GEOTHERMAL DIRECT USE

TECHNOLOGY & MARKETPLACE

WORKSHOP SUMMARY

August 17th, 2015, presented by:

- THE OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
- THE NATIONAL ENERGY TECHNOLOGY LABORATORY

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WORKSHOP SUMMARY

On August 17, 2015, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), along with the National Energy Technology Laboratory (NETL), sponsored the Geothermal Direct Use Technology and Marketplace workshop. The aim of the workshop was to explore the potential for geothermal direct use applications in the eastern United States. It is believed that there is a significant opportunity for geothermal energy to diversify U.S. energy supplies and contribute to net-zero energy goals. The workshop sought to both inform stakeholders and solicit input regarding geothermal opportunities across the Appalachian Basin. In this way, the workshop acted as a forum to exchange information on "hot-rock," heat-pump, and low temperature applications.

The goal of the workshop was *not* to obtain a consensus on the matter, but instead *gather insight and recommendations* such that an appropriate path forward can be proposed. A series of presentations were made during the workshop in an effort to share a current-state understanding of the opportunity to employ geothermal systems in the Appalachian Basin. The workshop concluded with a facilitated conversation that explored research opportunities and assessed the appropriate role for government in this research space. This report contains a brief summary of each presentation, workshop materials, and a copy of each presentation can be found within the appendix. The meeting participants included 64 registered attendees with roughly 1/3 each from industry, academia, and government or contractors.

The workshop's presenters included leading experts from across the country:

- **Brian Anderson:** Geothermal Resources in the Eastern United States
- **Jefferson Tester:** Geothermal Deep Direct Use Technology
- **Grant Ervin:** Sustainability Initiatives in Pittsburgh
- **Thorleikur Jóhannesson:** Geothermal Experience in Iceland
- **Jay Egg:** Geothermal Marketplace in the eastern United States

GEOTHERMAL RESOURCES IN THE EASTERN UNITED STATES

Dr. Brian Anderson, West Virginia University

Link to Geothermal Resources in the Eastern United States Presentation

Attractive low-temperature geothermal resources exist within the eastern region of the United States. Exploiting these pockets of energy requires not only a viable subsurface resource, but also surface demand, which is a function of the region's population and climate. The need for geothermal heat can be quantifiably depicted through "heat density" maps, which are produced using a region's population density as well as the energy demand of its residential, commercial, and industrial sectors.

To more fully explore the opportunity to employ geothermal systems in the eastern United States, a regional assessment model has been created to explore the factors that contribute to the levelized cost of heat associated with a geothermal system. To make this determination, the model includes the following four elements: Resource Assessment, Demand Assessment, Economic Analysis, and Surface Distribution Assessment. This model had been used to assess the economic potential of geothermal systems at specific locations across the eastern United States.

Ultimately, the major factors that influence the production economics of a geothermal system include the temperature gradient of the resource formation, which influences drilling depth, and the flow rate that is achievable given the porosity and permeability of the formation.

Opportunities exist to reduce the risk of geothermal exploration by updating maps and improving the predictive quality of thermal resource databases; mapping natural reservoirs that are high porosity; conducting field tests to evaluate flow and temperature; utilizing remote sensing techniques for reservoir characterization; improving fault maps to better understand the potential for induced seismicity; and developing utilization models (utilizing Geothermal Energy for the Production of Heat and Electricity Economically Simulated (GEOPHIRES) software) that are tailored to Appalachian Basin conditions.

The opportunity to employ geothermal systems in the Appalachian Basin region is aided by the fact that, due to the coal and oil and gas industries, it is a geologically data-rich region (though low-temperature geothermal resources are often significantly deeper than coal and oil and gas resources in the Appalachian Basin). This data and the analyses that it enables has the potential to reduce the risk and improve the projections of geothermal system performance. For example, the Marcellus Shale Energy and Environmental Laboratory (MSEEL) will provide a long-term field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development, including geothermal resources. The MSEEL effort will collect a significant amount of flow (porosity/permeability) and temperature data that will be utilized by Dr. Anderson and his team at West Virginia University.

GEOTHERMAL DEEP DIRECT USE TECHNOLOGY

Dr. Jefferson Tester, Cornell University

Link to Geothermal Deep Direct Use Technology Presentation

There are essentially two scenarios for direct use deep geothermal energy systems. The first is natural hydrothermal systems, and the other is enhanced/engineered geothermal systems (EGS), which require intervention (such as hydraulic fracturing or other means of stimulation) to create connectivity. Deep geothermal systems can be utilized for electricity, heating, or combined heat and power applications. Additional heating and cooling applications exist utilizing lower temperatures at shallow depths with geothermal heat pumps. In its simplest form, enhanced/engineered geothermal systems employ a two well, injector-producer (doublet) system that aims to emulate the natural circulation found in hydrothermal reservoirs. Ultimately, the commercial deployment of EGS will depend on drilling costs and well productivity as well as the type and proximity to end use demand. High flow and high productivity are vital components of EGS systems, but high drilling costs, particularly for lower grade geothermal resources, are a challenge for system development in today's energy markets.

Twenty-five percent of U.S. primary energy usage occurs at temperatures below 120 degrees Celsius (°C). Most of this energy is currently provided through the combustion of natural gas and oil. Of the various sectors that comprise U.S. energy demand, the building sector accounts for 40% of the total. Heating is the largest energy use associated within the building sector, and therefore represents a significant opportunity to realize efficiency gains and reductions in fossil fuel use using geothermal solutions. To implement a low–carbon energy strategy, the United States. will need to consider approaches to convert buildings to non-fossil energy heating. While the opportunity is large for direct use deep geothermal energy in the United States, achieving a complete transformation the nation will need to invest considerable capital in energy infrastructure over a long period of time. For example, Cornell University is currently incorporating renewables into its energy transition strategy to reduce its carbon footprint. With higher grade resources in its region, the university is evaluating deep EGS as an option for supplying hot water to its campus district heating system. Such a transformation does not happen overnight even with sufficient funding in place to proceed. Comparable to deployment of a hydrothermal system at a new site, achieving a working EGS system for the campus would require at least 10 years to fully develop.

SUSTAINABILITY INITIATIVES IN PITTSBURGH

Grant Ervin, The City of Pittsburgh

No Presentation Available

The city of Pittsburgh has recently issued its second climate action plan, which aims to reduce carbon emissions by 20% by 2025. Through outreach programs and strategic partnerships, the city of Pittsburgh was able to reduce carbon emissions by nearly 10% in a single year. While other cities may have more aggressive goals, Pittsburgh is focused on determining how to achieve its goal using the options currently at its disposal. The city of Pittsburgh has expanded its vision through the "Power of 32" initiative, which looks at a number of the surrounding regions that all support the Pittsburgh economy. In addition to its various initiatives to reduce carbon emissions and increase energy efficiency, the city of Pittsburgh is looking at Downtown Pittsburgh, Oakland, and the connection between to two (dubbed "Uptown") as potentially the largest 2030 district[1] (looking to achieve 50% reductions in energy and water usage) in the world. The city of Pittsburgh goals aim to "dramatically reduce energy and water consumption and transportation emissions, and improve indoor air quality while increasing competitiveness in the business environment and owner's returns on investment."

As the Pittsburgh region continues to explore opportunities to optimize its energy usage, district energy will serve as one of the main levers by which Pittsburgh achieves its goals. Reinventing existing systems is paramount in areas such as Pittsburgh, where dense urban environments require existing infrastructure be repurposed in an efficient way. Pittsburgh will be leading a series of dialogues in the near future as it seeks to make strategic investments in energy systems in a way that is consistent with its holistic vision of the future. Workforce development will continue to be key to the design, development, installation, and operation of the systems that will provide energy to the next generation of Pittsburghers.

[1] "2030 Districts are led by the private sector, with local building industry leaders uniting around a shared vision for sustainability and economic growth – while aligning with local community groups and government to achieve significant energy, water, and emissions reductions within our commercial cores."

GEOTHERMAL EXPERIENCE IN ICELAND

Thorleikur Jóhannesson, Verkis Consulting Engineers

Link to Geothermal Experience in Iceland Presentation

In recent history, Iceland experienced an environmental transformation similar to that of Pittsburgh. In the 1940s, Iceland relied heavily on first generation technology for its energy needs. As a result, the cities were heavily polluted with industrial emissions. Since that time, Iceland has continued to turn towards geothermal energy as the preferred technology to satisfy its heating needs. Today 90% of all homes are heated with geothermal systems and three large-scale aluminum plants are powered by geothermal energy. Maintenance for lower-temperature geothermal systems is relatively low, with geothermal wells and pumps requiring cleanup and re-installation on a regularly scheduled (yet infrequent) timeframe. In-home heat exchangers and heat pump systems also require minimal maintenance. The President of Iceland was recently quoted as saying, "The scale of the national savings resulting from geothermal space heating alone is demonstrated by the fact that every decade, Iceland saves what amounts to one year's GNP by not having to import oil and coal to heat its houses." The significant transformation that Iceland has achieved is a result of continual progress over the course of many decades as it sought to revamp its district heating system building by building and street by street. Iceland is also able to capture methanol from geothermal power production (as a result of carbon dioxide (CO_2) in the geothermal water resources) and sell it to European buyers on a small-scale.

GEOTHERMAL MARKETPLACE IN THE EASTERN UNITED STATES

Jay Egg, Egg Geothermal

Link to Geothermal Marketplace in the Eastern United States Presentation

The eastern United States is missing a tremendous opportunity to optimize the extraction of energy at various points along the system. For example, the average temperature of wastewater is 70 degrees Fahrenheit (°F). By taking a cascade approach, there is an opportunity for significant reuse of energy. Various companies have emerged and are attempting to harness untapped potential and unrealized resources. Such strategies cannot be employed with air source equipment. It is better to realize the opportunity for synergies early on in the design process. One example of this strategy includes a school in New York City that is incorporating geothermal structural piles to assist with heating and cooling while serving their purpose of structural integrity. One of the many advantages that geothermal offers is that it enables the optimization of water usage. The availability of freshwater for cooling is a significant challenge around the world. Traditional cooling towers pose a problem in that they require freshwater for operation, whereas a closed loop geothermal system requires no new water.

In addition to traditional geothermal systems, there is an opportunity to apply creativity in the design of hybrid systems including but not limited to:

- Geothermal and cooling towers
- Geothermal and solar thermal
- Geothermal and nearby lakes

INFORMAL GROUP QUESTION AND ANSWER SESSION

Julianne Klara, Moderator, National Energy Technology Laboratory

What are current research and analysis needs for direct use geothermal?

- More information is needed on engineering geothermal systems and subsurface "unknowns" as they pertain to geothermal energy development. This information should focus on geological reservoir characterization activities, reservoir operability, hydraulics and flow dynamics, and modeling capabilities.
- A more general discussion could include "Why is Geothermal worth it?" The role of the government in the development of geothermal energy technologies is not yet defined, though the role of the government to act as an educator and outreach entity is also necessary. As of the current state, geothermal heat pumps are the only widely available and applicable commercial-scale technology; more research relating to direct use is needed.
- The Frontier Observatory for Research in Geothermal Energy (FORGE) program; Subsurface Technology and Engineering Research, Development, and Demonstration (SubTER) initiative; and the Carbon Capture, Utilization, and Storage program all have varying degrees of cross-cutting applicability. Each of these programs will gather critical geologic data that will further our knowledge of the subsurface for a variety of energy and environmental purposes, including providing a means to develop higher resolution sensors, improved wellbore integrity (including an evaluation of the feasibility/practicality of dual completion wells), the use of laterals and hydraulic fracturing for improved reservoir performance, and better heat extraction efficiency.

What are the practical (non-technical) issues that need to be addressed?

- The primary focus on non-technical issues related to the development and deployment of geothermal energy technologies are innovative financing and deployment options. This would include the standardization of financing language and strategic program planning. Larger scale energy infrastructure is necessary for deployment, including a means to design regional distribution systems and local, single building use. Considerations for hybrid systems (geothermal and gas) and the co-location of these energy extraction sources is also needed.

What are the regulatory and development issues that might help or hinder geothermal energy?

- Regulatory and incentivization issues limit energy demand and use, and improving the efficiency factor of heat extraction is key.
- Regulatory framework for direct use geothermal application is available in certain states and locales around the United States, though Renewable Energy Certificates (RECs) are not available in each area, which may hinder the adoption of geothermal.

What hurdles exist for community-wide geothermal sourced energy plants?

- Control issues for geothermal energy are important considerations in district system development, including how property ownership transfers impact energy usage and upkeep.
- The development of district heating systems is dependent on who or what entity pays for the design, permitting, development, and construction of the system. How can district heating systems be utilized and optimized from a cost development and ownership standpoint?

WORKSHOP DISCUSSIONS

The workshop concluded with a facilitated conversation that explored research opportunities and assessed the appropriate role for government in this space. Specifically, the audience was asked to comment on the geothermal opportunity according to three dimensions: Impact, Additionality, and Enduring Economic Impact.

Impact: Is this a high-impact problem (>1% Impact on local goals if successful)?

Participants were asked to indicate if the use of geothermal would provide a high impact on local goals if successful. They were instructed to consider both direct geothermal and heat pumps; while some did, others focused on only one or the other. Though the question was focused on local impacts, the participants were instructed not to confine their thinking to only local applications. Of the 26 written responses provided, 19 indicated that they believe the potential exists for a large impact if geothermal is adopted. Both direct use and ground source heat pumps were mentioned. Reasons for the responses pointed to the high heating need in the eastern United States, much of it low-profile heat, and that the ability exists to integrate it into district heating with big energy savings potential and environmental benefit. However, market acceptance and high front-end costs were mentioned as hurdles. The value of geothermal was still unclear to four respondents who indicated that more information, analysis, and R&D is needed. Three participants were skeptical of the impact of geothermal due to issues with low rate of return, long financial return times, non-existence of incentives, and the challenges of drilling to the necessary depths.

Additionality: Will work in this area make a large difference relative to what the private sector (and other funding entities) is already doing?

Workshop participants were asked whether public funding would enable industry to address challenges that the private sector is not able to solve. In other words, can the government catalyze and contribute to existing activity within the private sector to enable advancement that otherwise would not be possible? To understand the opportunity, participants were asked, "What technology challenges is industry facing?" as well as, "What are industry's near- and long-term research needs?" The majority of the participants responded positively to the question with the consensus being that government is uniquely suited to address many of the grand challenges associated with geothermal activity in the eastern United States. Currently, the significant costs and limited understanding of geothermal prevents wide-scale adoption in the eastern United States. To combat these challenges it was suggested that government should address the technical, financial, and regulatory risks associated with scaling geothermal systems. For example, government could address some of the technical challenges by characterizing the regional resources, establishing environmentally effective techniques, and facilitating information exchange with other programs and sectors that have geologic information. From a financial perspective it was suggested that government could assist by providing bonds to support infrastructure additions and by evaluating the financial strategies that will adequately reduce risk and promote investments. Finally from a regulatory perspective, there is a felt need for outreach assistance and policy guidance to facilitate adoption and educate the public on the safety and efficiency of geothermal technology.

Enduring Economic Benefit: How will geothermal direct use result in enduring economic benefit to the United States?

Participants were asked to comment on the extent to which geothermal direct use will result in an enduring economic benefit to the United States. That is, what are the fundamental trends and drivers that are creating this opportunity, and does geothermal represent a solution that can have a positive, sustainable impact on the U.S. economy? The responses suggested that the ability of geothermal systems to have an enduring economic benefit in the eastern United States will depend largely on the evolution of the natural gas industry, which currently provides much of the heat that direct geothermal systems offer. To compete with natural gas, geothermal must be strategically scaled in choice locations where the underground supply matches the aboveground demand. In addition, to extract the maximum amount of energy from geothermal sources will require that cities and communities reevaluate their approach to district heating and employ a cascade strategy that optimally uses available heat throughout the system. If the geothermal industry is able to develop business models and deployment strategies that enable wide-spread adoption, the technology could result in an enduring economic benefit as it offers a sustainable and reliable energy option to communities in the eastern United States.

APPENDIX 1:

WORKSHOP AGENDA

Geothermal Direct Use Technology & Marketplace

Hilton Garden Inn Pittsburgh/Southpointe

1000 Corporate Drive, Canonsburg, PA 15317

Workshop Agenda – Monday August 17, 2015

This workshop is a forum to exchange information on low temperature geothermal applications. To that end, participants will be asked to provide recommendations and information based on personal experience, individual advice, information, or facts regarding this topic. The objective of the workshop is not to obtain any group position or consensus; rather, the DOE is seeking as many recommendations as possible from all individuals at this meeting.

8:00 a.m. – Check-in for all Registrants/Continental Breakfast (Parlor A Foyer)

General Session - Parlor A

9:00 a.m. – Introduction and Background

9:15 a.m. – Geothermal Resources (in the Eastern U.S.) Parlor A

Discussion Lead- Brian Anderson, WVU

- Where are the geothermal hot spots and how are these discoverable?
- At what temperatures can various geothermal technologies operate?
- Which innovative hybrid technologies can utilize local energy sources?
- Geologic variability in the sub-surface and issues pertaining to flow rate.

10:15-10:45 a.m. – BREAK (Parlor A Foyer)

10:45 a.m. – Geothermal Deep Direct Use Technology

Discussion Lead - Jefferson Tester, Cornell University

- What is geothermal direct use technology?
- What is geothermal deep direct use technology?
- How has direct use been practiced?
- How does direct use differ from geothermal ground-source heating and cooling?

11:45 a.m. – Sustainability Initiatives in Pittsburgh

Presenter- Grant Ervin, Chief Resilience Officer, Office of Mayor William Peduto

12:00-1:30 p.m. – Luncheon and Presentation on Geothermal Experience in Iceland (Parlor A)

Presenter- Thorleikur Jóhannesson, Verkis Consulting Engineers

1:30 p.m. – Geothermal Marketplace (in the Eastern U.S.)

Discussion Lead - Jay Egg, Egg Geothermal

- What are GSHP Payback and Market Space?
- What are the economics behind hybrid energy systems?
- How do Federal, State and Local Incentives Work to Lower Costs?
- Which states include GSHP and Direct Use in Renewable Portfolio Standards?

2:30-3:00 p.m. – BREAK (Parlor A Foyer)

3:00-4:30 p.m. – Discussion of Geothermal Opportunities in the Region

- **High Impact:** Is this a high-impact problem (>1% Impact on local goals if successful)?
- **Additionality:** Will work in this area make a large difference relative to what the private sector (and other funding entities) is already doing?
- **Enduring Economic Benefit:** How will geothermal direct use result in enduring economic benefit to the U.S.?

Optional Presentation – Regional Geothermal Data, presented by Arlene Anderson – Parlor C

APPENDIX 2:

SPEAKERS BIOGRAPHIES

GEOTHERMAL DIRECT USE TECHNOLOGY & MARKETPLACE
Canonsburg, Pennsylvania–August 17, 2015
Presented by the National Energy Technology Laboratory
And the Geothermal Technologies Office

Speakers

ARLENE ANDERSON is a Technology Manager and Physical Scientist in the Science and Energy mission space at the U.S. Department of Energy (DOE). Within Science and Energy, Arlene's organization, "Energy Efficiency and Renewable Energy," takes its place alongside offices focused on basic energy sciences, oil and gas development; energy development on tribal lands; electricity grid modernization; and nuclear energy. Since 2008, Arlene has led nearly $50 million of DOE funded Geothermal RDD&D including the development of a federated National Geothermal Data System (NGDS). She currently leads the DOE Geothermal Data Repository node on the NGDS and several new strategic materials and low-temperature geothermal projects. Arlene also serves on DOE's crosscutting Energy-Water Nexus Team and specializes in renewable energy benefits assessment, including water and greenhouse gas life cycle analysis. Arlene has a Bachelor of Science degree from Pennsylvania State University, College of Earth and Mineral Sciences, with a minor in cartography and remote sensing, and she received her Master's Degree in Planning from the University of Virginia's School of Architecture.

BRIAN J. ANDERSON is the Director of the West Virginia University (WVU) Energy Institute and the GE Plastics Materials Engineering Professor in chemical engineering at WVU. He was awarded the 2012 Presidential Early Career Awards for Scientists and Engineers, the highest honor bestowed by the U.S. government on science and engineering professionals in the early stages of their independent research careers and a 2014 Kavli National Academy of Science Frontiers of Science Fellow. He has been a NETL-RUA Faculty Fellow at the National Energy Technology Laboratory since 2008 where he is the coordinator of the International Methane Hydrate Reservoir Simulator Code Comparison study. In 2011, he was awarded a Secretary Honor Achievement

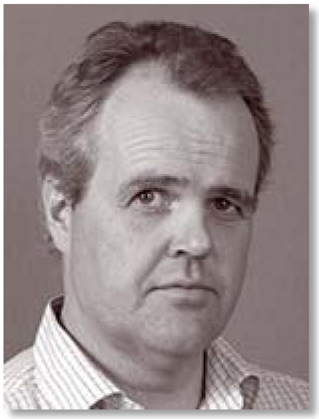
Award from the Secretary of the Department of Energy for his role on the Flow Rate Technical Group, a team spanning multiple National Laboratories that worked in response to the Deepwater Horizon oil spill. Dr. Anderson received his Bachelor's degree in chemical engineering in 2000 at WVU and his MS and PhD in chemical engineering from the Massachusetts Institute of Technology in 2004 and 2005 respectively. After joining the faculty at WVU in January of 2006, he coauthored the MIT report, "The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century." He serves on the technical advisory board of AltaRock Energy and in the 2011, along with colleagues from Stanford, MIT, Cornell, University of Utah, Southern Methodist University, and the University of Nevada, he co-founded the National Geothermal Academy. His research interests include molecular, reservoir, and multiscale modeling applied to energy and biomedical systems.

JAY EGG started Egg Systems in 1990 to provide energy efficient geothermal air conditioning systems to Florida markets, and especially the Tampa Bay area. Jay conducted his first geothermal speech in 1994. Afterwards, Tampa Electric Company (TECO) began to rely on Mr. Egg's training expertise utilizing him in various forums from conventions to in-house educating. Jay co-authored with Brian Howard for McGraw-Hill a professional book on the subject of Geothermal HVAC, Green Heating and Cooling, published in 2010. He also co-authored with Greg Cunniff and Carl Orio a graduate – level textbook for McGraw – Hill, Modern Geothermal HVAC Engineering and Controls Applications which was published in July, 2013. Jay is a featured writer and speaker, most recently having been selected as featured speaker on geothermal technologies for the International Green Building Conference in Singapore, September 2-4, 2015.

GRANT ERVIN serves as the Chief Resilience Officer for the City of Pittsburgh were he oversees the integration of sustainability and resilience into city services, programs, and policy. Prior to joining the City of Pittsburgh, Grant served as the

Regional Director for 10,000 Friends of Pennsylvania, a statewide smart growth and sustainable development policy organization; and as Public Policy Manager for Pittsburgh Community Reinvestment Group (PCRG). Grant brings fifteen years of experience, intersecting the worlds of environmental, community & economic development and infrastructure policy to create innovative and sustainable solutions for local governments, community development organizations, and state agencies. Grant has helped lead the development of a variety of innovative programs including the Uptown Eco-

Innovation District, Pittsburgh and Neighborhood Community Information System, and the Pennsylvania Community Transportation Initiative.



ÞORLEIKUR JÓHANNESSON, VERKÍS Consulting Engineers, is an expert in geothermal power projects, including wells, steam field systems, power plants, cooling systems, reinjection systems etc. He is also a specialist in multiple use of low temperature geothermal energy with years of experience in design of district heating systems including pumping and control stations, distributing networks and house connections. He has in-depth experience in preparation of feasibility studies, process design, preliminary and detailed design, design review, technical assistance during procurement, technical reviews and tender evaluation, site supervision, support during commissioning and testing as well as support to the operators for the operation of geothermal power plants and district heating systems. In the last decade, he has acted as project manager/team leader for design and implementation of the 100 MW Reykjanes geothermal power plant, feasibility study and design for extension and rehabilitation of the 35 years old Svartsengi geothermal power plant (now producing 75 MW electricity and 150 MW heat), and 15 well- head power plants in Olkaria with installed capacity of 80 MW. He is accustomed to working in international contexts, and has served as a geothermal expert and project manager in Kenya, USA, China, Turkey, and Portugal. In addition to his commercial experience, Mr. Jóhannesson teaches process and mechanical engineering for geothermal power plants at the University of Iceland, and he is a supervisor of United Nations University geothermal training program.

JEFFERSON W. TESTER is the Croll Professor of Sustainable Energy Systems at Cornell University, Director of the Cornell Energy Institute, and a fellow of the Atkinson Center for a Sustainable Future. For four decades, he has been involved in research and development as it relates to geothermal energy extraction and conversion. He has published extensively in the energy area having co-authored over 225 research papers and 10 books. Experimental and theoretical geothermal studies currently under investigation include advanced drilling technologies employing hydrothermal jets and flames, geothermal resource assessment for the U.S., energy recovery from and modeling of fractured EGS reservoirs; thermal energy storage, geothermal heat pumps, district heating, power cycle modeling, and life cycle and techno-economic systems analysis of energy and mass flows for geothermal energy supply and utilization.

Dr. Tester's other assignments include, H.P. Meissner Professor of Chemical Engineering at MIT (1990- 2009), Director of MIT's Energy Laboratory (1989-2001), Director of MIT's School of Chemical Engineering Practice Program (1980-1989) and group leader in the Geothermal Engineering Group at Los Alamos National Laboratory (1974-1980). Dr. Tester is a Fellow of the Royal Chemical Society. He served on the advisory boards of the Massachusetts Renewable Energy Trust as chair, the Los Alamos National Laboratory, and the Paul Scherrer Institute in Switzerland. Dr. Tester currently serves on the Advisory Council of the National Renewable Energy Laboratory (1998 to present, and as Chair 1998-2009) and on the Science and Technology Advisory Council of the Idaho National Laboratory. He was a member of the Energy R&D Panel of the President's Committee of Advisors on Science and Technology (PCAST) in 1997 and has served as an advisor to the USDOE and the National Research Council in areas related to concentrating solar power, geothermal energy, biomass, and other renewable technologies. At MIT in 2006-2007, Dr. Tester chaired an 18-member international panel that evaluated the long term geothermal potential of the U.S. From 2008-2012, he served as the U.S. Representative for geothermal energy to the IPCC for the Special Report on Renewable Energy. In 2011 Dr. Tester received the Special Achievement Award, Geothermal Resources Council.

