U-bend
- Manifolds in 5 buried, accessible vaults with 100% access and control to any individual circuit with balancing manifolds
- Easy to balance and purge each circuit

Calculated Payback:

- ~8 years (lifetime from wellfield is 50+ years)
- Lifecycle cost savings $430,000 over 20 years (in PV 2008 Dollars)
- Reduction of greenhouse gases 50,000 kg CO_2 per year

MINNIE HOWARD ELEMENTARY SCHOOL

DIFFERENT CIRCUIT LENGTHS



LOUDOUN COUNTY - LUCKETTS COMMUNITY CENTER

LUCKETTS, VA

Project:

- Lucketts, VA Community Center

System Used:

- Hybrid vertical boreholes with horizontal circuits using PEXa ground loop heat exchangers

Description:

- 3 boreholes, each approximately 300 ft deep
- 27 circuits, each at 1,000’ feet length (layered at 4’ and 6’ depth in 250 ft. trench)
- 100% PEXa continuous Double U-bend loop technique
- Very reliable and fast connections
- Easy to balance and purge each circuit
- 100% access and control to any individual circuit with balancing manifolds

PARTNERING WITH REHAU

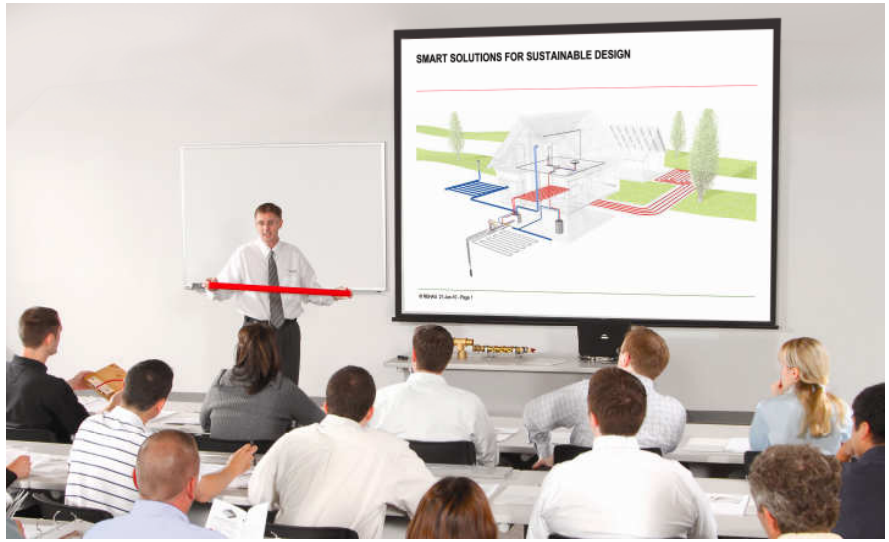
- Specification Guides
- Product Samples and Displays
- Point of Purchase Materials
- Local and Regional Advertising
- Training and Reference Materials
- Design Assistance
- On-site Inspections with Contractors

PROGRAMS AND SERVICES

REHAU ACADEMY

REHAU Academy is the central knowledge institute for REHAU solutions in the construction field

- REHAU Academy conveys crucial product information and relevant industry experience, giving our customers and partners a competitive edge
- With first-class presenters providing classroom instruction, hands-on technical training, lunch and learn seminars and online e-learning programs, the Academy offers more than 50 types of seminars in categories such as:
  - Building technology
  - Installation
  - Design
  - Lunch-and-Learn (engineers)
  - Continuing education (architects)
  - Web-based recorded seminars
  - Live webinars