TIM REINHARDT is currently at the Department of Energy (DOE) in the Geothermal Technologies Office (GTO) as a physical scientist and Program Manager for the Systems Analysis and Low-Temperature (SALT) Program. Tim provides oversight and program guidance for demonstration, R&D, feasibility and analysis projects; as well as direction for future GTO activities. The GTO is committed to developing and deploying a portfolio of innovative technologies for clean, domestic power generation. The Office researches, develops, and validates innovative and cost-competitive technologies and tools to locate, access, and develop geothermal resources in the United States. Tim received his bachelor's degree from Northwestern University. He served in the United States Navy for nine years as an officer and Naval Aviator, and holds Master's Degrees from the University of Oklahoma and the University of Texas at Austin.

APPENDIX 3:

WORKSHOP INTRODUCTION: **Geo Richards**

Geothermal Direct Use Technology & Market

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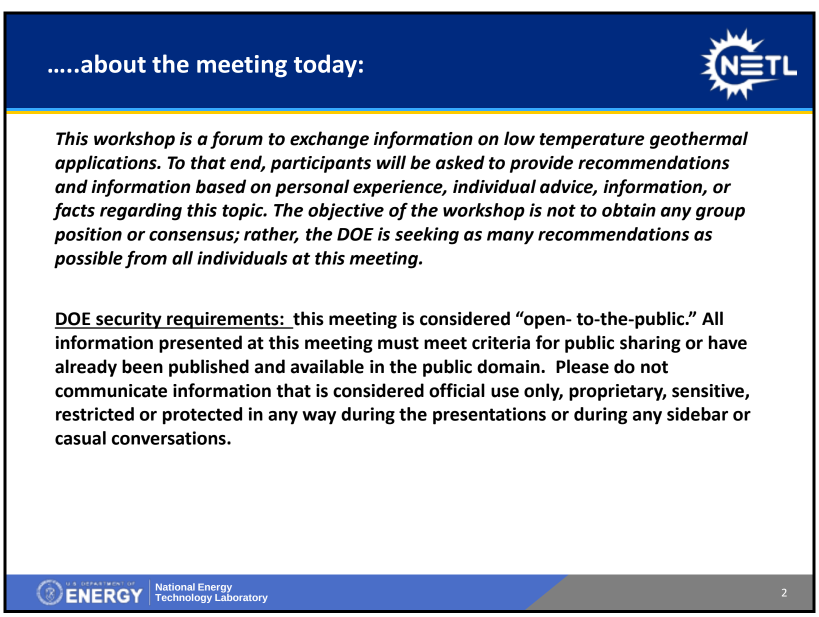

WORKSHOP INTRODUCTION: **Arlene Anderson**

Geothermal Direct Use Technology & Market

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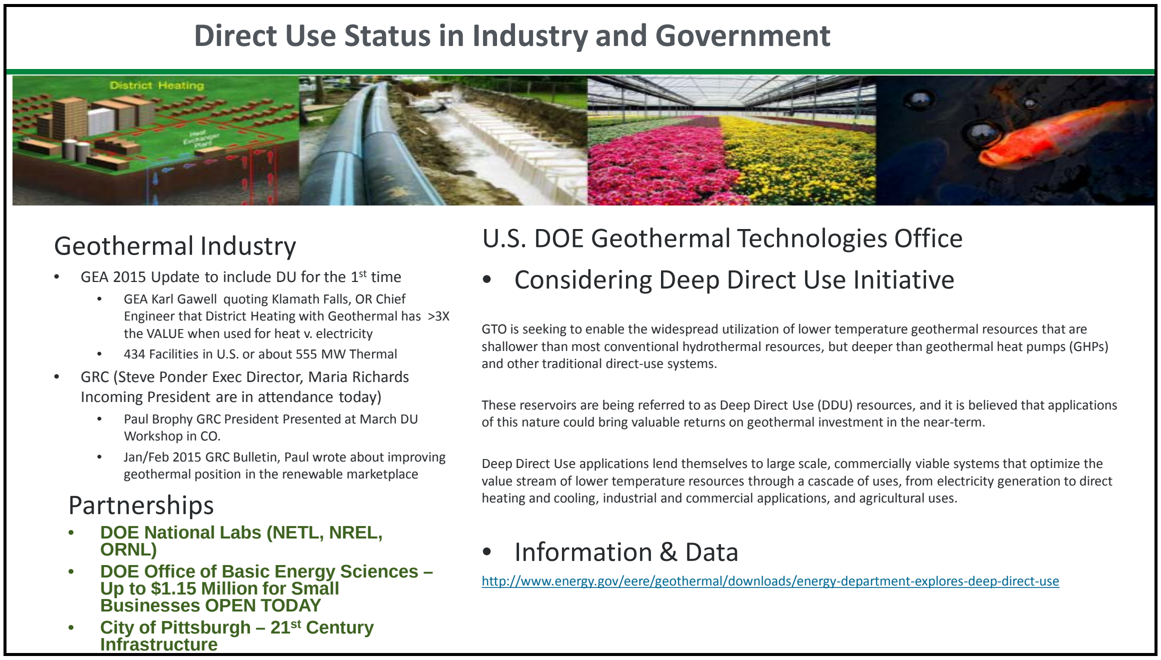

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Background

Direct-use is the oldest, most versatile and most prevalent form of geothermal energy. Techno-economic analysis conducted over decades provides support for geothermal direct use and district heating from geothermal resources, however technical, cost and institutional barriers to implementation remain.

A 1980 study on geothermal resources in the Eastern U.S. (John Hopkins Applied Physics Laboratory) references a paper by J.E. Tillman published in the journal Science which notes that:

"a geothermal resource that consists of hot water at moderate temperatures (below 125°C) underlies many areas in the central and eastern United States.

Programs funded by the Department of Energy have revealed that this resource is definable and economically competitive with conventional fuels for use in direct heat applications.

The resource, therefore, has the potential for reducing our dependence on the imported oil used for space heating. However, front-end costs and risks to explore, drill, test, and evaluate the magnitude of the resource have inhibited development.

The question is, therefore, how much federal stimulation will be needed to convince private capital to exploit this widespread low-quality energy source."

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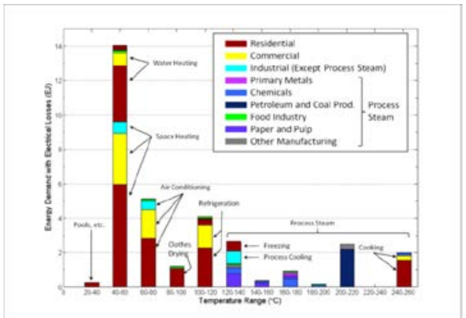
Geothermal Direct Use Technology & Marketplace – Where * What * Why

Brian Anderson – Where

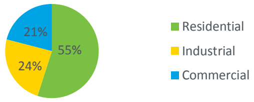
- DOE Project: "Low Temperature Geothermal Play Fairway Analysis for the Appalachian Basin"
- Geothermaldata.org – National Geothermal Data System



Jefferson Tester - What

- DDU systems would utilize a similar temperature range of fluids, but on a much larger scale.
- Typical geothermal direct-use operations utilize a natural resource -- a flow of geothermal fluid at elevated temperatures
- Capable of providing heat and cooling (via absorption chillers) to: buildings, commercial and residential applications, industrial processes, greenhouses and aquaculture ponds.

2008 Thermal Energy Demand for 0-260°C: 33.5 EJ



Jay Egg - Why

- 80% of the 33.5 EJ provided heat below 150 Degrees Celsius

SPEAKER PRESENTATIONS: **Brian J. Anderson**

Geothermal Resources in the Eastern U.S

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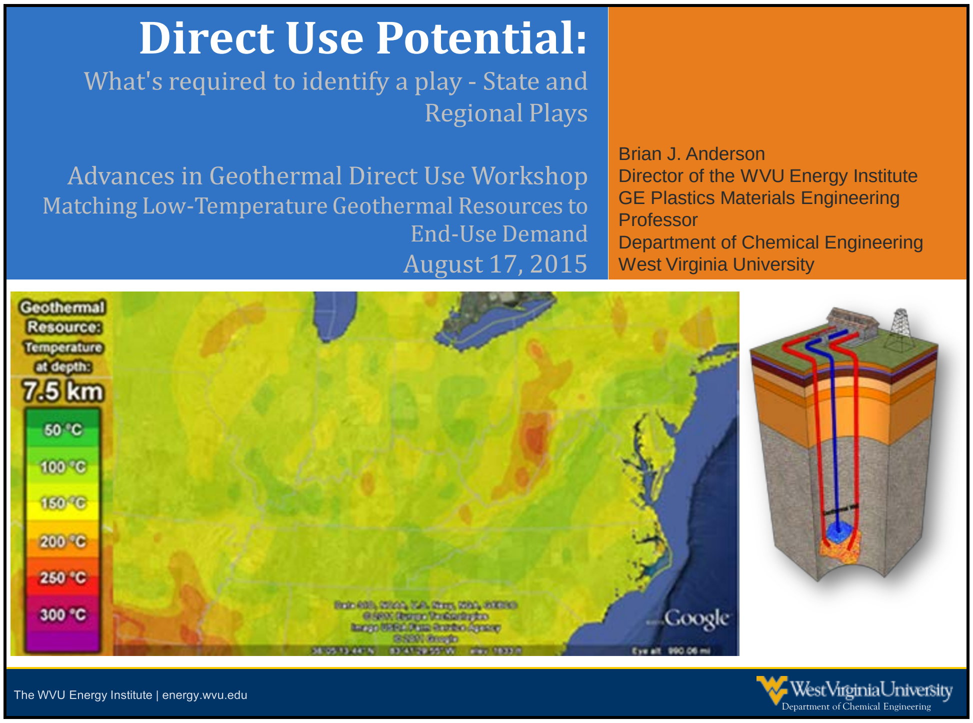

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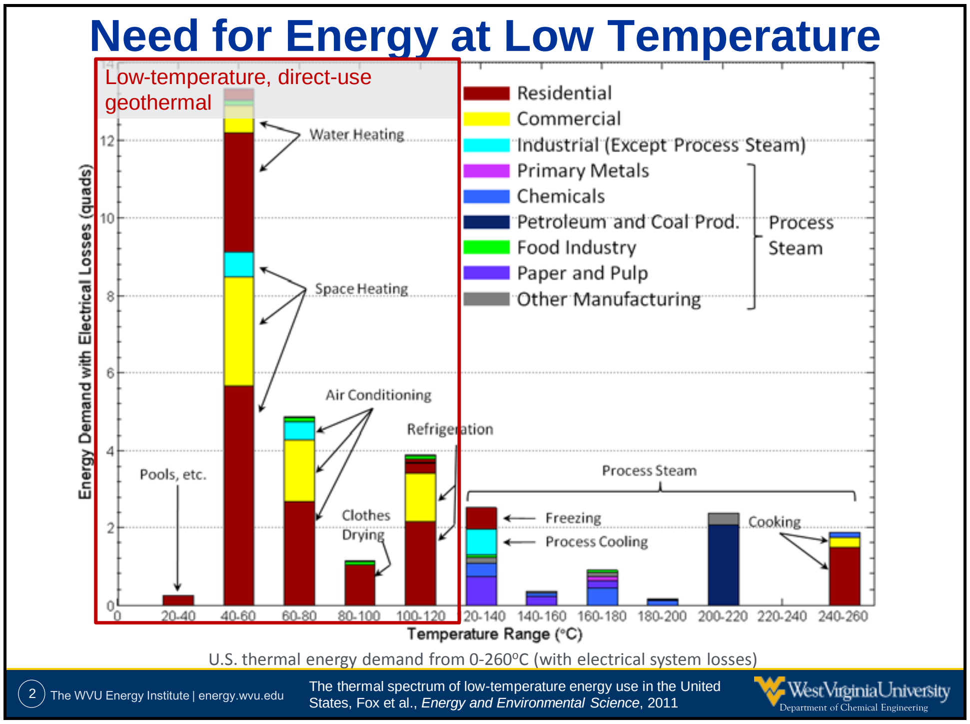

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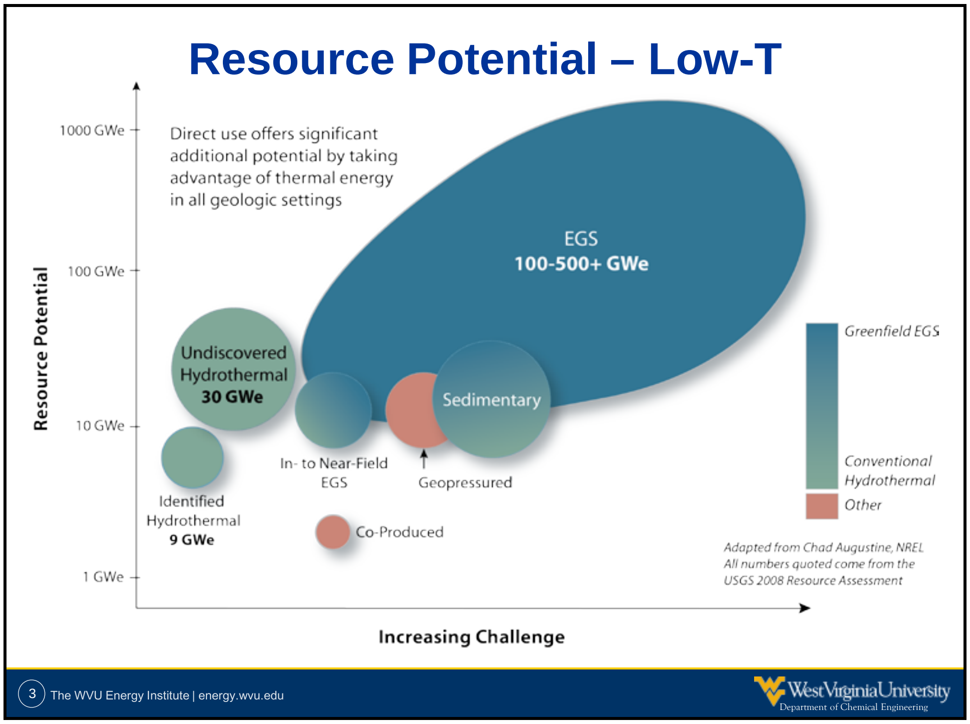

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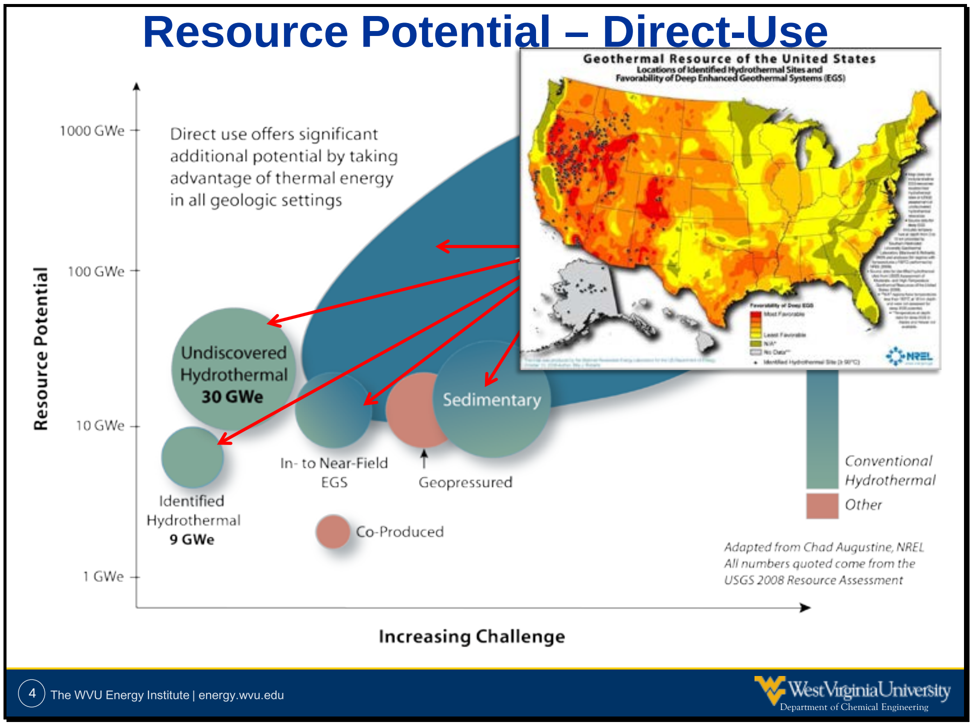

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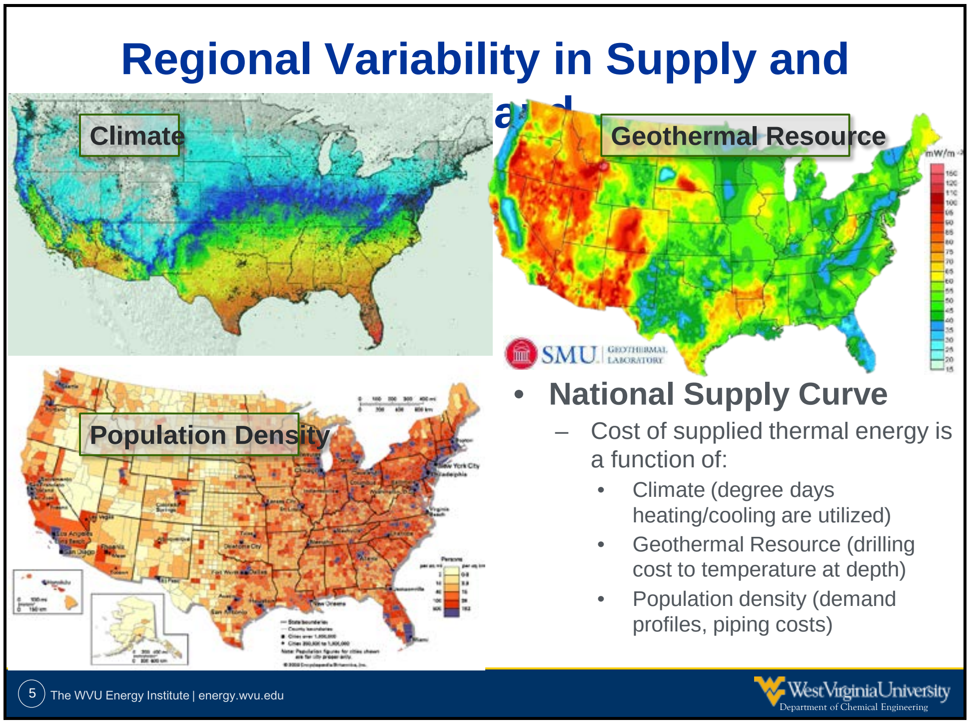
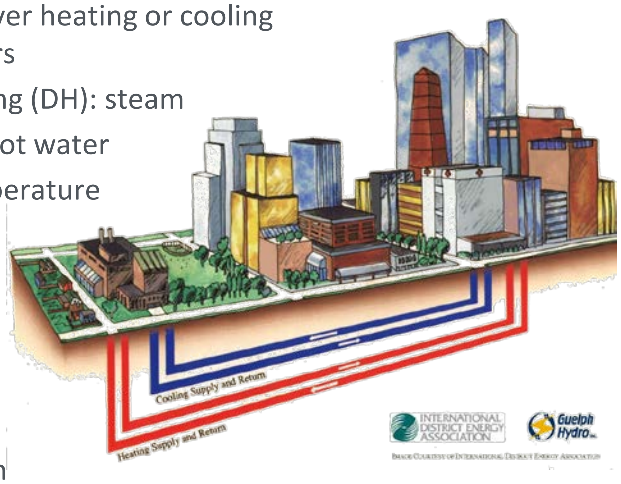


Slide 6

District Heating Energy Brief

- Piping networks deliver heating or cooling streams to consumers
- 1st gen District Heating (DH): steam
- 2nd and 3rd gen DH: hot water
- 4th gen DH: low temperature fluid, ~55°C
- 4th gen DH enable penetration of renewable sources
- Higher utilization efficiencies than electricity production



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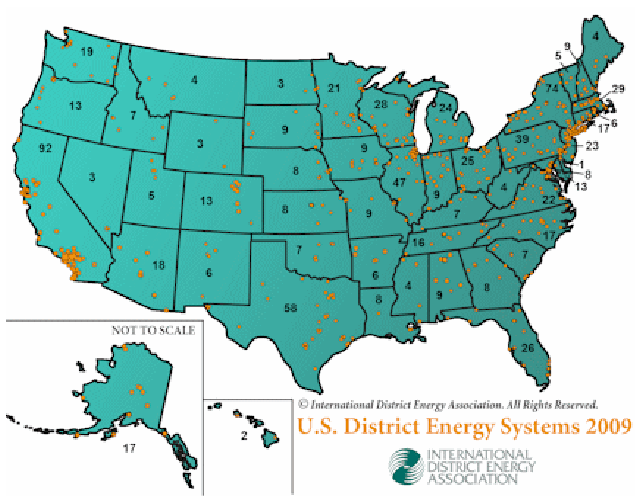
Slide 7

District Energy Systems in the US

- **Over 800 district energy systems in the United States**
- **Operating in the US for over 100 years**
- **Serving more than 4.3 billion ft^2 of building space**



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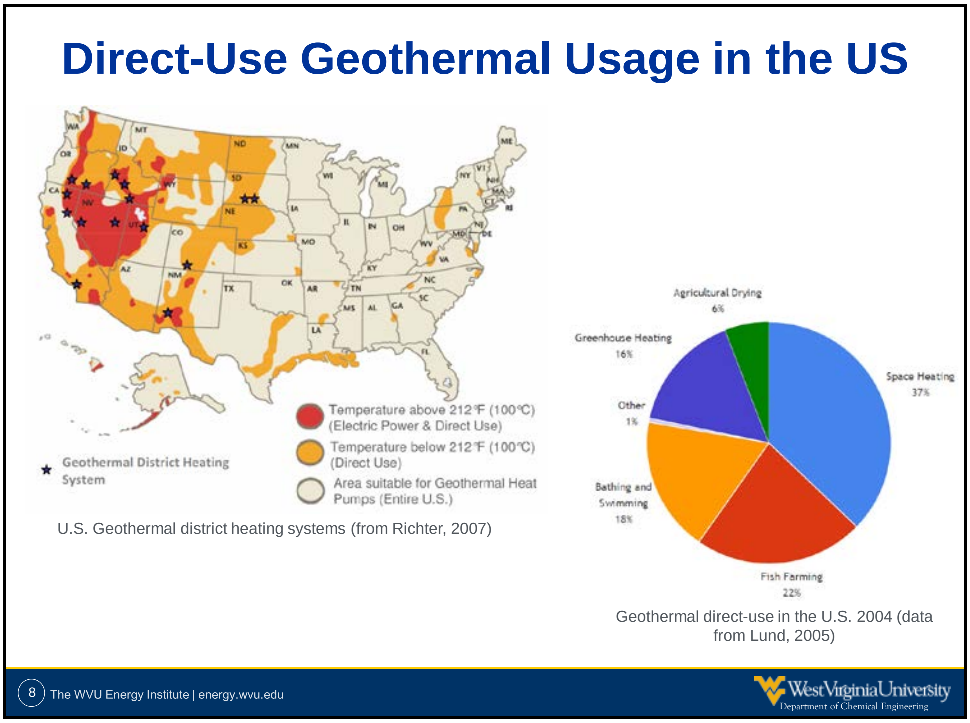

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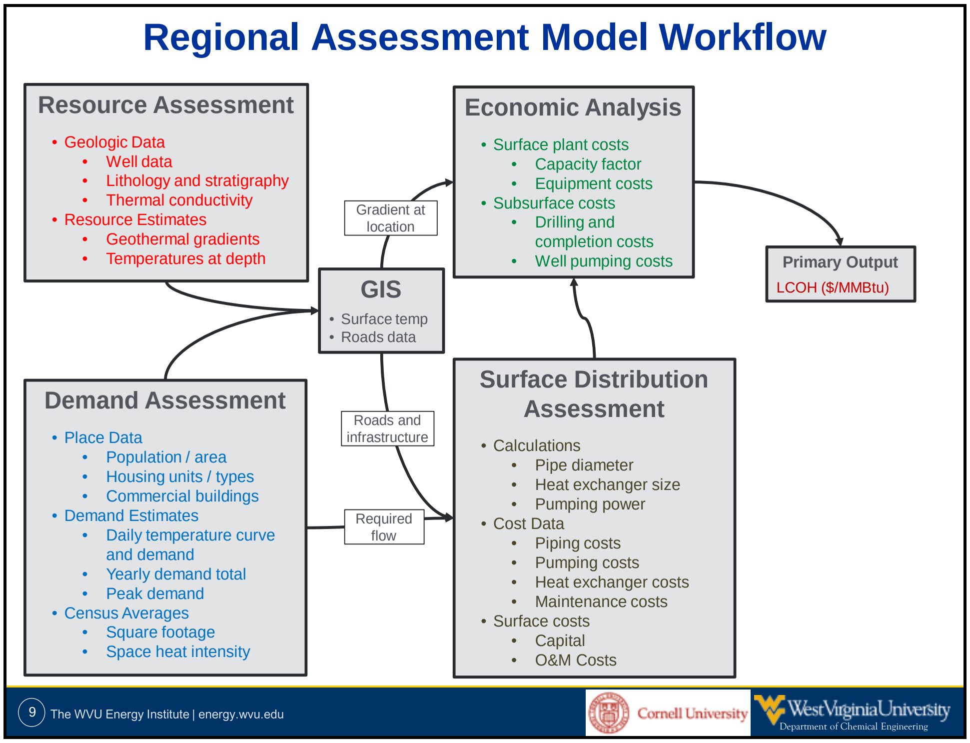

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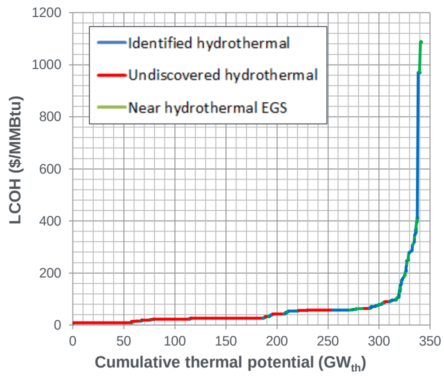
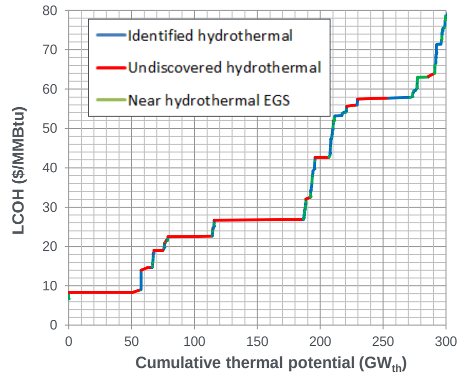
Supply characteristics- *Summary*



Supply curve integrated with three categories of geothermal resources.



Partial enlargement of the integrated supply curve.

He, X., and Anderson, B.J., "Supply Characterization of Geothermal District Heating and Cooling Applications in United States", Proceedings of the Thirty-Ninth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, February 24-26, 2014, SGP-TR-202

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Boise, ID

- **Largest of 17 US geothermal district heating systems**
- **First system installed in 1892**
- **Four systems currently operating**
  - Boise Public Works – downtown core area
    - 170°F (77°C), 65 customers, 1.8 million ft^2 including: City Hall, Ada County Courthouse, Idaho Water Center, Boise High School and YMCA
  - State of Idaho – State Capital and Capital Mall complex
    - 165°F (74°C), 9 buildings in the Capitol Mall complex, including the State Capitol (Neely, 1994). Currently, the system is used to heat about 1.5 million ft^2
  - Veterans Administration – VA campus
    - 400,000 ft^2 in 22 buildings on the VA grounds
  - Boise Warm Springs Water District – residential hot water

Photo credits: Idaho Capital Commission (top), Idaho Governor's Office of Energy Resources (middle), and Idaho State Historical Society (bottom)

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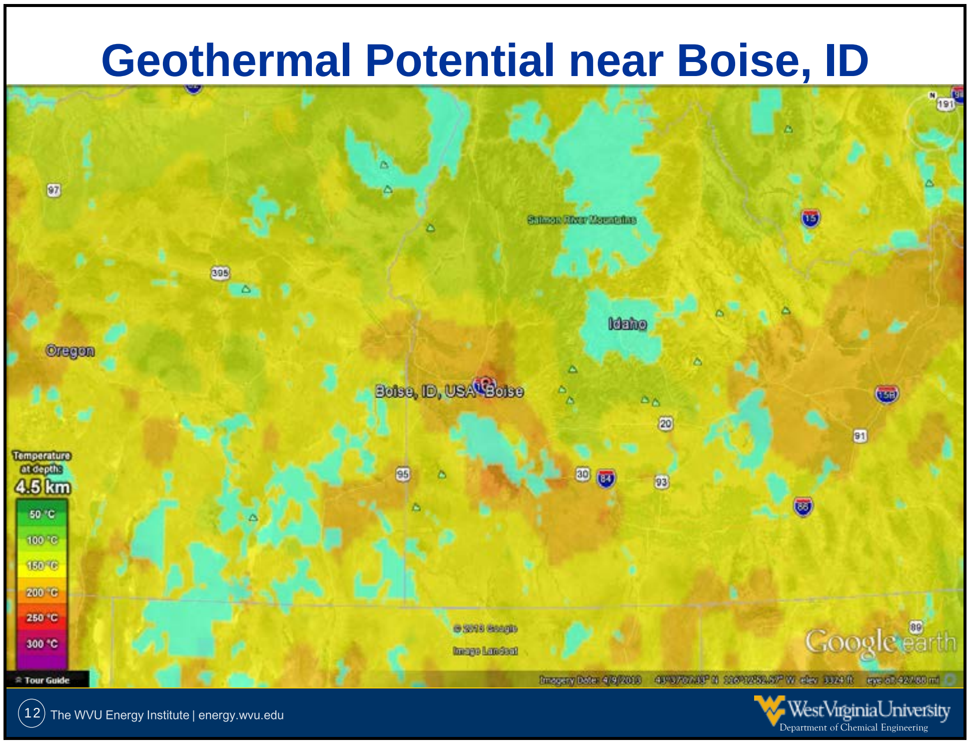

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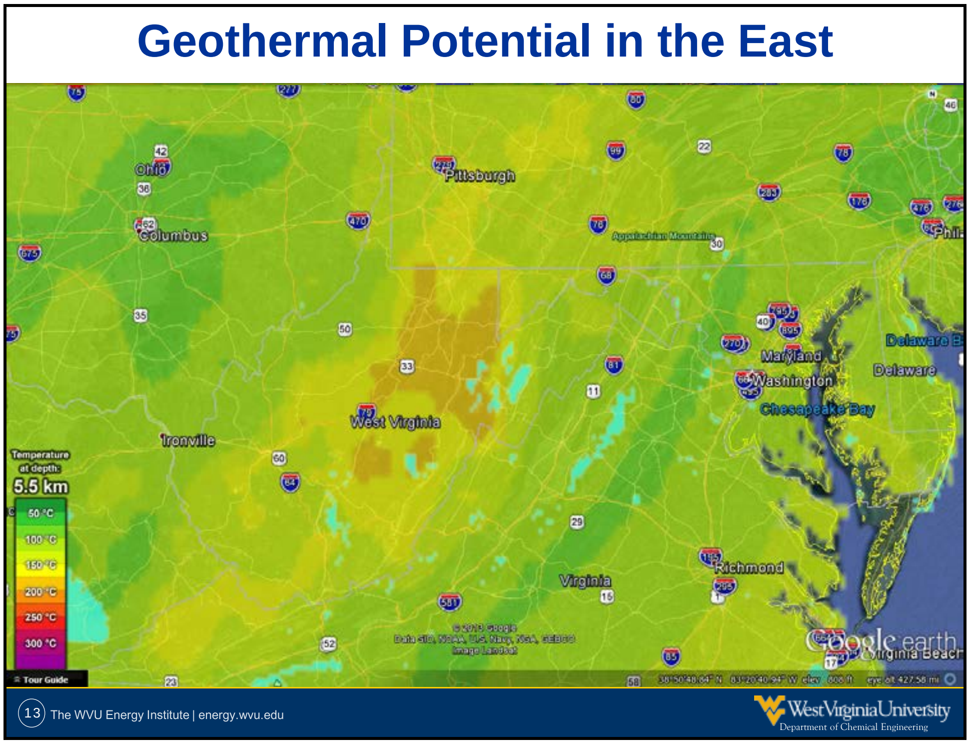

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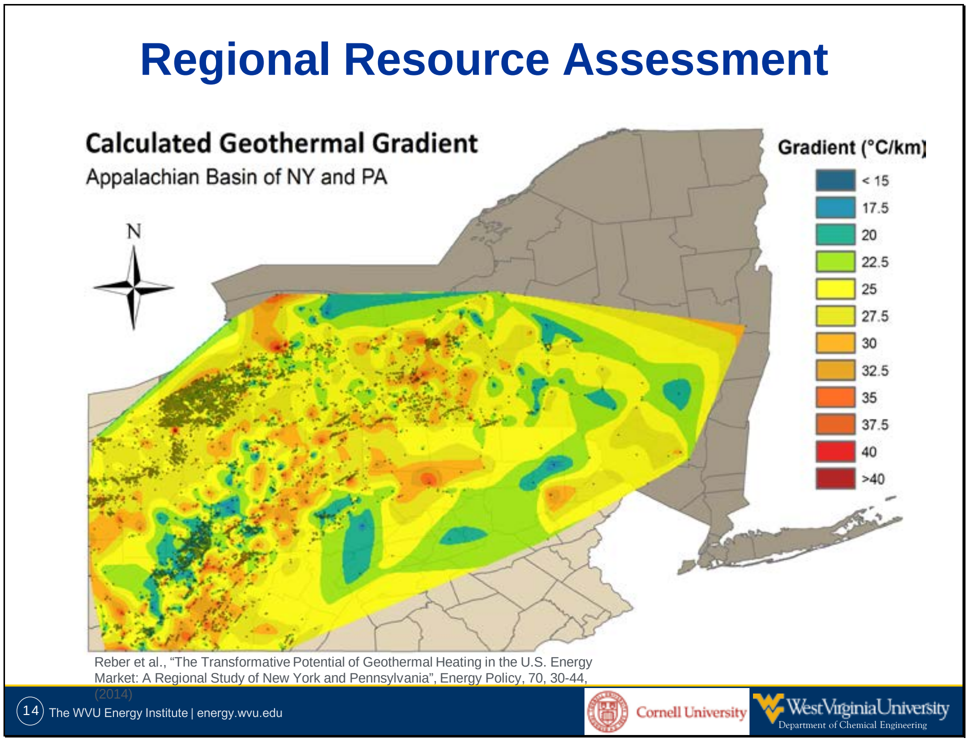

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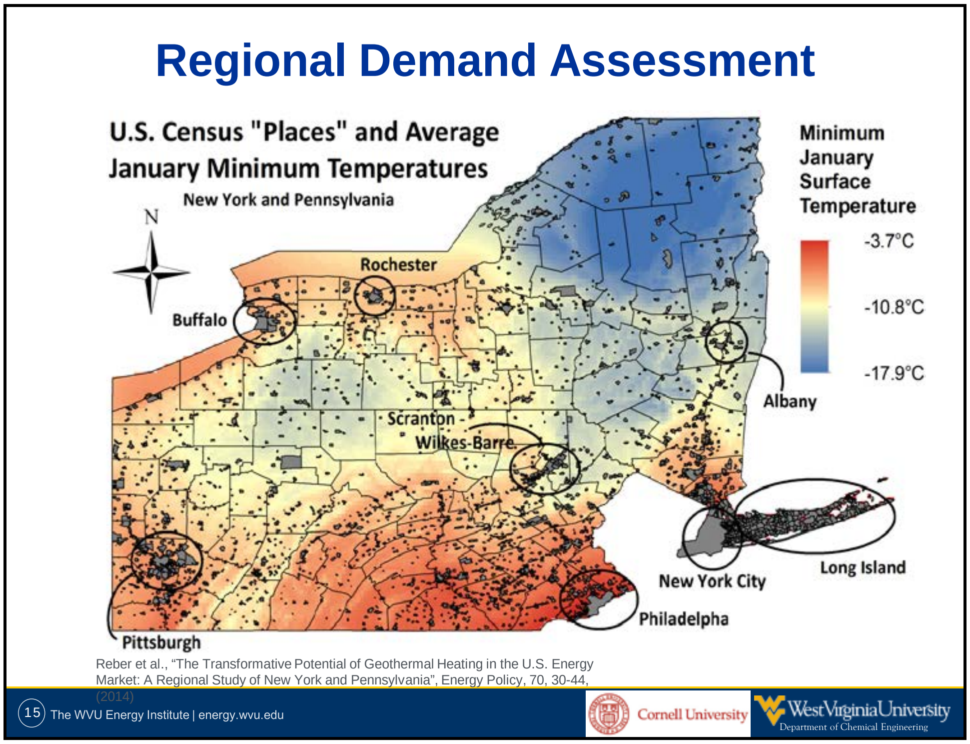

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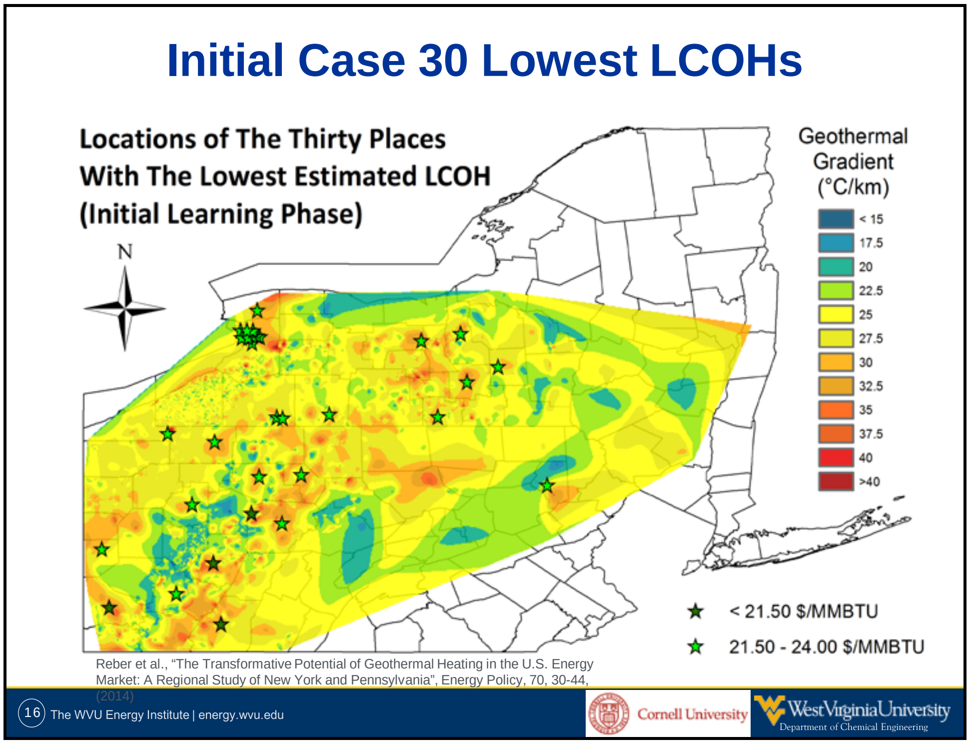

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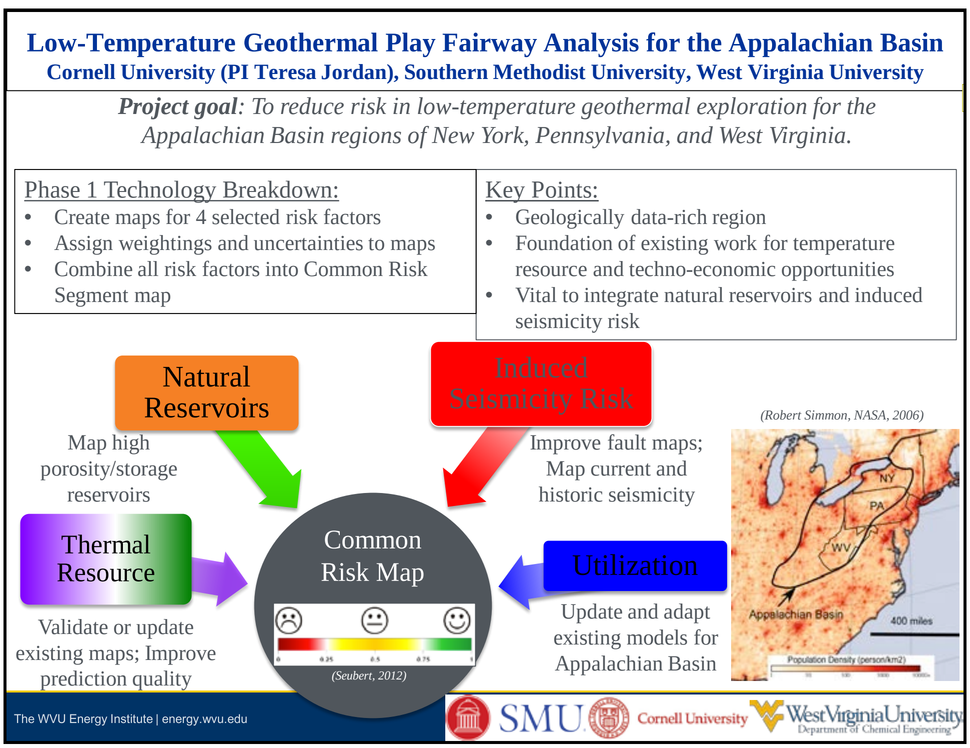

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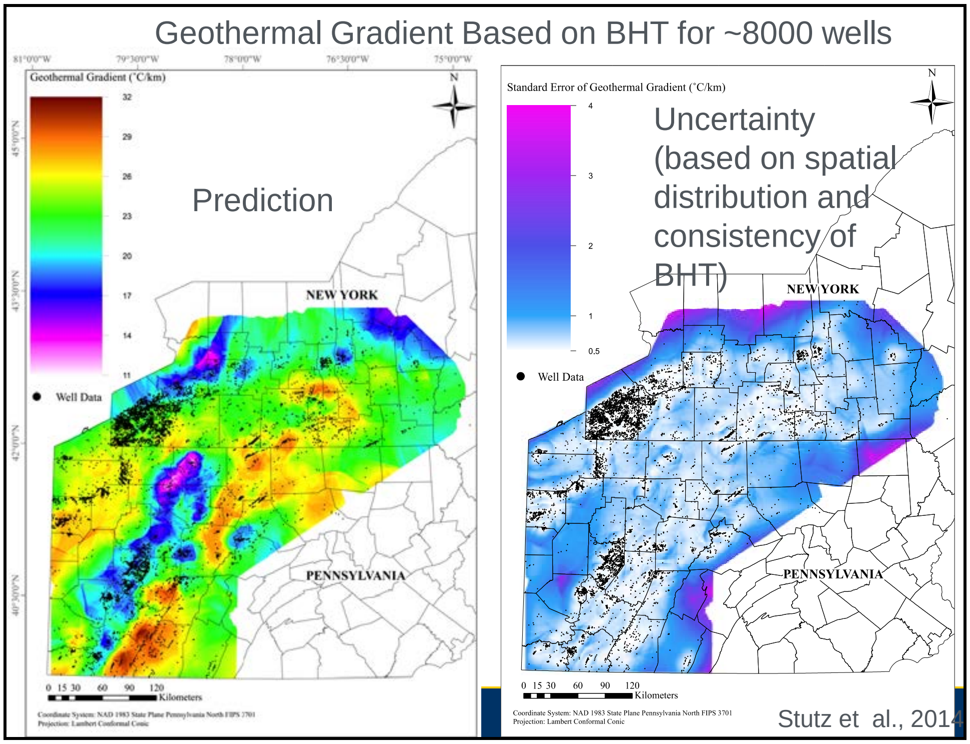

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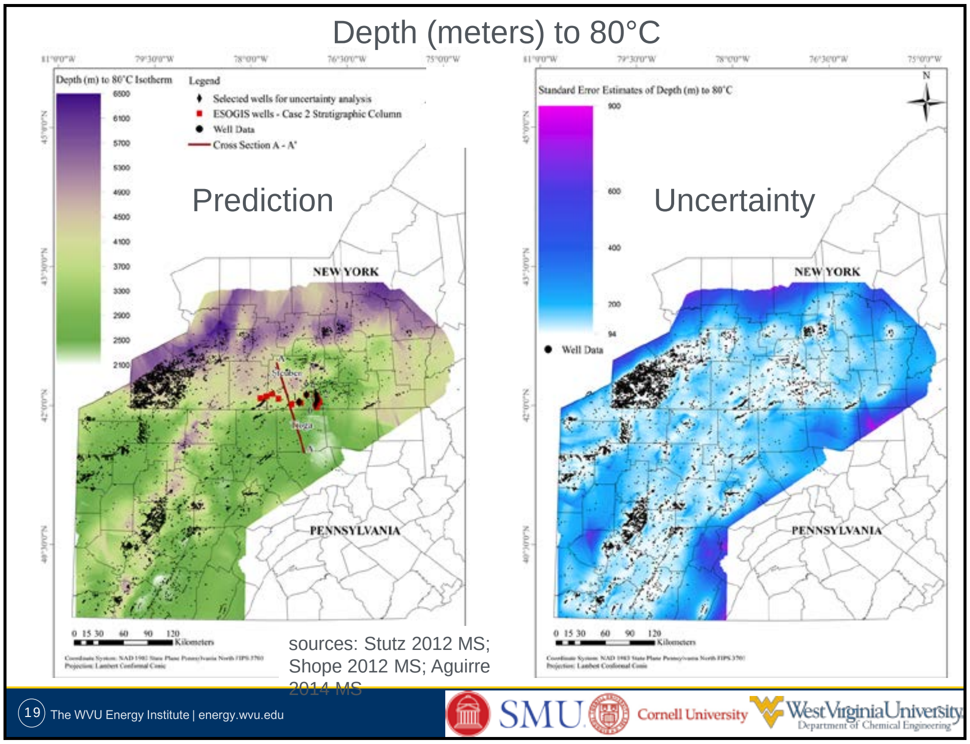

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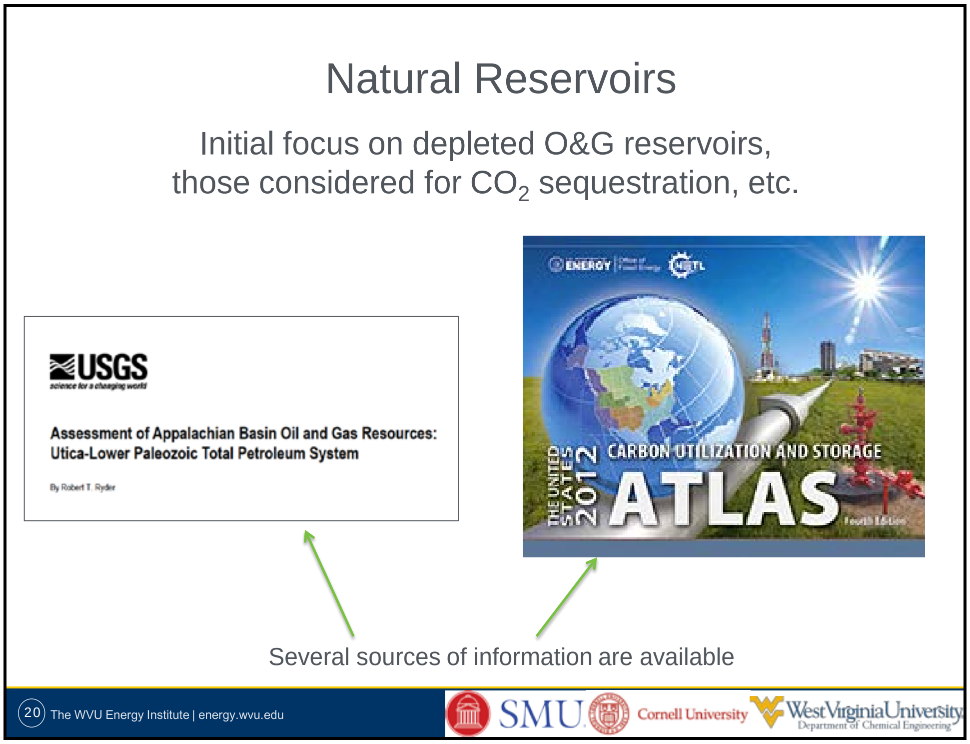

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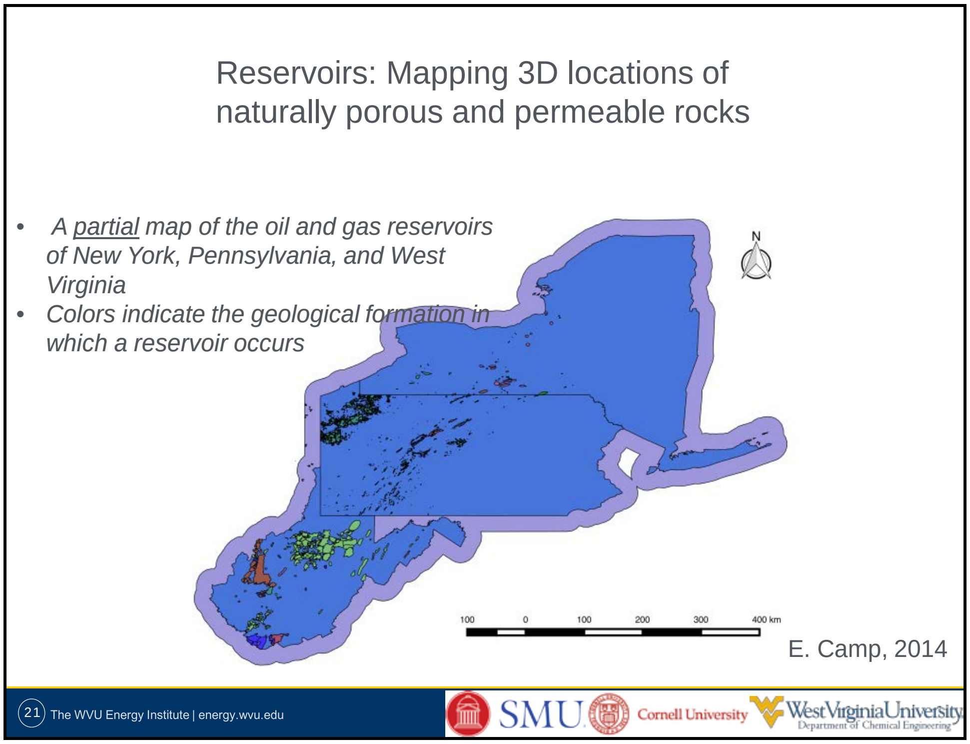