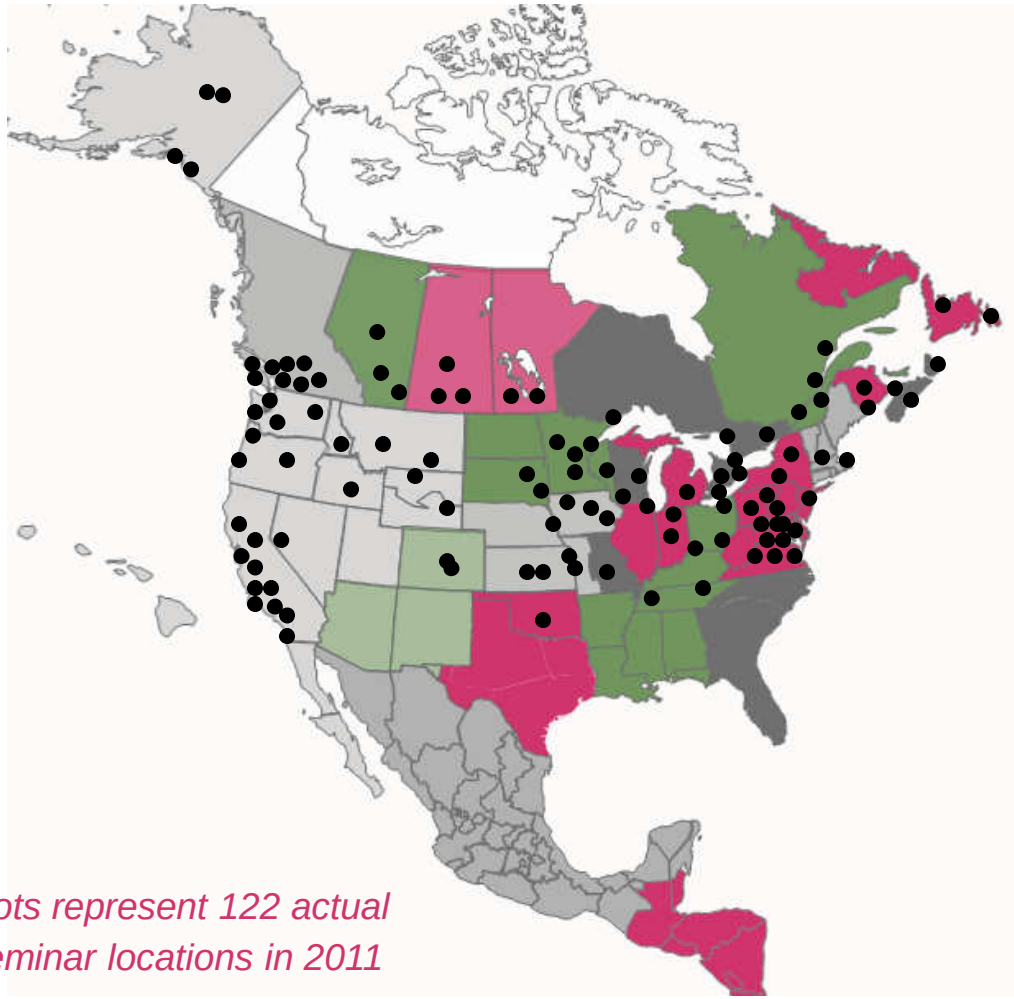
PROGRAMS AND SERVICES

REHAU ACADEMY

CLOSE TO THE CUSTOMERS

2011 In-person Seminars

- 2,800 attendees at 243 seminars in 122 cities



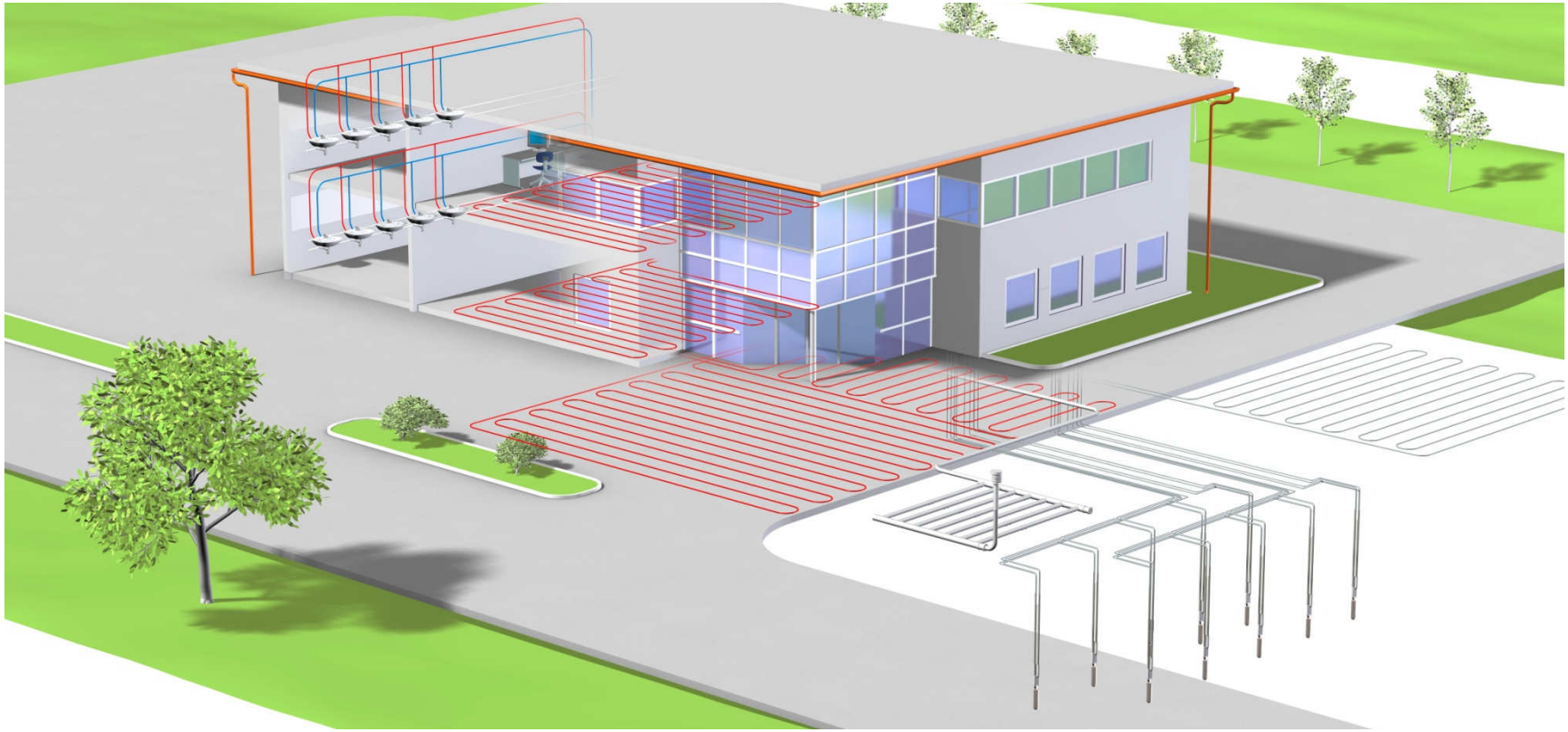
Dots represent 122 actual seminar locations in 2011

WHEN TALENTS MERGE

GREAT THINGS HAPPEN

REHAU SUSTAINABLE BUILDING TECHNOLOGY

SMART SOLUTIONS FOR SUSTAINABLE DESIGN



THANK-YOU

QUESTIONS?

REHAU QUALITY ENERGY EFFICIENCY