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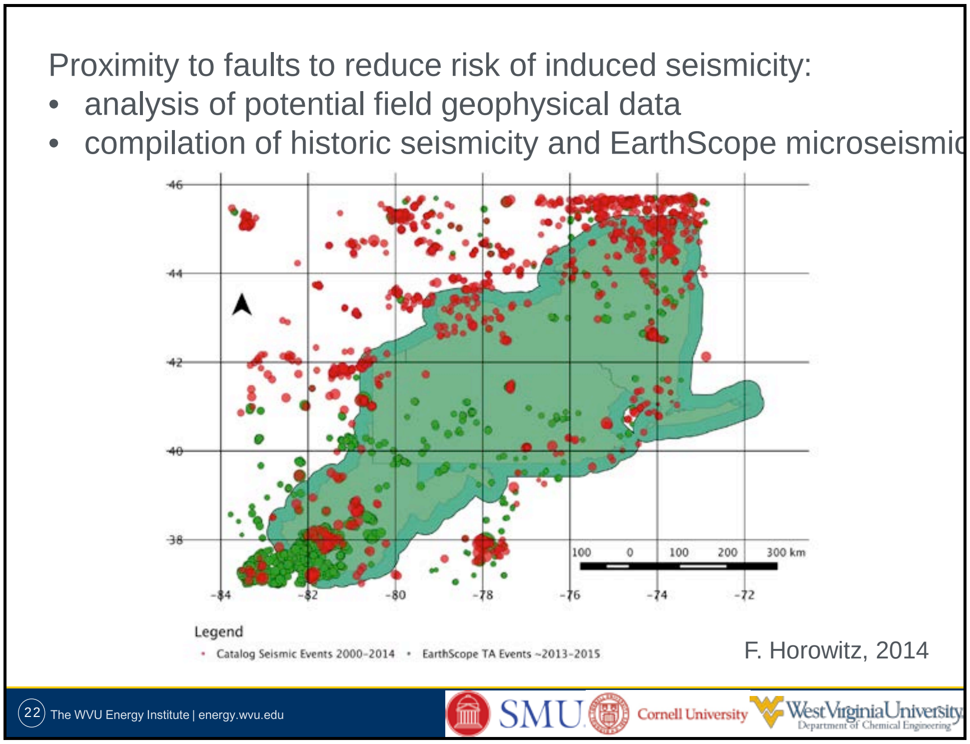

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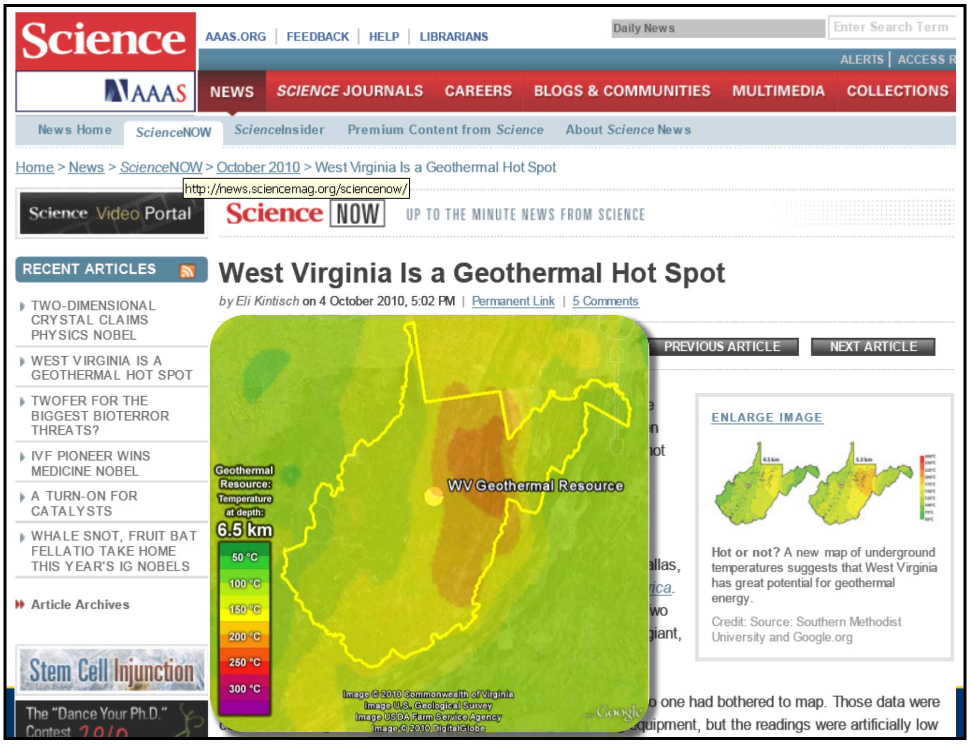

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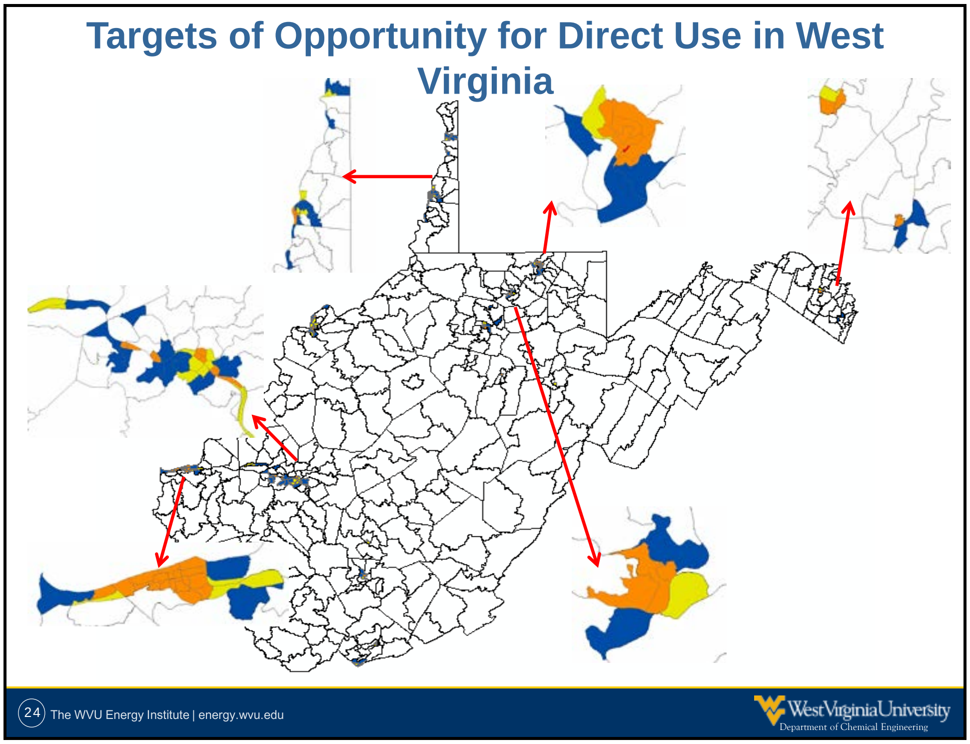

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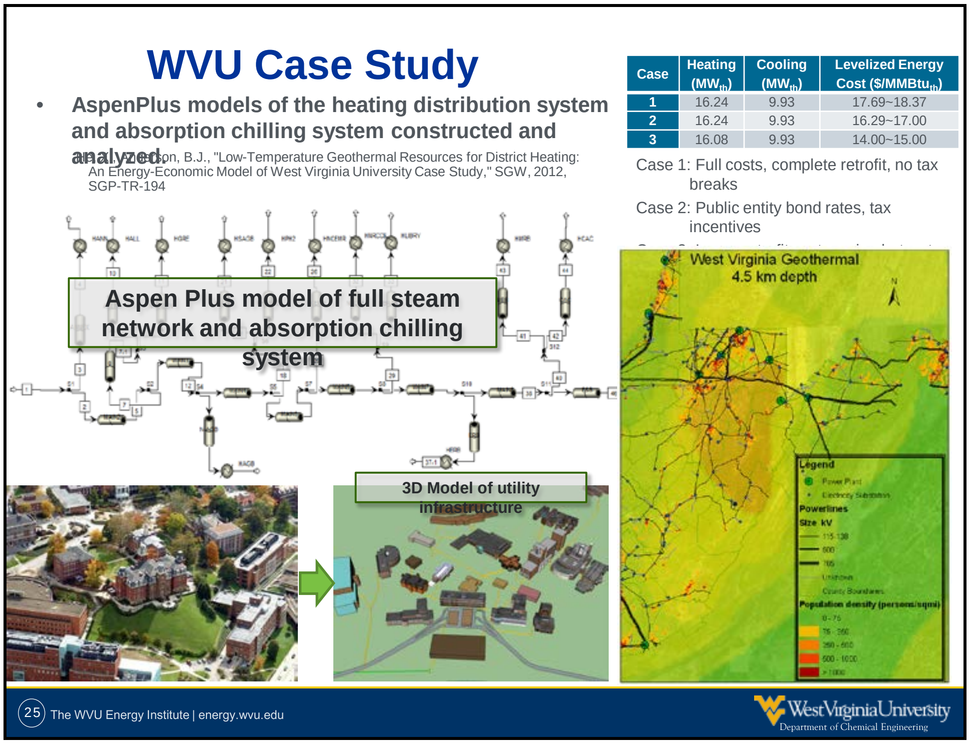

Slide 26

Geologic observations

- Lack of drilling data for target reservoir creates uncertainty for achievable flowrates
- Comparing with current operating projects:

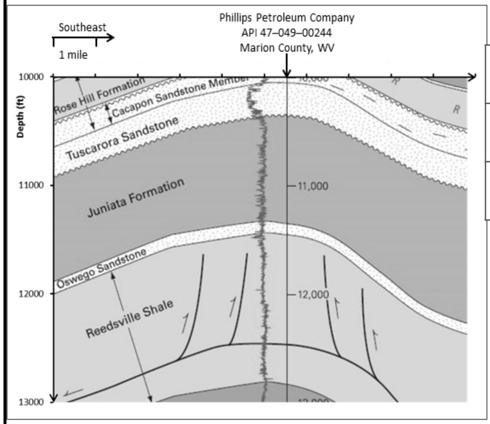

Fig. 23: Geologic formations near Morgantown, WV at depth of 3 to 4 km, formation Tuscarora and Oswego Sandstone are of interest for GDHC development.

Tab. 6: Comparison of the geologic conditions between Gross Schoenebeck and Morgantown

	Rock Type	Depth (m)	Permeability (mD)	Porosity (%)
Gross Schoenebeck	Conglomerates	4200 to 4230	0.003	4.8
	Volcanics	4230 to 4294	0.005	4.3
WVU	Tuscarora Sandstone	3200 to 3350	0.0048	6.8

**Gross Schoenebeck is running a 70 KW geothermal power plant.*

- Oswege formation extends to central NY state, where horizontal wells are drilled, and making it the fourth largest natural gas production formation in NY state.

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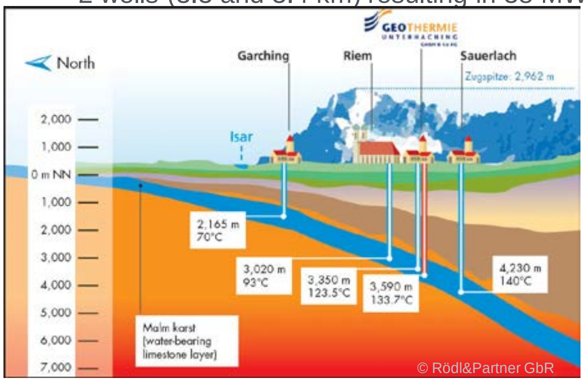
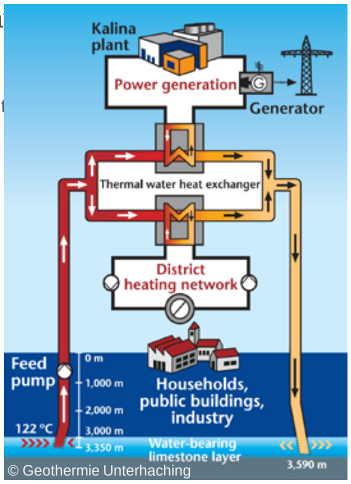
Slide 27

Geothermal Combined Heat and Power

- **Unterhaching geothermal plant near Munich, Germany**
  - Located in the Bavarian Molasse Basin (similar geologic setting as the Eastern US)
  - Low-temperature (122°C) production of hea
  - Heating 5,000 households
  - 2 wells (3.3 and 3.4 km) resulting in 38 MW





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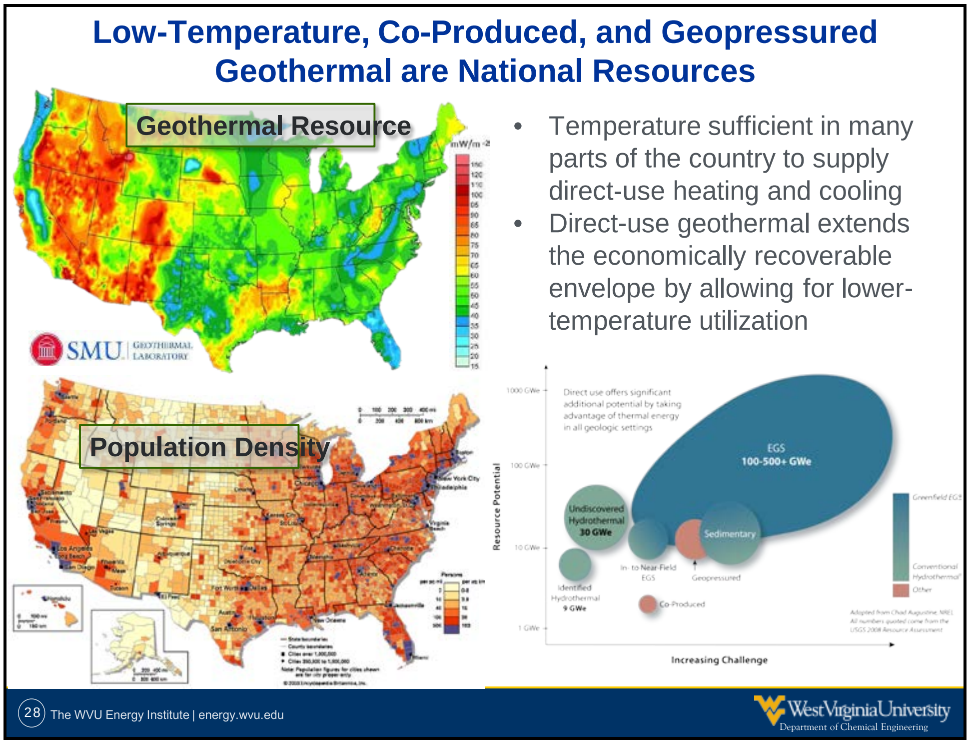

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Thank you

Questions?

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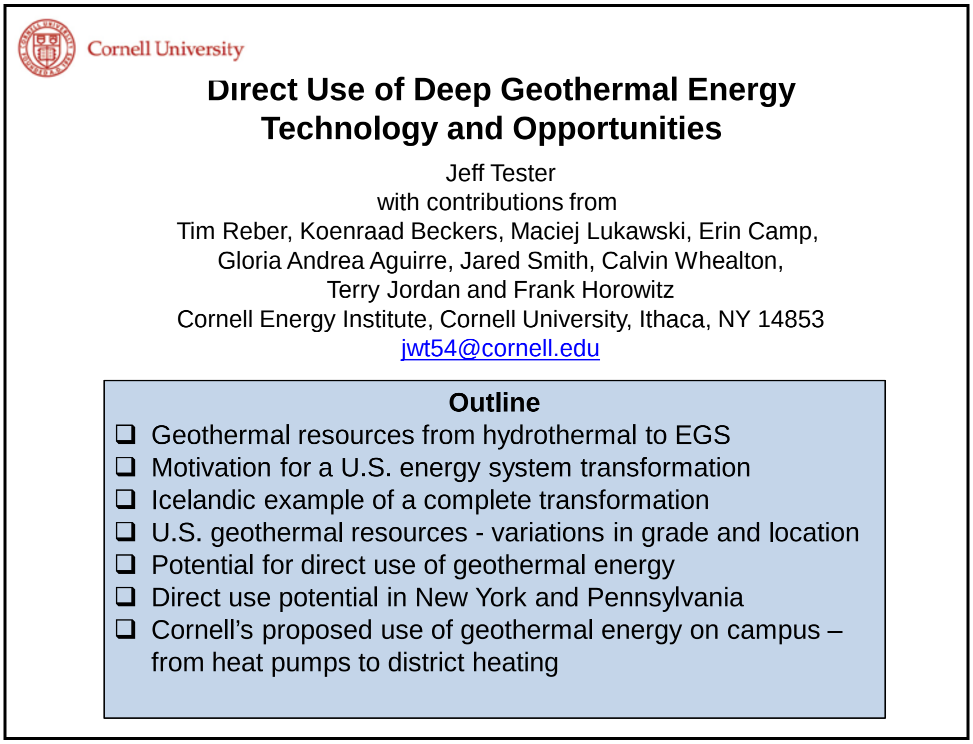
SPEAKER PRESENTATIONS: **Jeff Tester**

Geothermal Deep Direct Use Technology

Slide 1



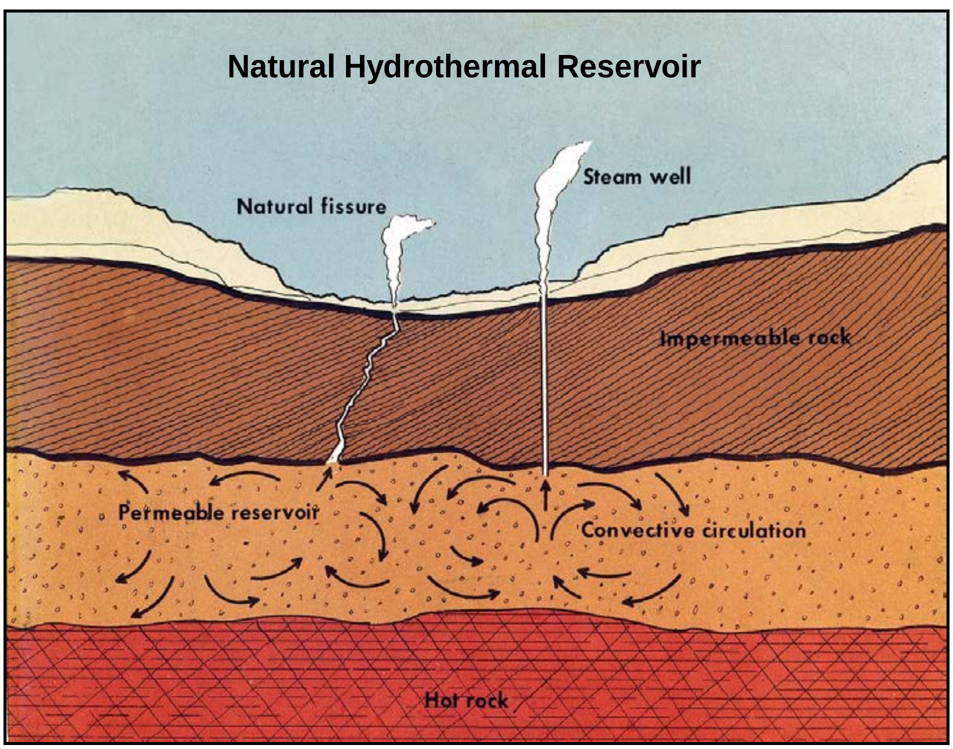
Slide 2

Two Main Types Deep Geothermal Resources

1. Natural hydrothermal systems containing hot water and/or steam with sufficient permeability/porosity

2. Enhanced/Engineered geothermal systems (EGS) that require intervention to create connectivity and stimulate their productivity

Slide 3



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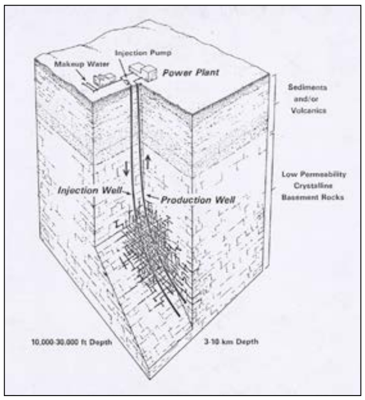
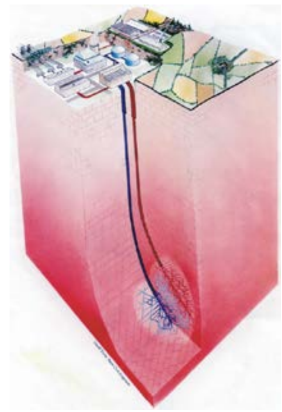
Enhanced/Engineered Geothermal Systems (EGS)





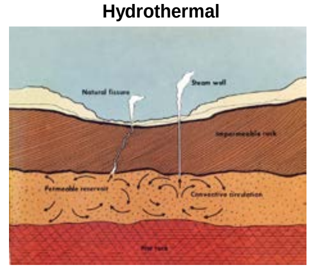
EGS defined broadly as engineered reservoirs that have been stimulated to emulate the production properties of high grade commercial hydrothermal resources.

Slide 5

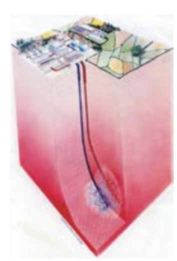
Geothermal systems – common characteristics and limitations

- An accessible, sufficiently high temperature rock mass underground
- Connected well system with ability for water to circulate through the rock mass to extract energy
- Production of hot water or steam at a sufficient rate and for long enough period of time to justify financial investment
- Means of directly utilizing or converting the thermal energy to electricity

Hydrothermal

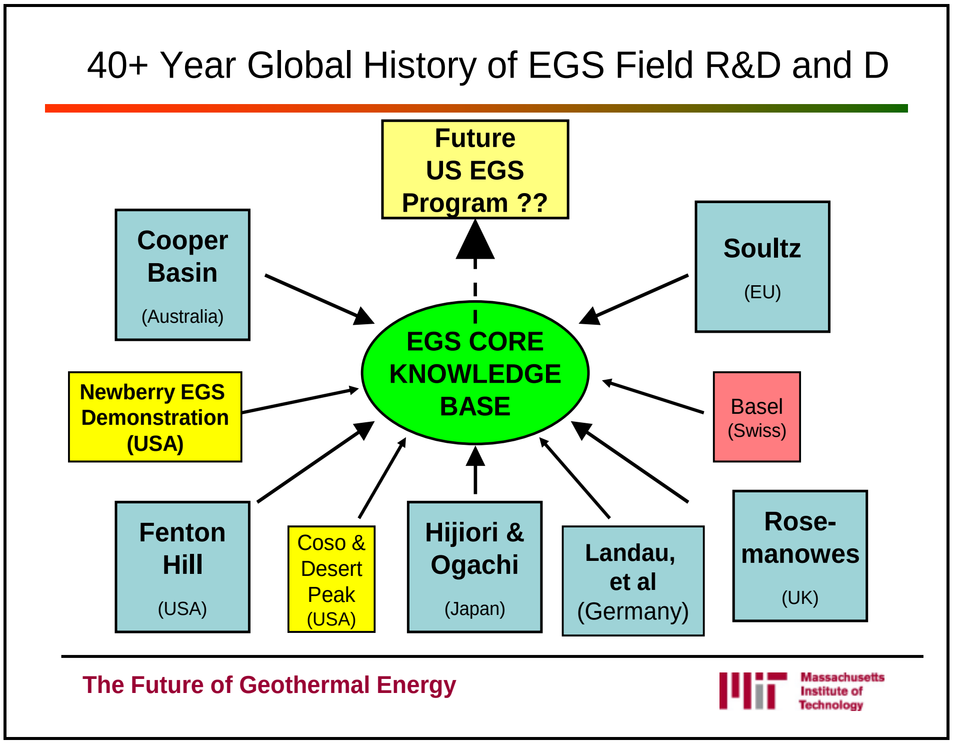


Enhanced Geothermal Systems (EGS)



Geothermal Power Plants

Slide 6



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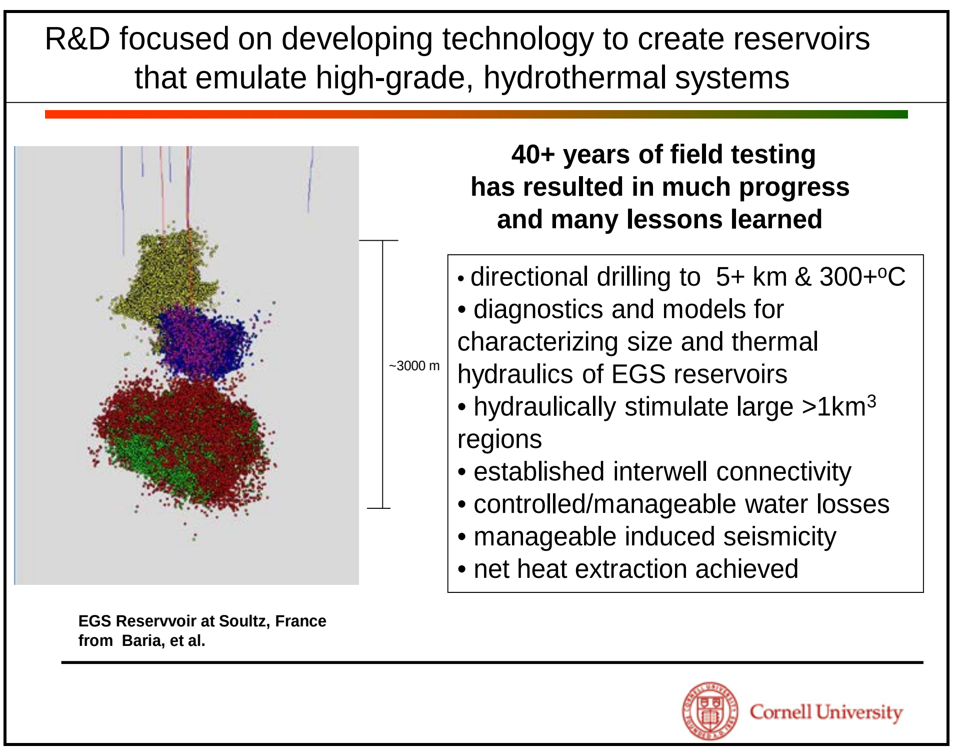
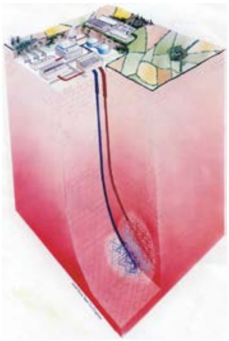


Slide 8

Although much has been accomplished
there are a few things left to do

1. Commercial level of fluid production with an acceptable flow impedance thru the reservoir
2. Establish modularity and repeatability of the technology over a range of US sites
3. Lower development costs for low grade EGS systems



Slide 9

Utilization of Geothermal Energy

1. **For Electricity -- as a source of thermal energy for base load electricity**
2. **For Heating -- direct use of the thermal energy in district heating or industrial processes**
3. **For Geothermal Heat Pumps – as a source or sink of moderate temperature energy in heating and cooling applications**

Slide 10

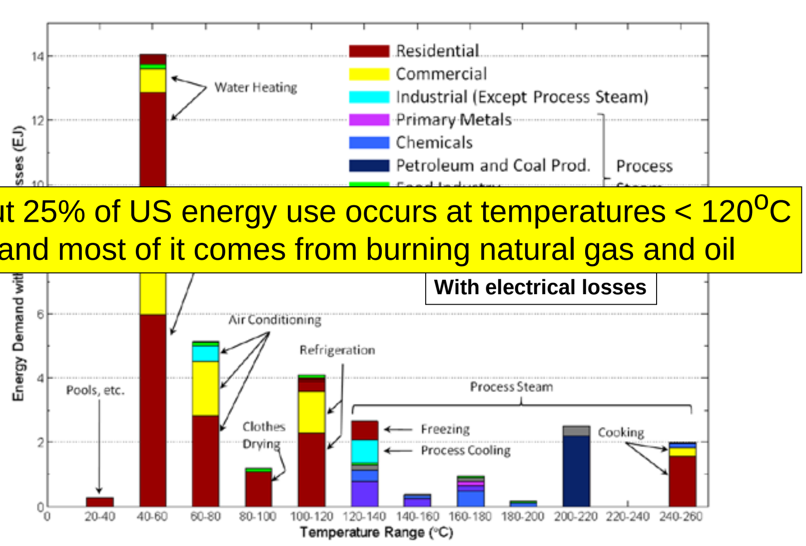
Geothermal energy today for heat and electricity

- From its beginning in the Larderello Field in Italy in 1904, currently 12,600 MWe of capacity worldwide today
- Additional capacity with geothermal heat pumps (e.g >100,000 MWt worldwide) with significant growth in direct use
- Current costs -- 7–10¢/kWhe
- Attractive technology for dispatchable base load power and heat for both developed and developing countries

Condensers and cooling towers, The Geysers, being fitted with direct contact condensers developed at NREL

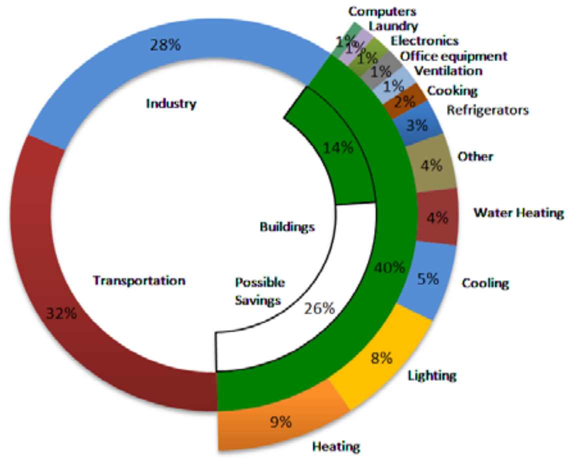
Slide 11

The Thermal Spectrum of U.S. Energy Use
Energy consumed as a function of utilization temperature
© by J.W. Tester, D.B. Fox and D. Sutter, Cornell University 2010



Slide 12

US Energy Consumption
And Possible Savings in Buildings



Source: Martin and Hencey, 'Building Energy Savings through Predictive Modeling and Control', Sibley Graduate Research Conference, Ithaca, NY, March 2010

Slide 13

Geothermal has enabled Iceland's transformation

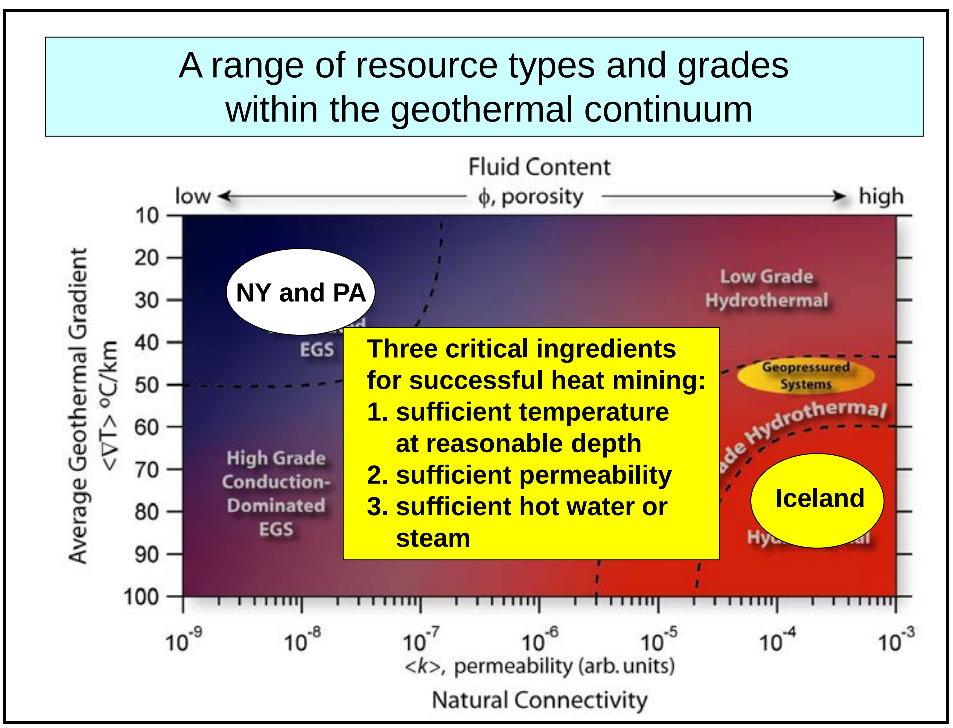
- In 50 years Iceland has transformed itself from a country 100% dependent on imported oil and coal to a renewable energy supply based on geothermal and hydro
- >95% of all heating provided by geothermal district heating
- >20% of electricity from geothermal – remainder from hydro
- 3 world scale aluminum plants powered by geothermal and hydro
- Currently evolving its transport system to hydrogen/hybrid/electric systems based on high efficiency geothermal electricity

Reykjavik, Iceland in the 1940's

Reykjavik, Iceland today

Slide 14

Slide 15



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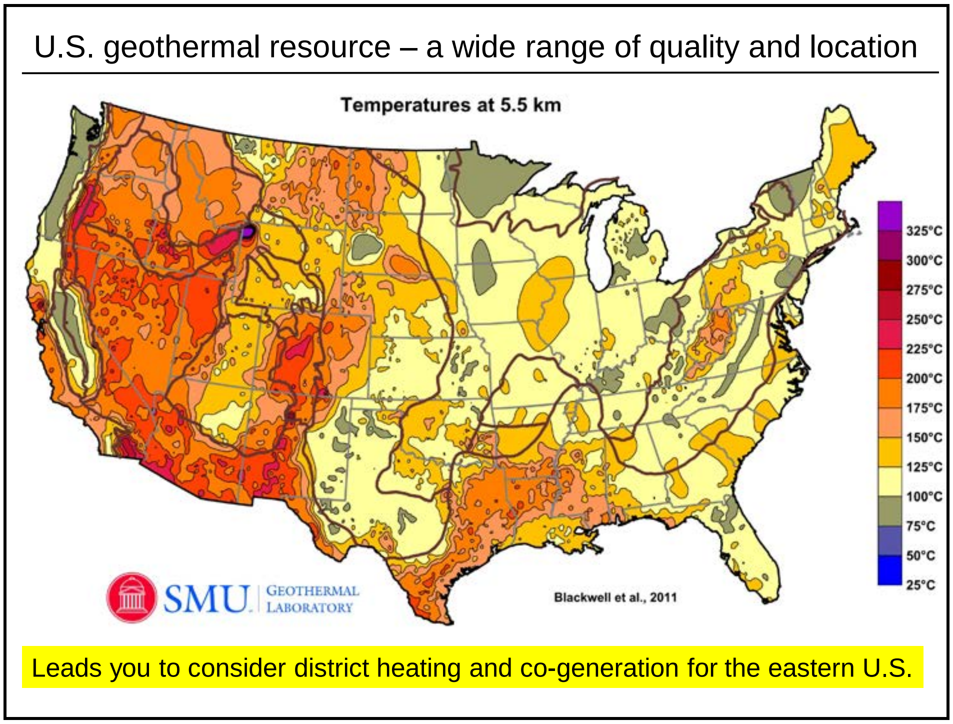

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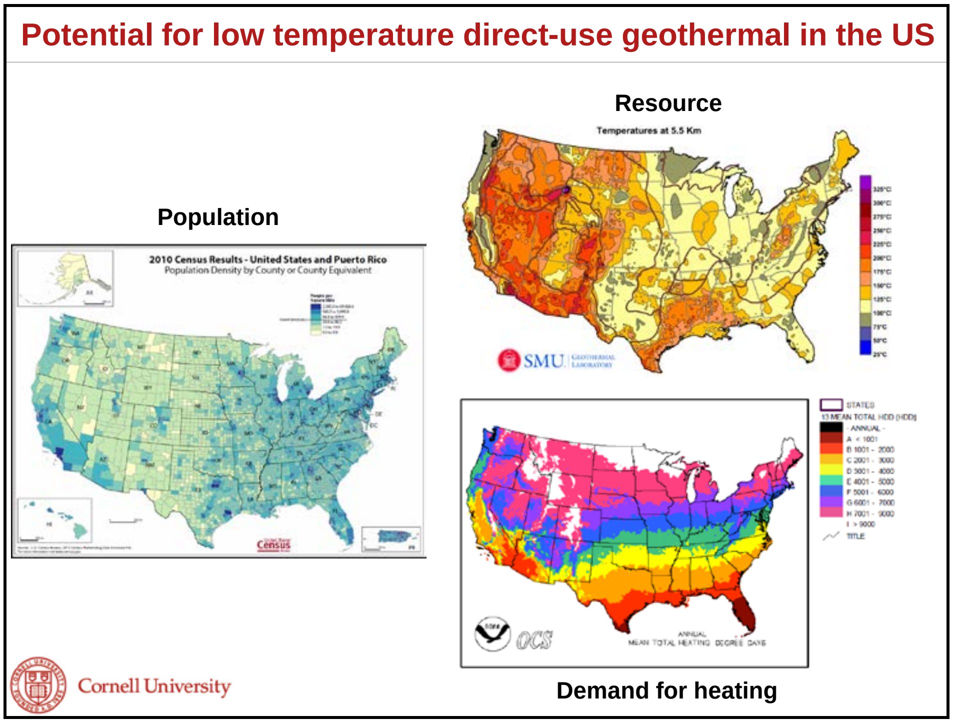

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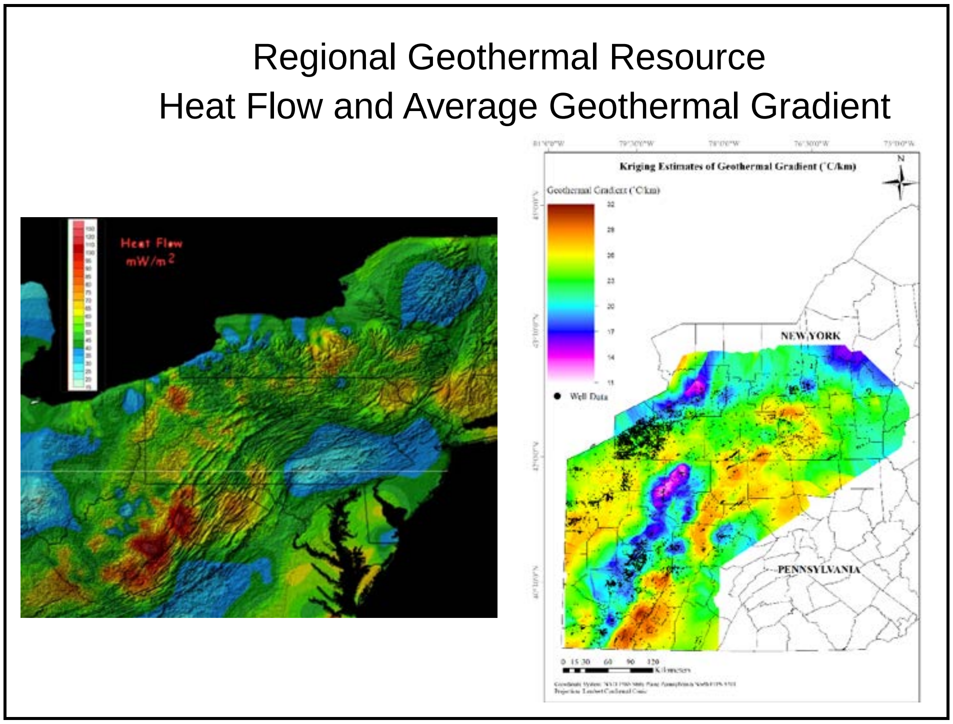

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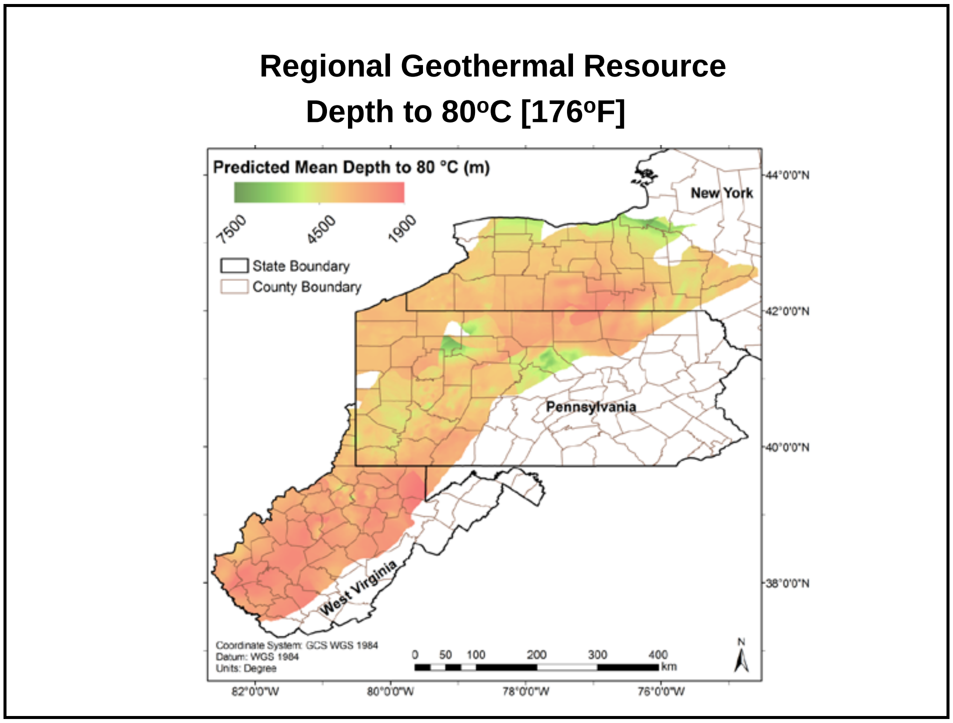

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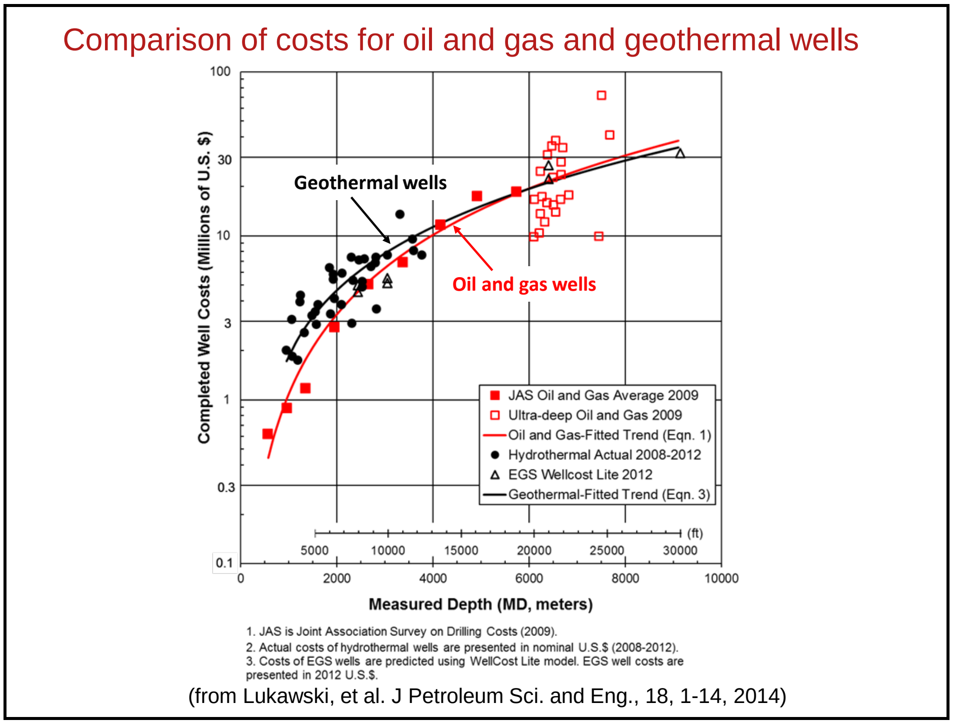

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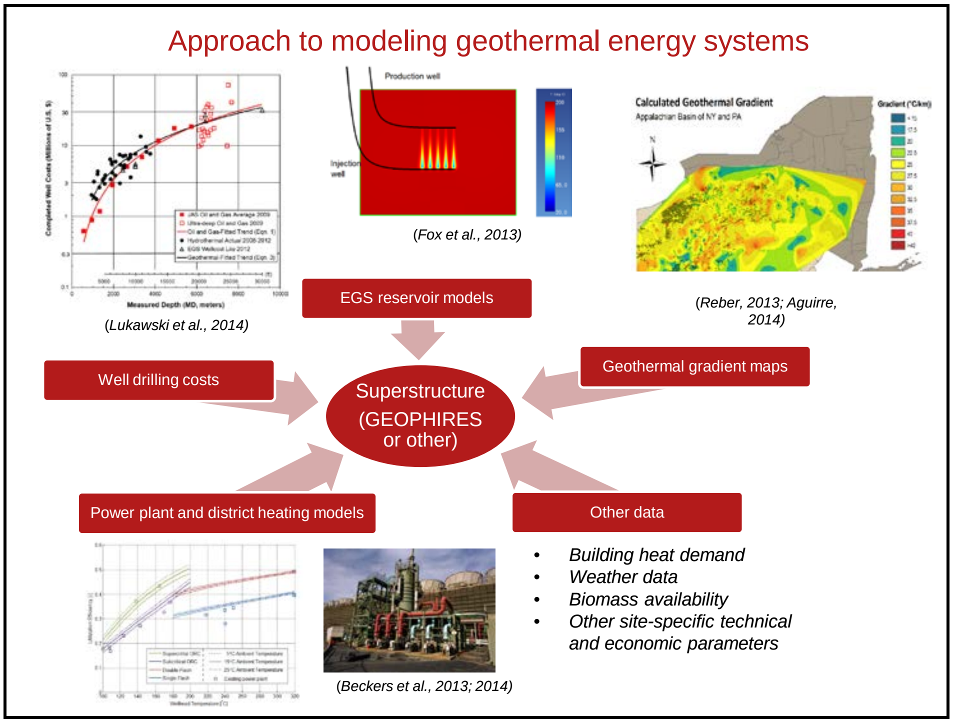

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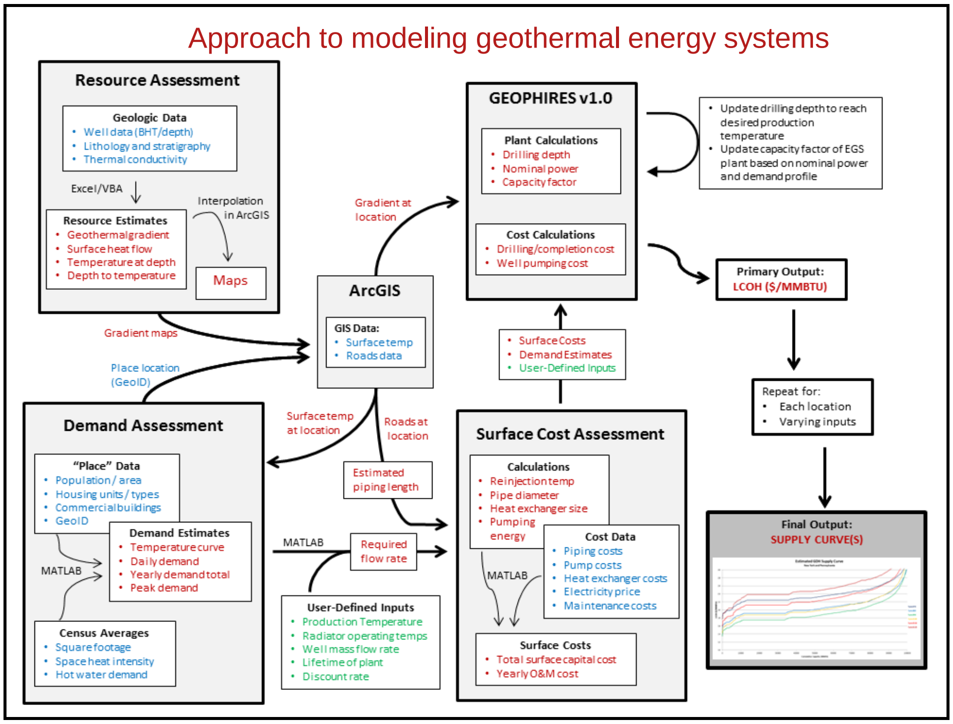

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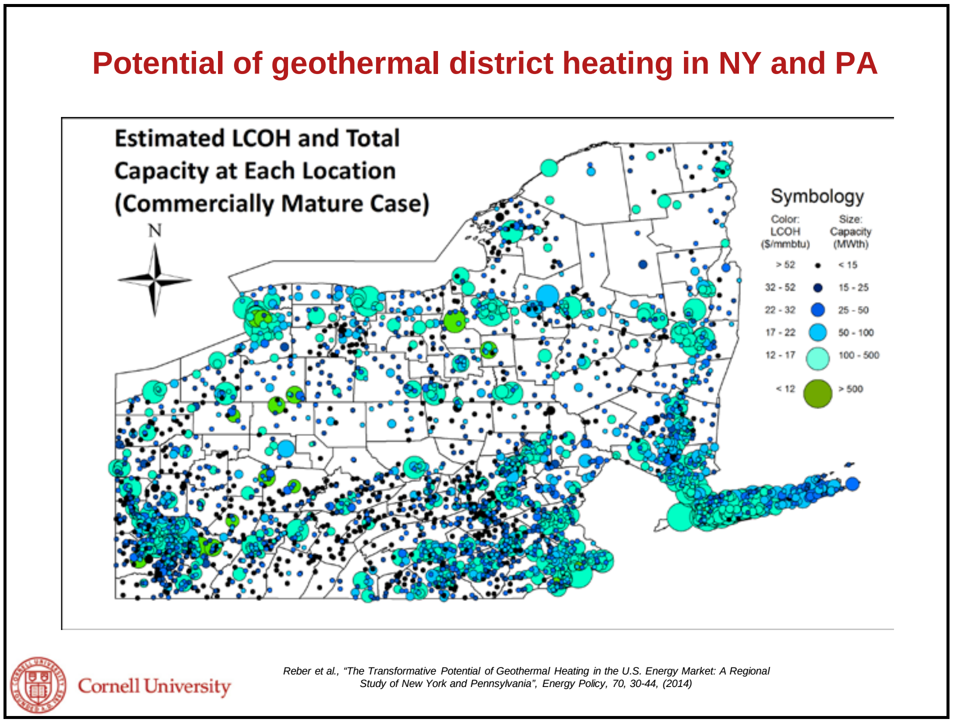


Slide 24

Cornell 's involvement in transformational renewable energy options for NY

Atkinson Center for a Sustainable Future
www.ccsf.cornell.edu
Cornell Sustainable Campus
www.sustainablecampus.cornell.edu
Cornell Energy Institute
www.energyinstitute.engineering.cornell.edu

Slide 25

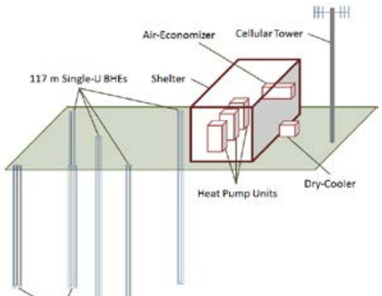
Three examples utilizing geothermal energy

1. Geothermal Heat Pumps for Verizon Wireless: from campus demonstration to nationwide deployment
2. Energy options for Sustainable Communities in NY
3. Transforming Cornell's energy system to a low carbon footprint

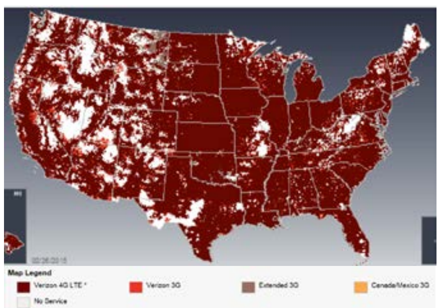
Slide 26

Geothermal Cooling In Cell Towers

- Feasibility of using geothermal heat pumps for cooling cellular tower shelters
- Validation of techno-economic model from the Cornell Campus demonstration and assessment of nationwide potential



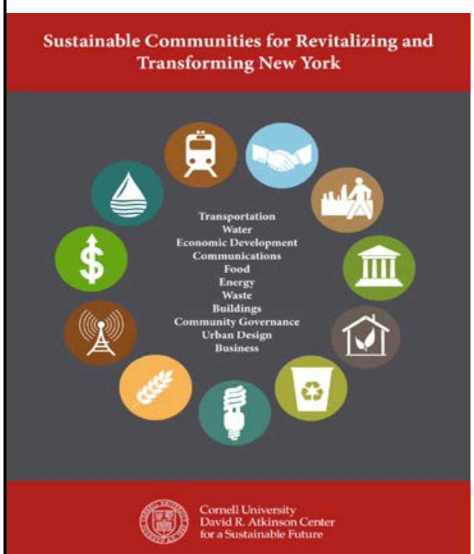
From Regional to Nationwide Impact



Cornell Field Test

Slide 27

Recapturing our Nation's Assets through a Sustainable Community Systems View



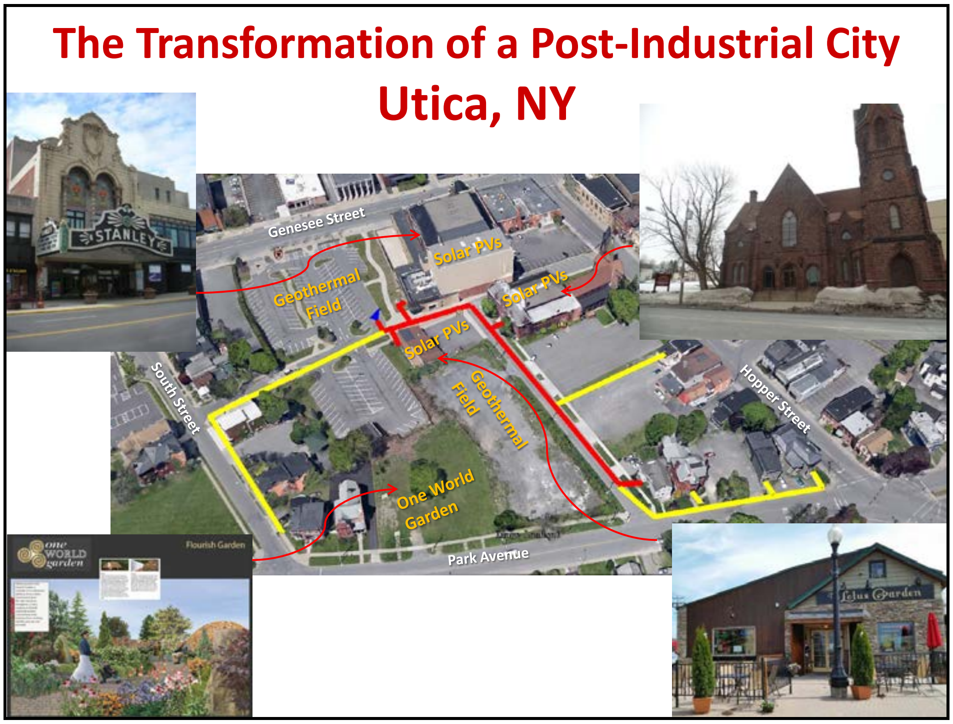
Interdisciplinary approach:

- Systems
- Energy
- Engineering
- Environment
- Landscape Architecture
- Community Development

Metrics:

- Technical
- Economic
- Social
- Environmental

Slide 28



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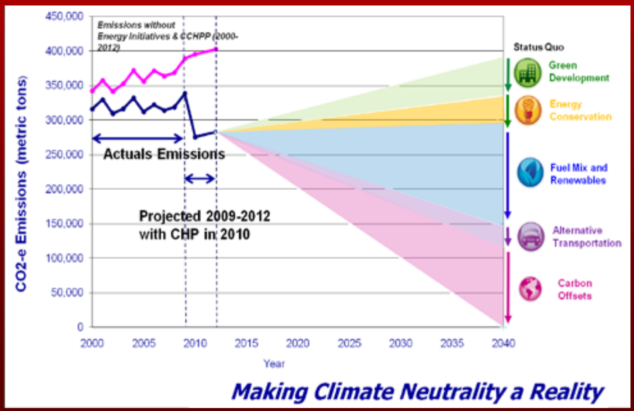
Slide 30

Cornell's approach includes:

- Climate Action Plan (CAP)
- Atkinson Center for a Sustainable Future (ACSF)
- Cornell University Renewable Biofuels Initiative (CURBI)
- Cornell Energy Institute (CEI)



Slide 31

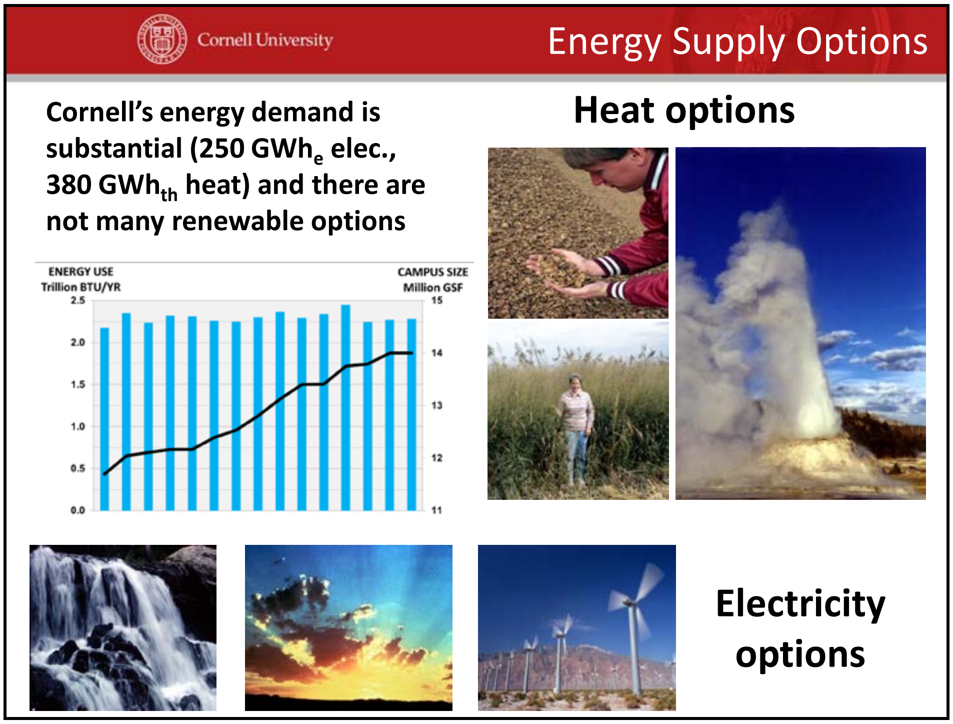
Transforming Cornell's District Energy System

Renewable energy options for Cornell's campus with 30,000 students, faculty and staff

1. Lake source cooling implemented 14 yrs ago
2. Transition from coal to natural gas
3. Cornell's hydro plant upgraded and operational at 1 MW_e
4. Solar PV at 2 MW_e expanding to 10 MW_e
5. 12 MW_e of wind power deployed with partners at the Black Oak Wind Farm
6. Biomass using Cornell's 14,000 acres of ag and forest land
7. Geothermal of lower grade in the East – useful for district heating and co-gen

Extensive district energy infrastructure

Slide 32



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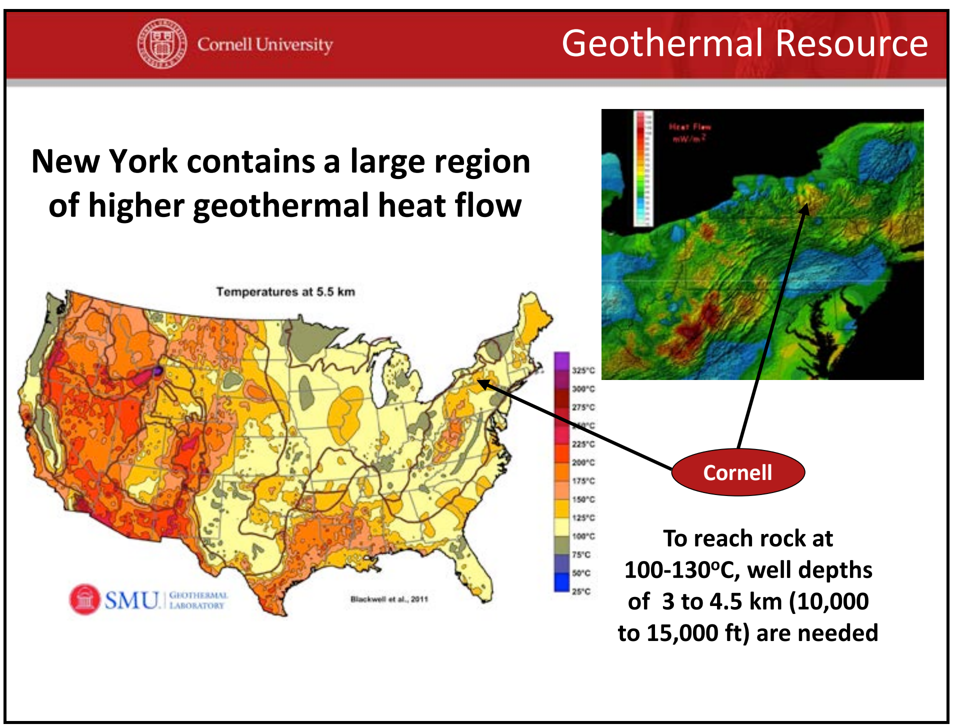

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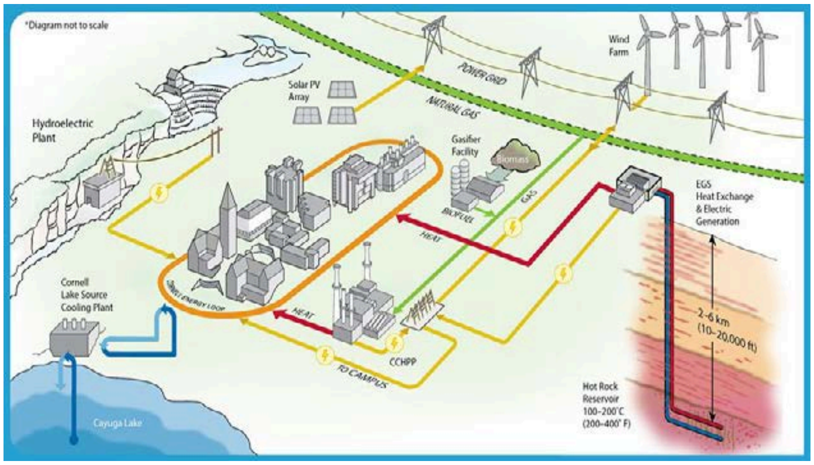
Cornell University

Transformation

To meet Cornell's heating demand deep geothermal and biomass are feasible and land exists for siting a demonstration



To achieve this goal a supportive team is needed – faculty, students, staff, NY state NYSERDA, US DOE, and Trustees

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Cornell University

Cornell Case Study

Economic considerations

Base Case Conditions for District Heating Demonstration

Resource

- Geothermal Gradient <∇T> = 20, 30, 40 °C/km
- Drilling Depth = 3 - 6 km
- Ambient Temperature = 15 °C

Reservoir

- Well System = Doublet
- Flow Rate = 50 kg/s
- Water Loss Rate = 2%
- Thermal Drawdown Rate = 0.5 %/year
- Pressure Drop = 0.15 MPa/(l/s) = 1.4 psi/GPM

Economics

- 2012 US Drilling Costs
- Discount Rate = 3%
- Capacity Factor = 70%
- Surface Infrastructure Cost = $150/kW
- Electricity Charge for Pump Power = 7 ¢/kWh
- Plant Lifetime = 30 years

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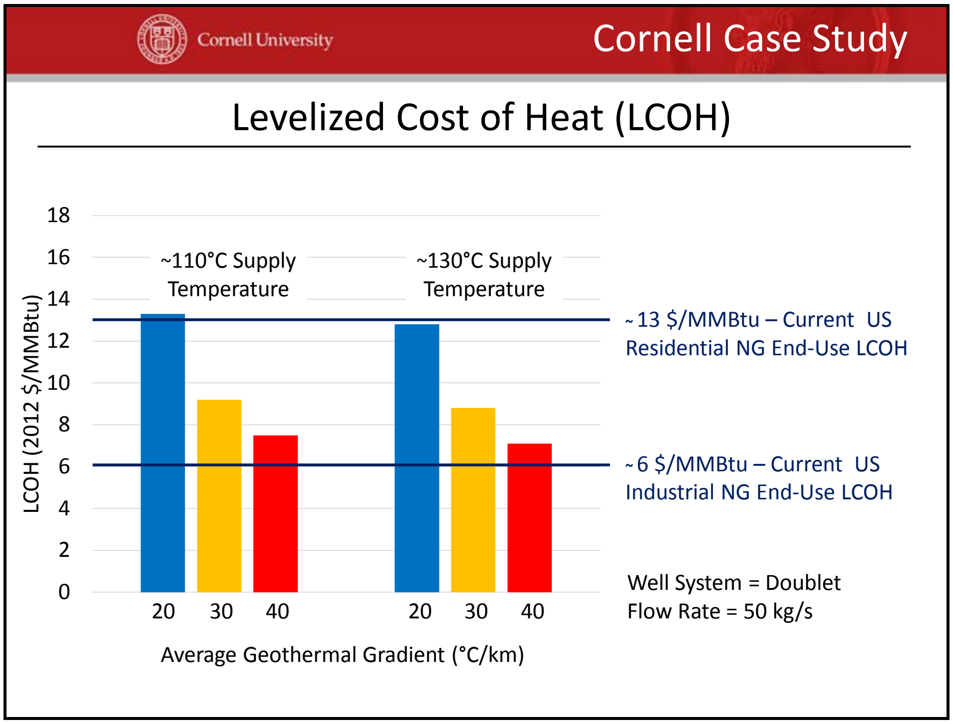

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Summary

1. Differences between hydrothermal and EGS
2. Status of the deep geothermal technology
3. Opportunities for utilization – from Iceland to USA
4. Important parameters affecting costs (reservoir productivity and drilling)
5. Examples of deployment
   - Geothermal heat pump cooling for wireless cell towers
   - Regional deployment of geothermal for sustainable communities
   - Geothermal for carbon-free district heating as a key part of Cornell's Climate Action Plan

Cornell is working with partners including:

nyserda Energy. Innovation. Solutions. | WestVirginiaUniversity | ORMAT | Iceland Geothermal Cluster Initiative | U.S. Department of Energy | Capuano Engineering Company | SMU | AltaRock | ÍSOR | HS Orka HF

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SPEAKER PRESENTATIONS: **Thorleikur Jóhannesson**

Geothermal Experience in Iceland

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Table Of Contents

- Verkís Consulting Engineers
- Geothermal district heating in Iceland
- Reykjavík Geothermal District Heating development
- Heating requirements and meeting annual heat demands
- Piping systems and installation
- Cost of district heating systems
- District heating systems - Concluding remarks.

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Iceland /USA

- Iceland
  - Population 330 000
  - Size 103 000 km^2
  - Population density 3.20 persons pr. km^2

- USA
  - Population 319 000 000 (1000 times more people)
  - Size: 9 900 000 km^2 (100 times bigger)
  - Population density 32.4 persons pr. km^2 (10 times more crowded)

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VERKÍS

CONSULTING ENGINEERS

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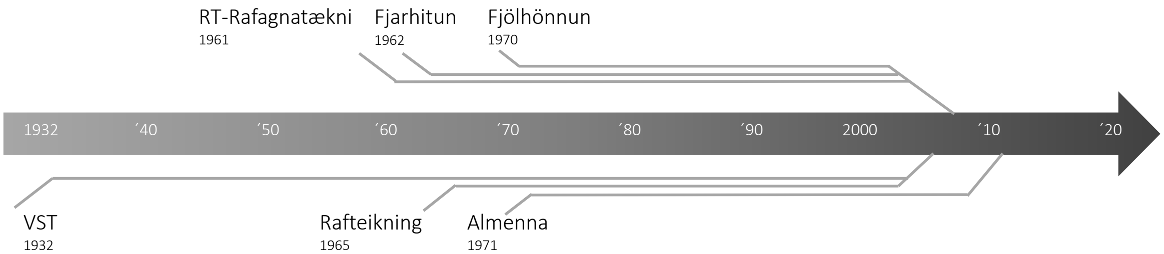
Verkís Consulting Engineers

- Verkís was founded in 2008 by merger of five leading Icelandic consulting engineering firms
- The origin of the firm dates back to 1932
- Partnership owned by 93 professionals with a staff of 320 employees



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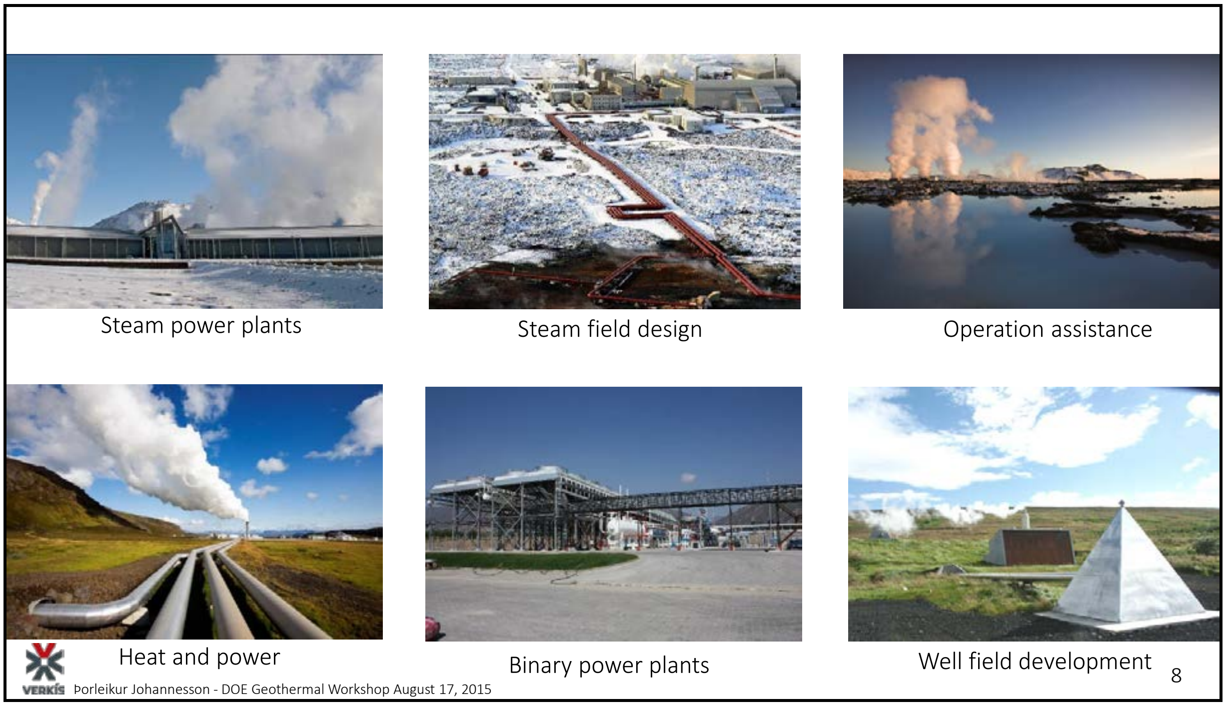

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Geothermal District Heating in Iceland

Over 90% of all homes heated with geothermal

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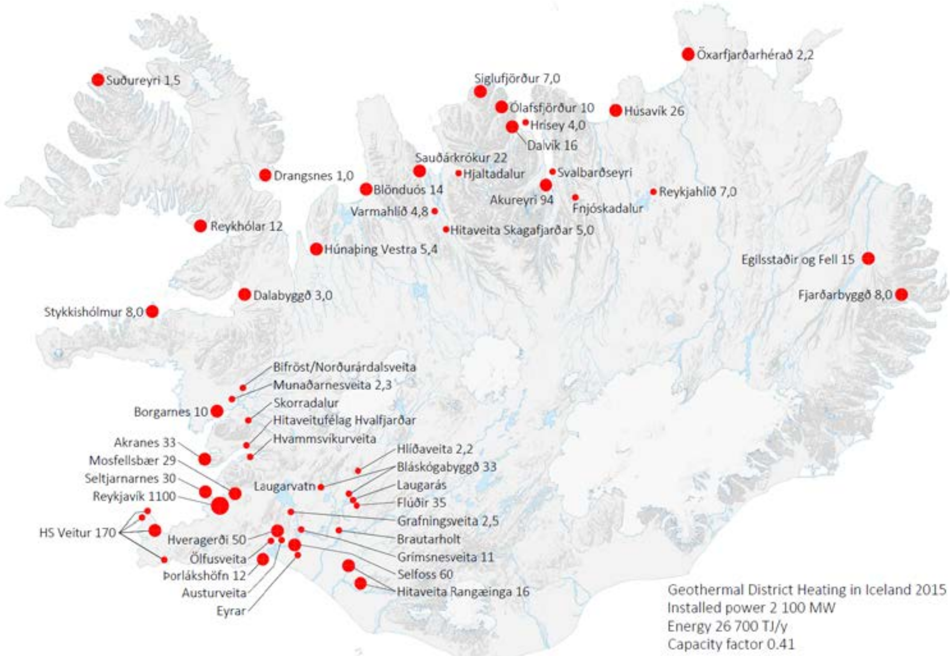

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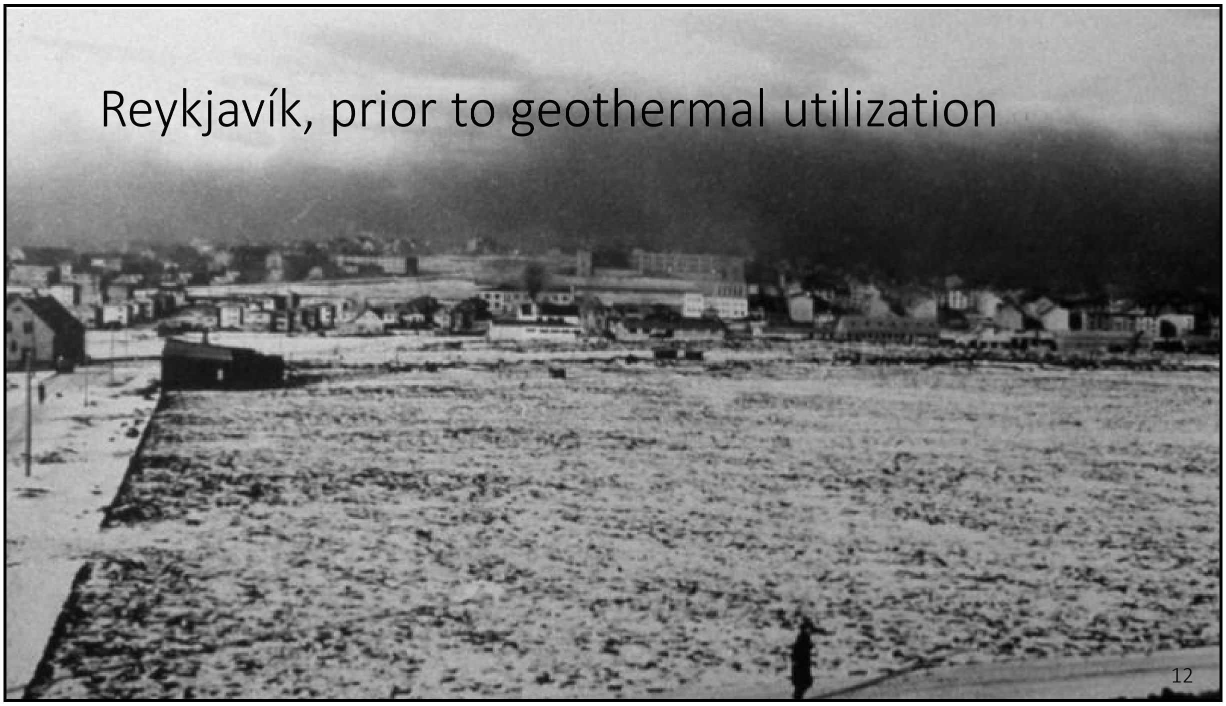

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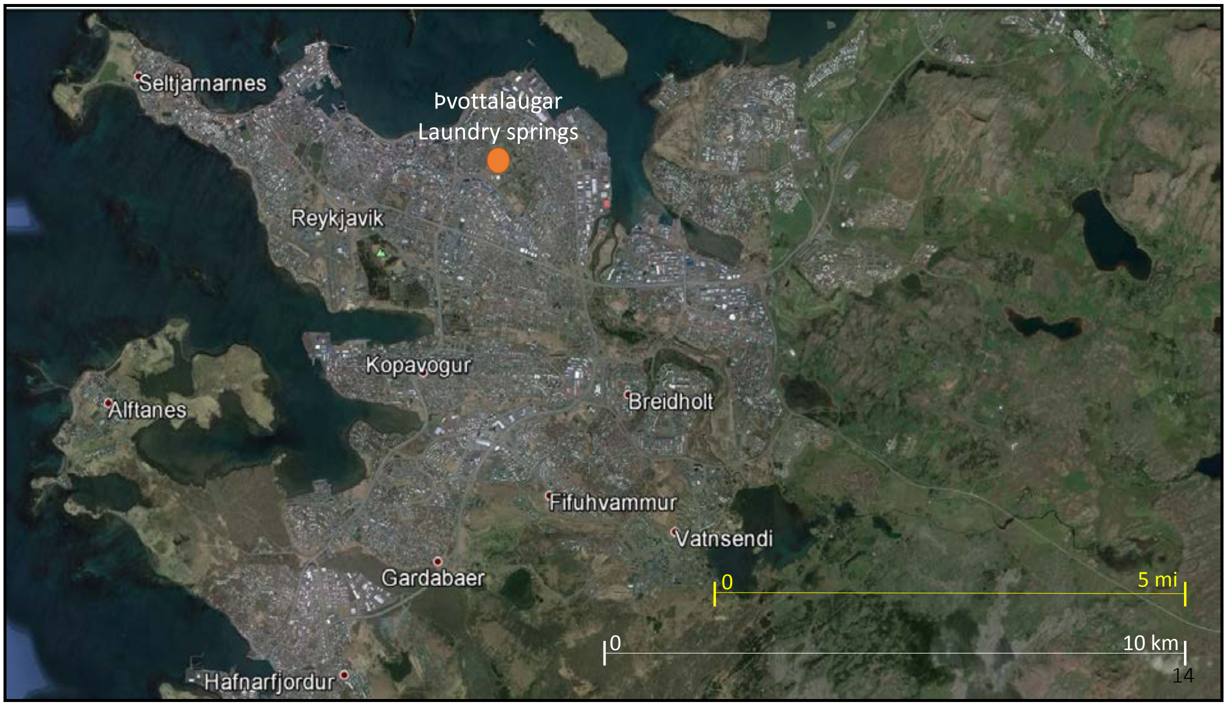

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Reykjavík Geothermal district heating

- 1908 - Farmer piped geothermal water from a hot spring into his house
- 1930 – Laugaveita
  - 14 shallow wells, 14 l/s of 87°C hot water in the vicinity of the laundry springs
  - 3 km long transmission pipeline from the hot springs towards the town center
  - Primary school, Austurbæjarskóli, Swimming pool and 60-70 houses heated
- 1943 – Reykjaveita
  - Shallow wells, self flowing, 200 l/s of 86°C hot geothermal water
  - 17 km long transmission pipeline, first Reykir piping main
  - 2 850 houses connected

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Reykjavík Geothermal district heating

- 1958 - More wells drilled and deep well pumps installed
- 1970 – All houses in Reykjavík heated. Increased capacity from Reykjaveita and second Reykir piping main. Expansion starts to the neighboring suburbs
- 1990 – Nesjavellir CHP power plant taken into service (Nesjavellir piping main)
- 2005 – Hellisheiði CHP power plant taken into service (Hellisheiði piping main)
- 2015 - Reykjavík and all suburbs heated, serving 190.000 people

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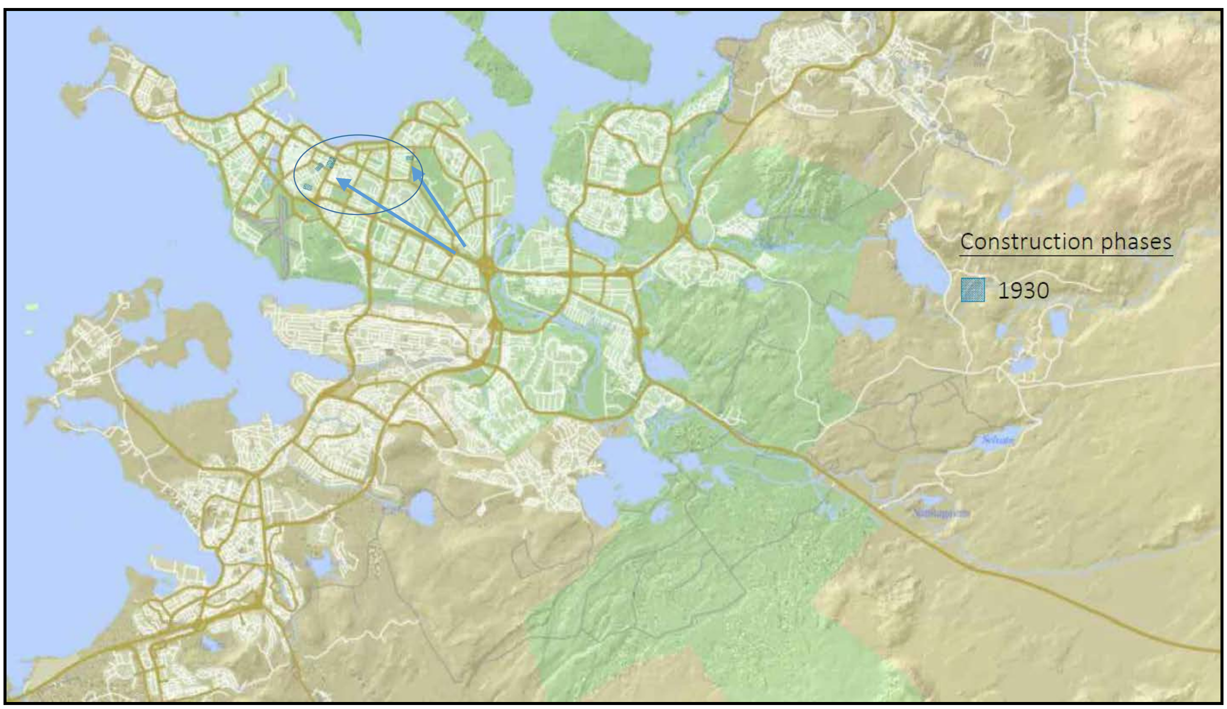

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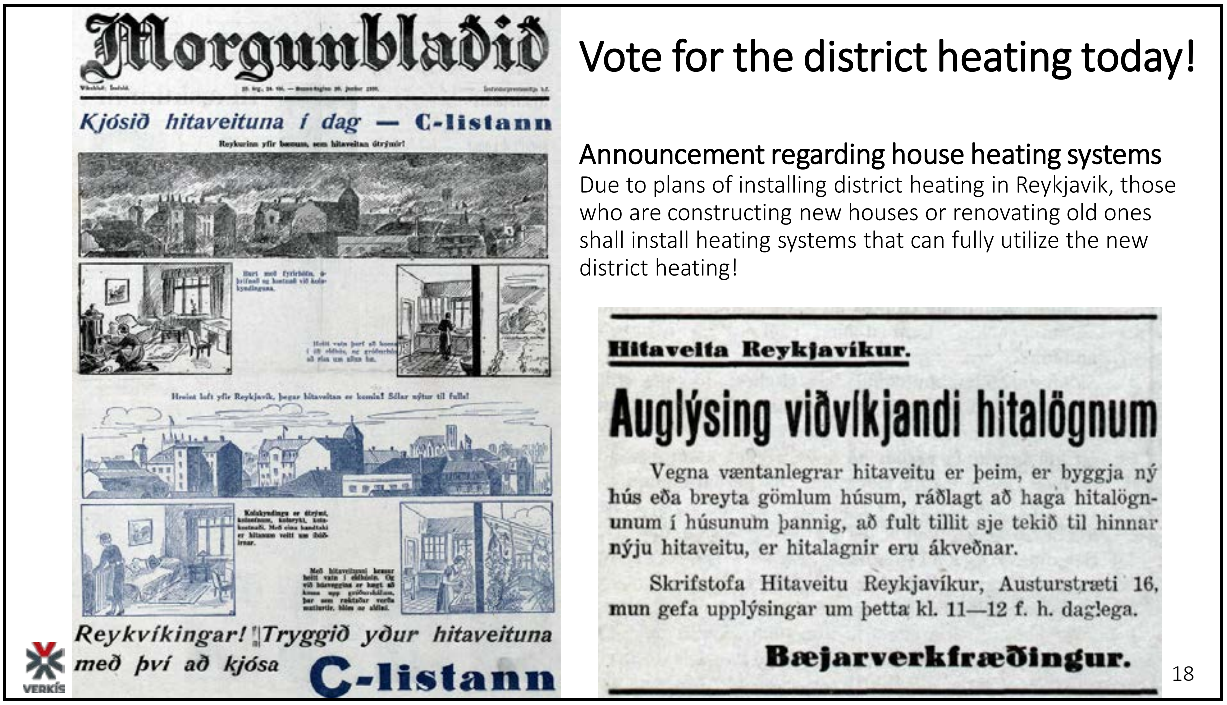

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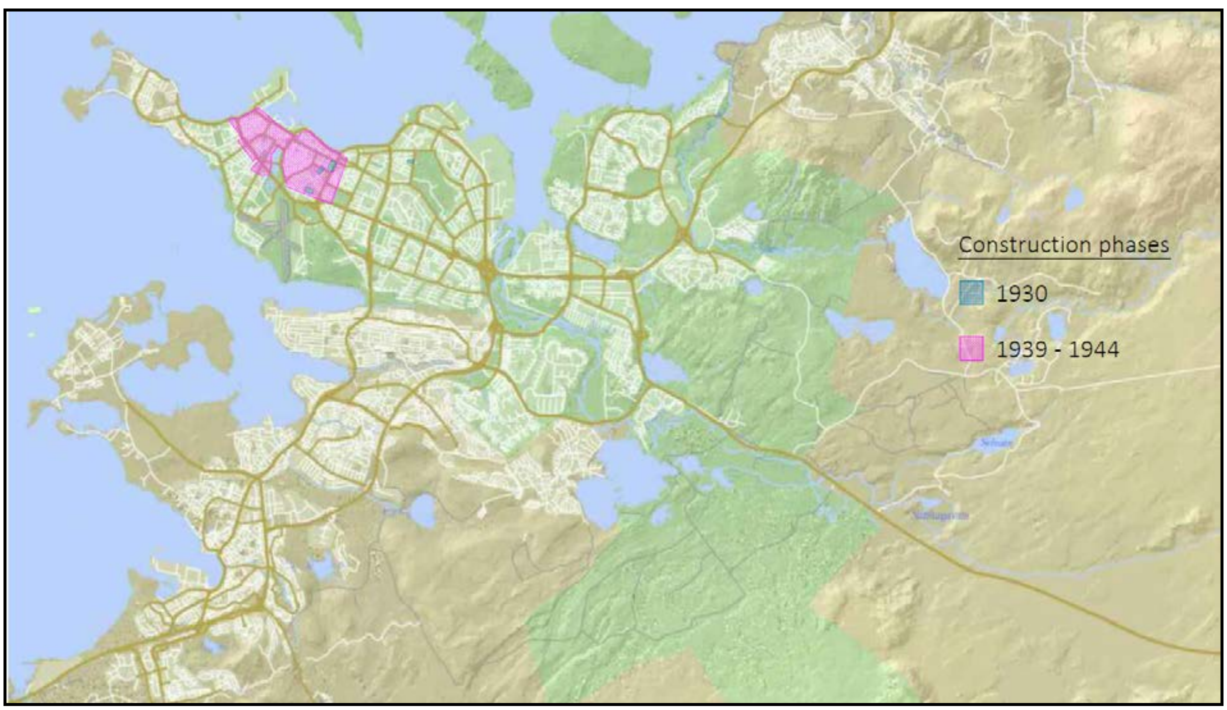

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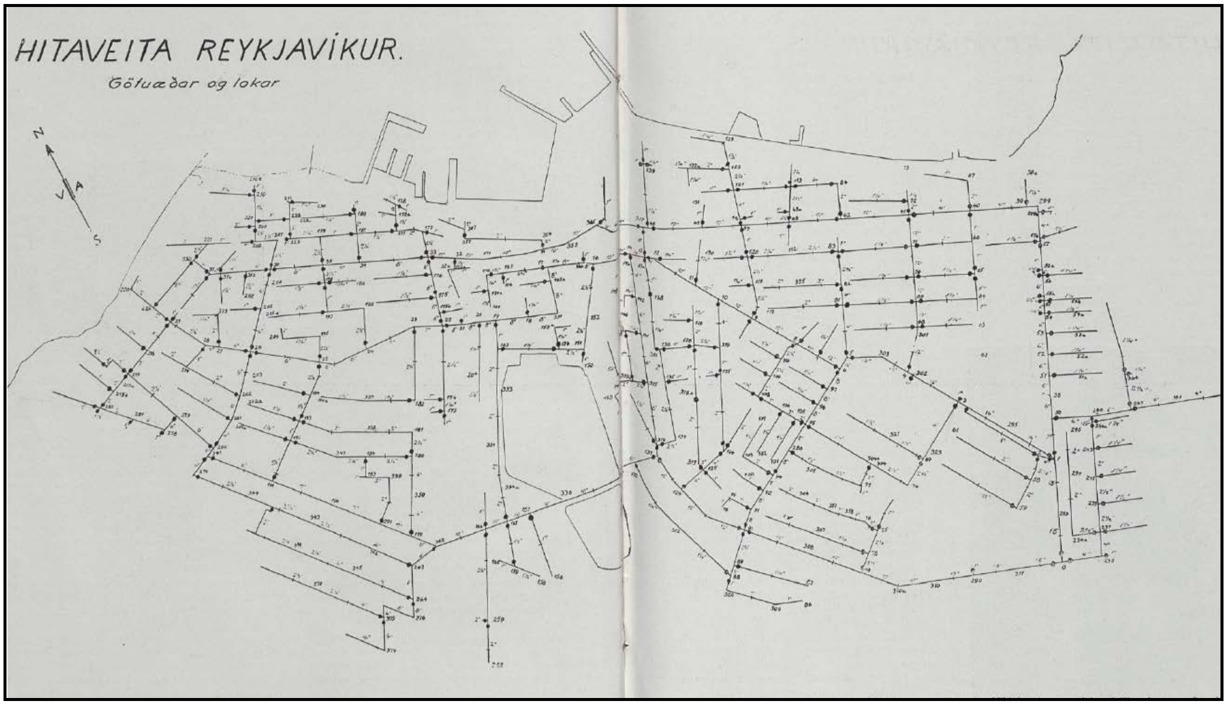

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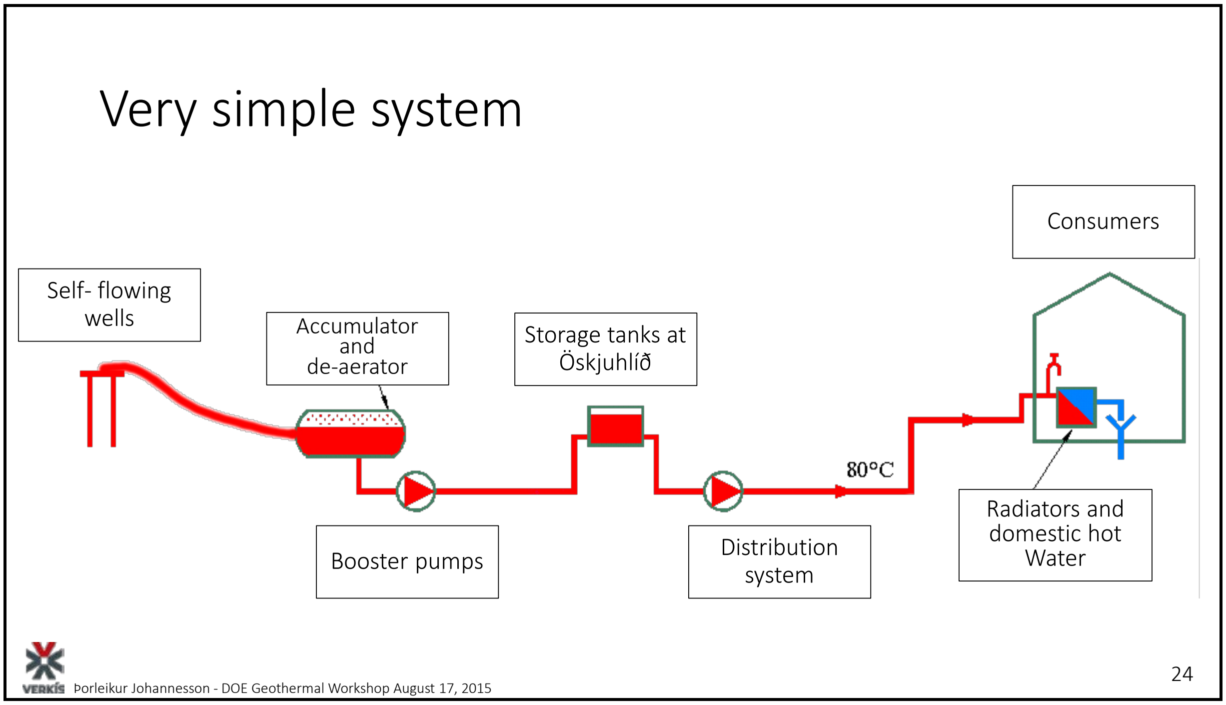

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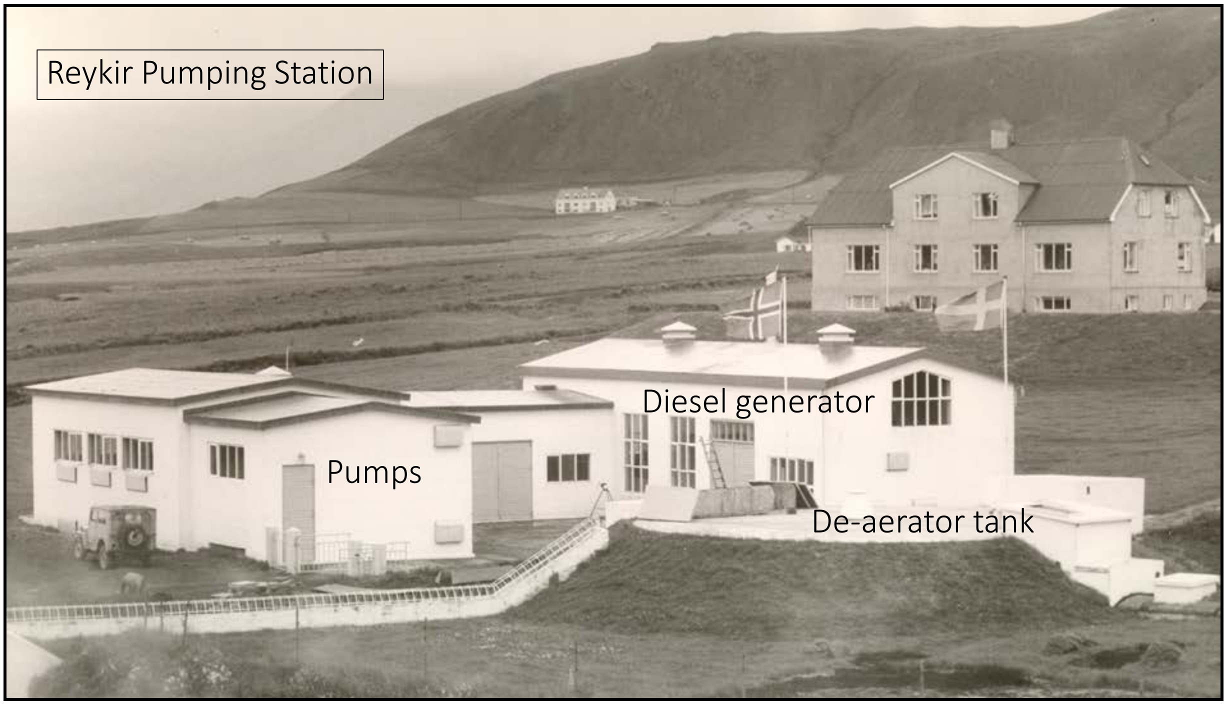

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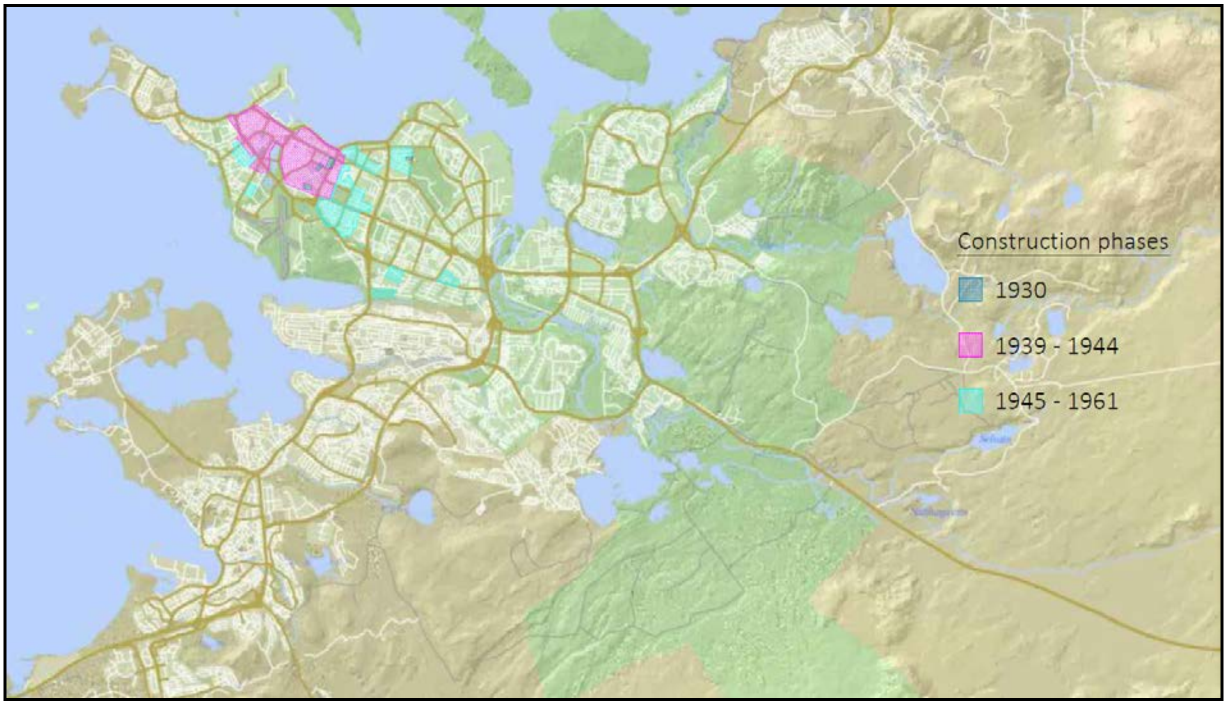

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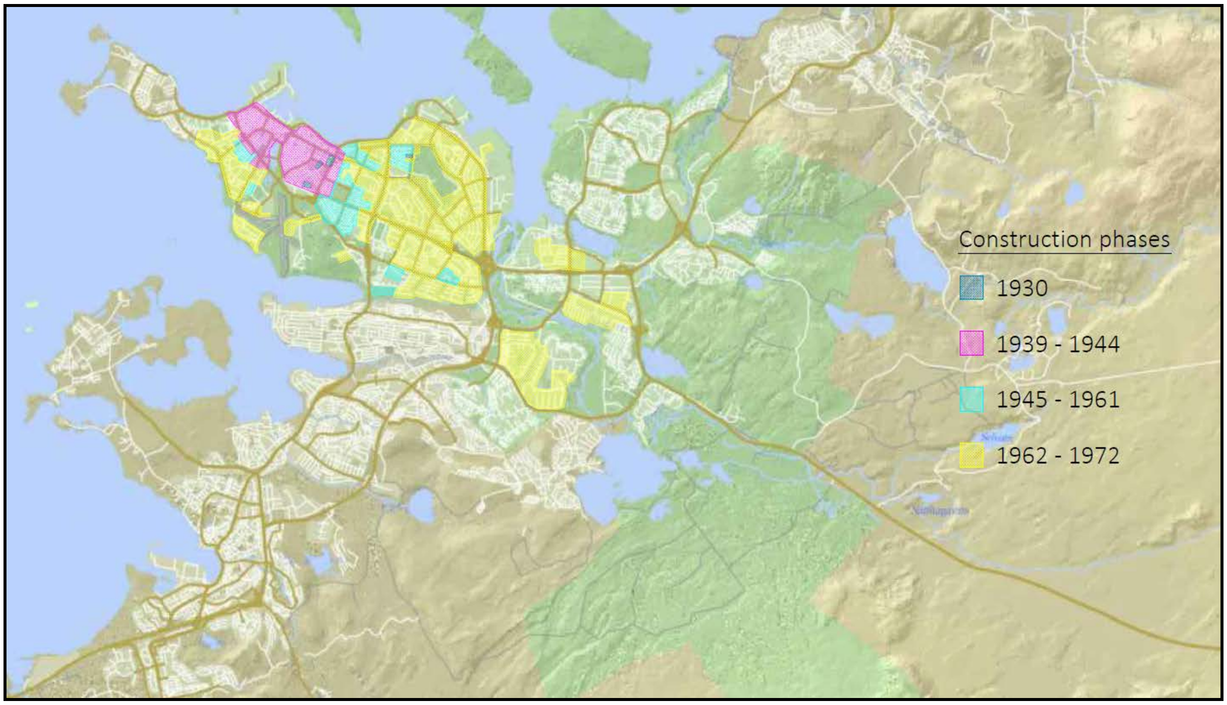

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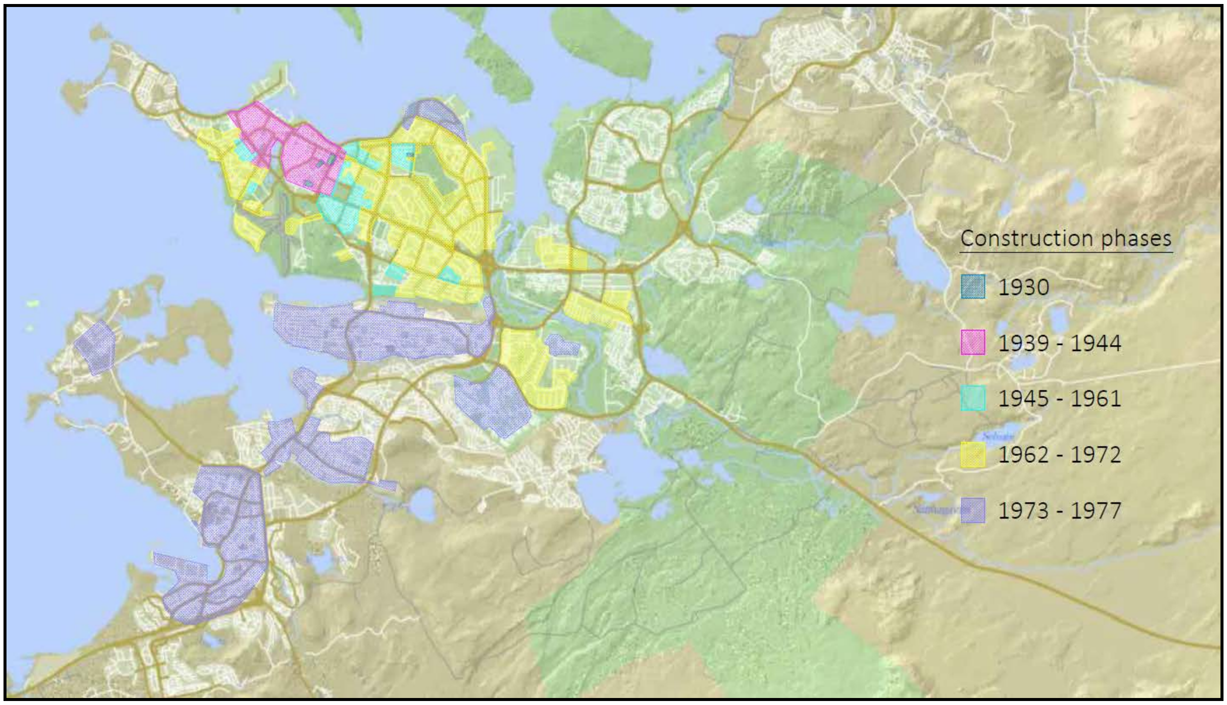

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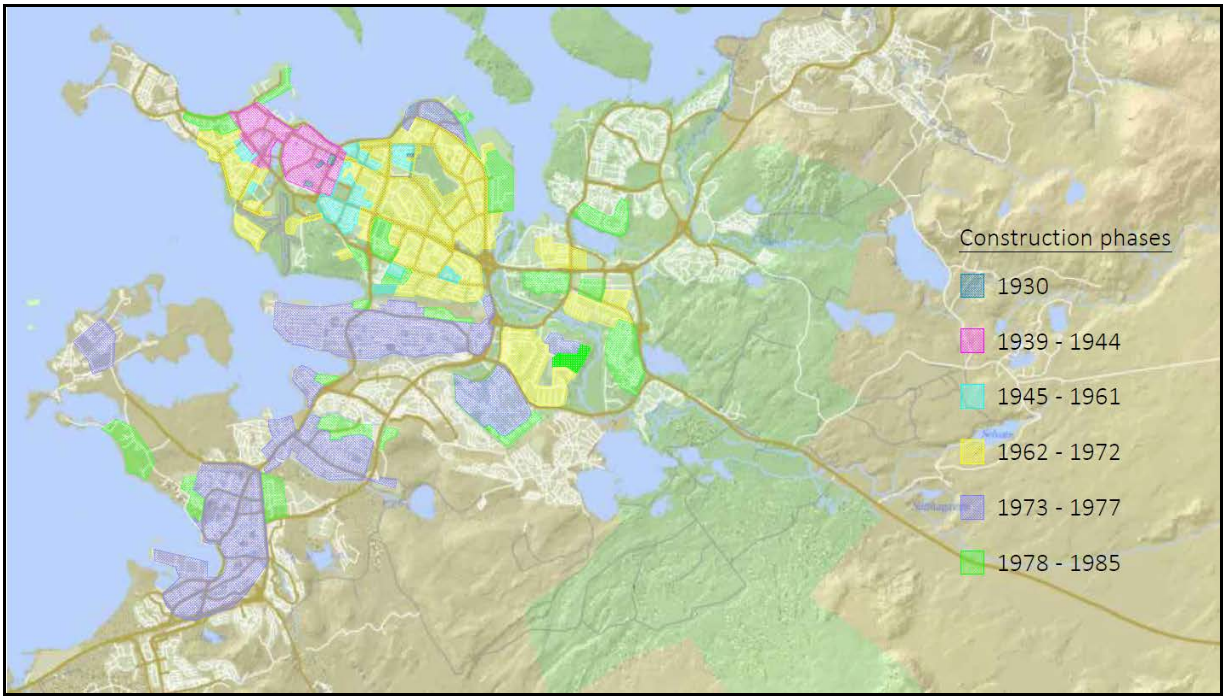

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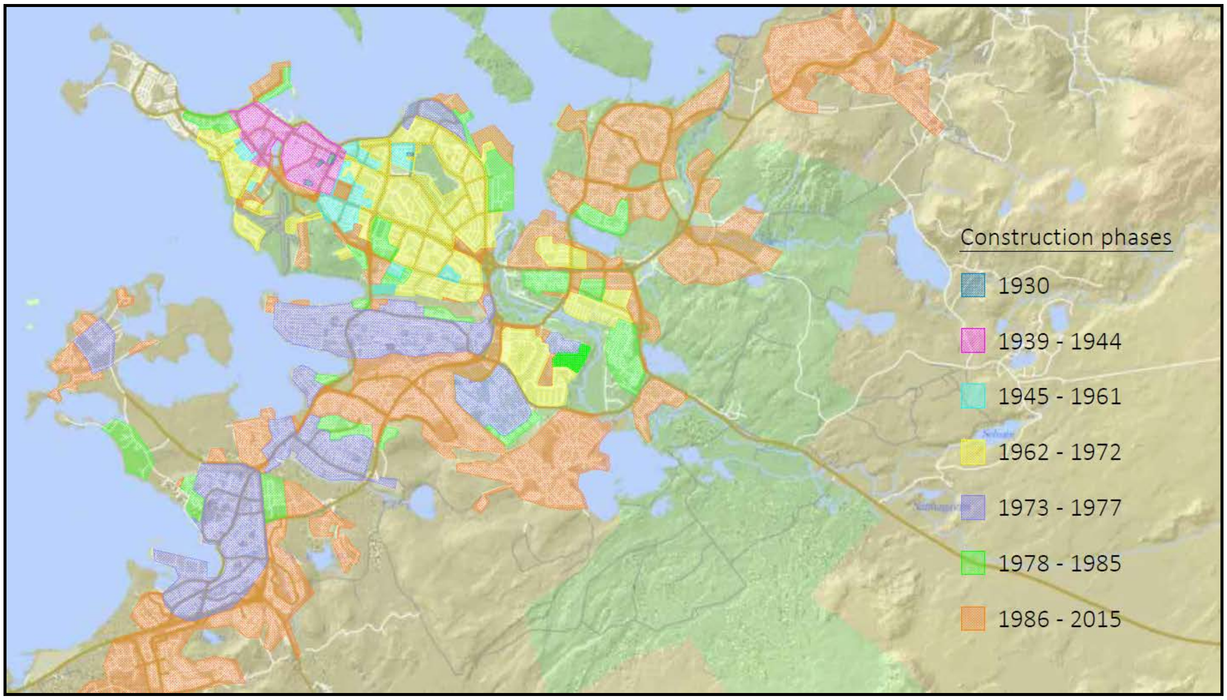

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Reykjavík geothermal fields, 1000 MW

- Laugarnes
  - 10 wells, 340 l/s, 125 – 130°C, 125 MWt
- Ellidaar
  - 8 wells, 260 l/s, 85 – 95°C, 50 MWt
- Reykir – Reykjahlid
  - 34 wells, 1980 l/s, 85 – 100°C, 375 MWt
- Nesjavellir – CHP
  - Heated and de-aerated cold water, 1680 l/s, 83°C, 300 MWt
- Hellisheiði – CHP
  - Heated and de-aerated cold water, 800 l/s, 85°C, 150 MWt

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Reykjavík geothermal systems

- High grade, high porosity „open“ hydrothermal reservoirs
- Relatively easy to harness
- „High quality“ low temperature (80-130°C) geothermal water, used directly on district heating systems
- No re-injection needed as long as you keep the inflow/outflow balance
- In CHP plants, cold water is heated in the plant condensers and geothermal heat added in exchangers
- Key factors of why geothermal heating in Reykjavik is inexpensive!

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Heating Requirements

Design of district heating systems

http://www.wunderground.com

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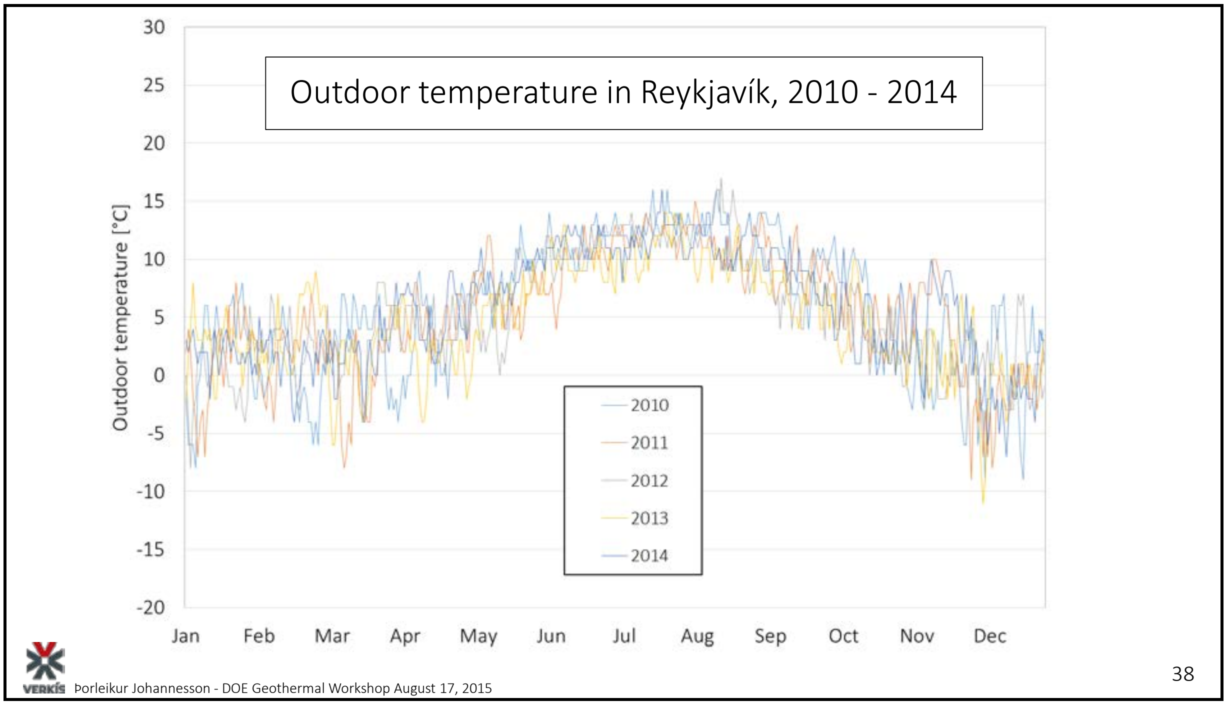

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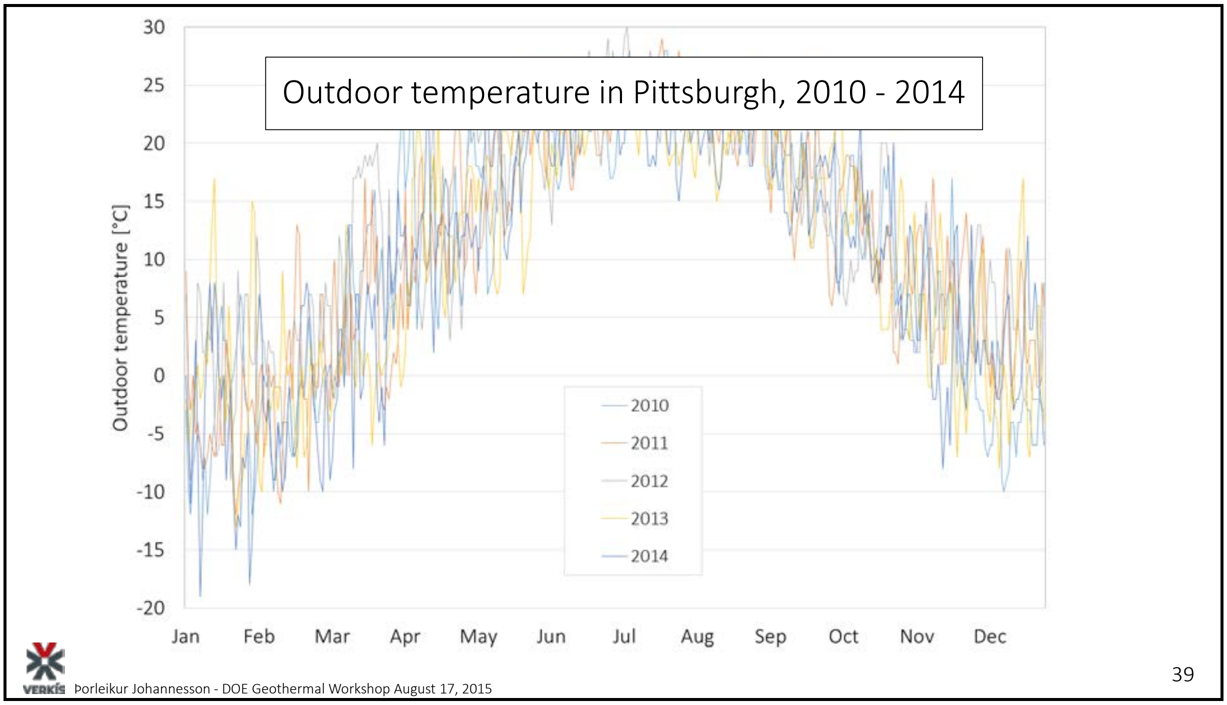

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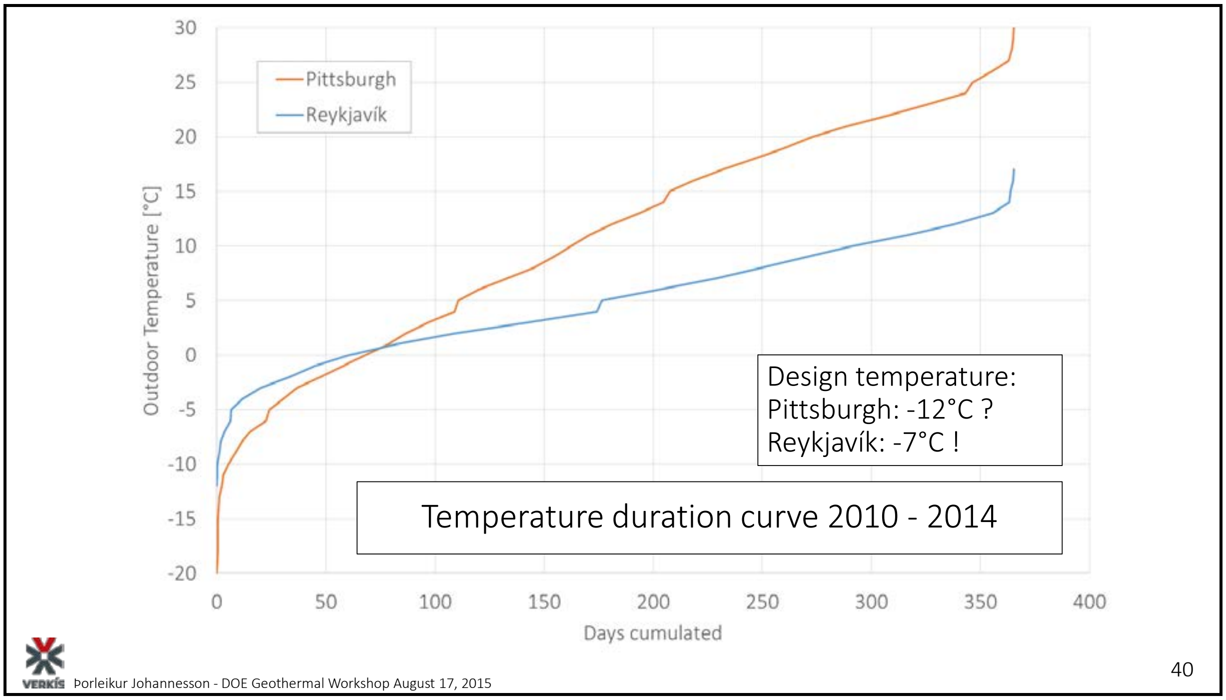

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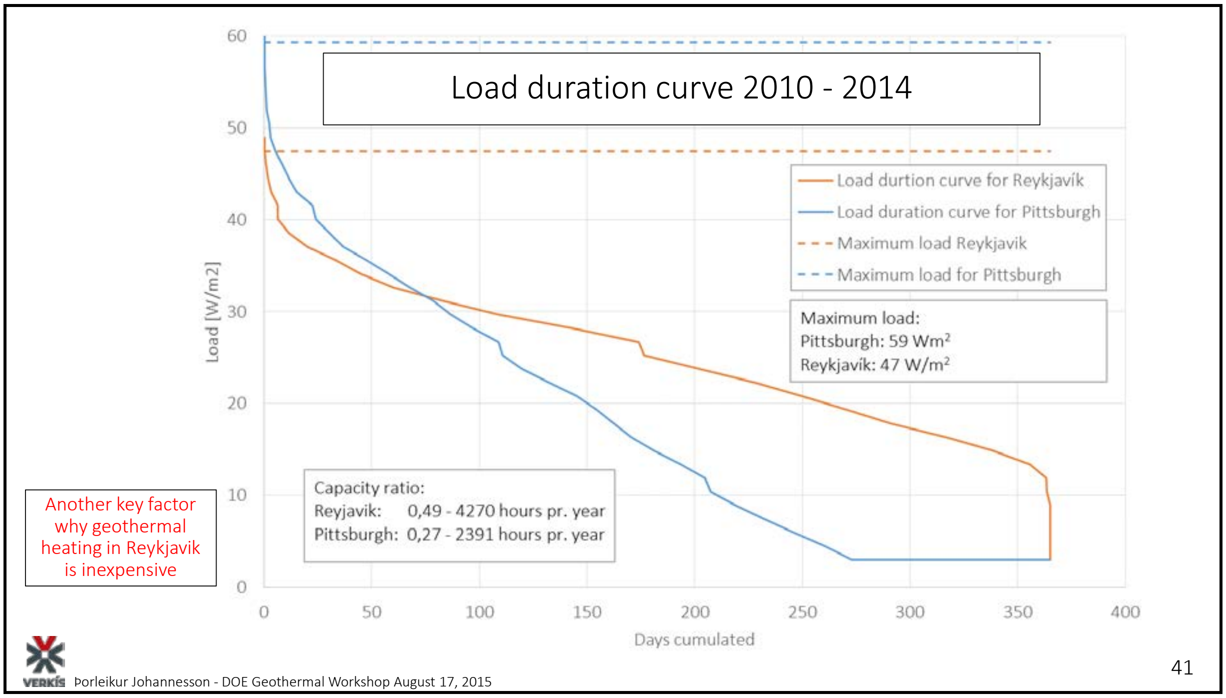

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Design load

- Heating and Domestic hot water
  - **Design load for Reykjavík 40 W/m^2 (Pittsburgh 47 W/m^2 ?)**
  - Supply water 80°C from pumping stations
  - Average temperature at consumers 75°C
  - Return from heating systems 35°C
  - Flow: 0,86 l/h pr. m^2 – 0,30 l/h pr. m^3 (ΔT =40°C)

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Meeting the annual heat demand

Power and energy

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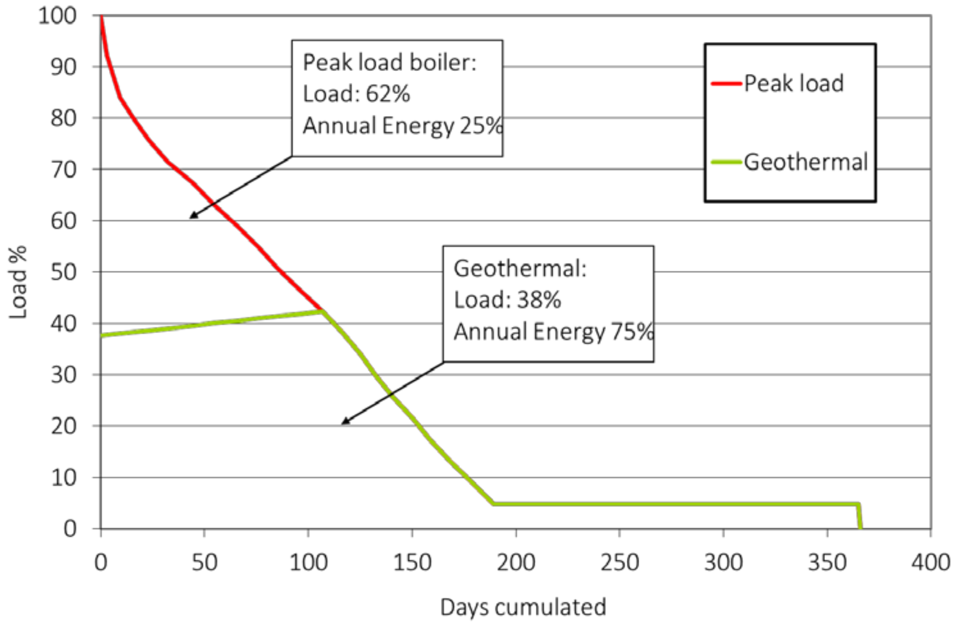

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Piping and installation

Pipe systems and material

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- Pre-insulated steel pipes according to EN 253
  - Steel pipe
    - St 37.0 (DIN 1626) or P235 TR1 (EN 10217 T1)
    - Weld factor 1,0
    - Manuf. certificate to EN 10204 – 3.1B
    - Beveling ends to DIN 2559 T1/T22 and ISO 6761
  - Insulation
    - Polyurethane
    - Density 60 kg/m^3
    - Compressive strength 0,4-0,6 N/mm^2
    - Closed cells > 88%
    - Continuous operating temperature: max 149°C for 30 years
  - Jacket pipe
    - HDPE
    - Optimum bonding between jacket and polyurethane

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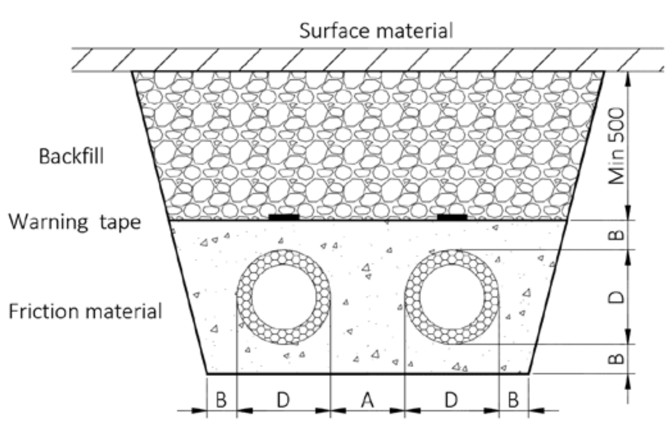
Preinsulated piping system – Cross section



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Installation cost, unit prices, USD/m_{trench}

Double Distribution systems - Price 2015			
Pipe size		EN 253, insulation class I	
DN, mm	inches	New-construcion	Re-construction
DN20-25	$^3/_4$ - 1	135	267
DN32-40	1 $^1/_4$ - 1 $^1/_4$	152	283
DN50-65	2 - 2 $^1/_2$	169	305
DN80	3	199	336
DN100	4	262	384
DN125	5	294	419
DN150	6	325	452
DN200	8	433	569
DN250	10	616	773
DN300	12	733	901
DN350	14	844	1020
DN400	16	993	1182
DN500	20	1291	1507
DN600	24	1527	1757
DN700	28	1743	1985

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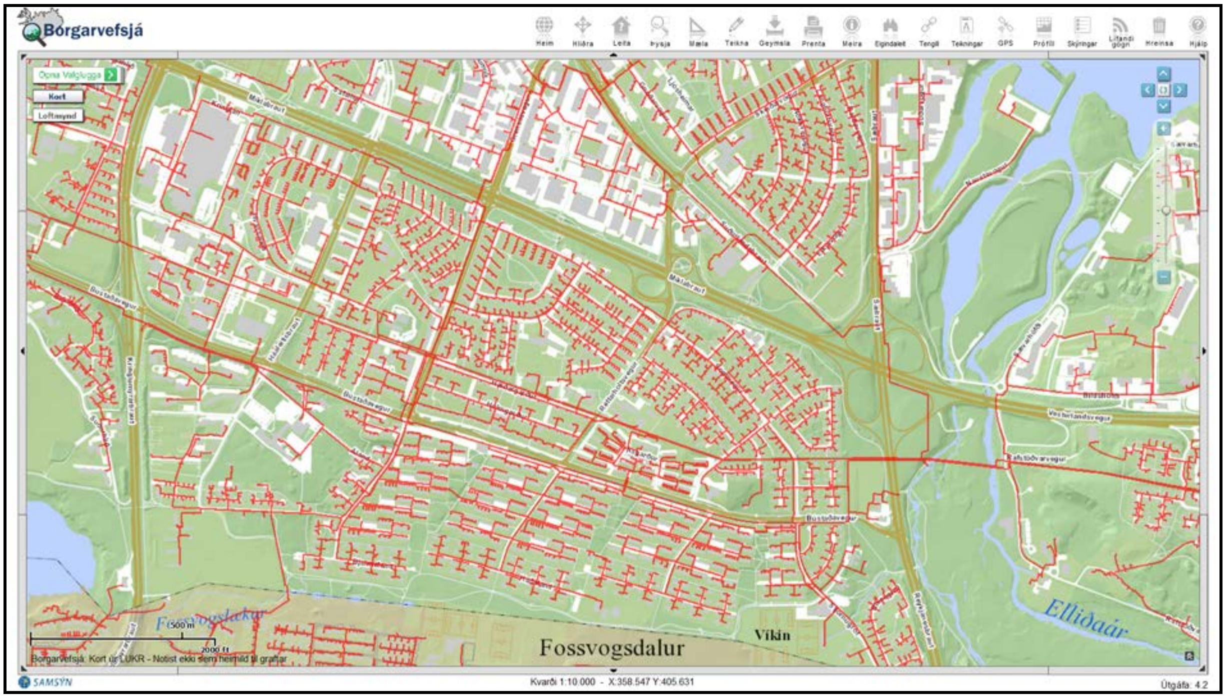

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Estimation of pipe price within an area of land

- Extract all pipes within a given area from the Reykjavík Energy graphical information system,
- Group pipes according to sizes, DN 20, DN 25.....etc.
- Calculate sum of pipes within each size range
- Add the unit price
- Calculated the price of all pipes within a given area
- ....and the results

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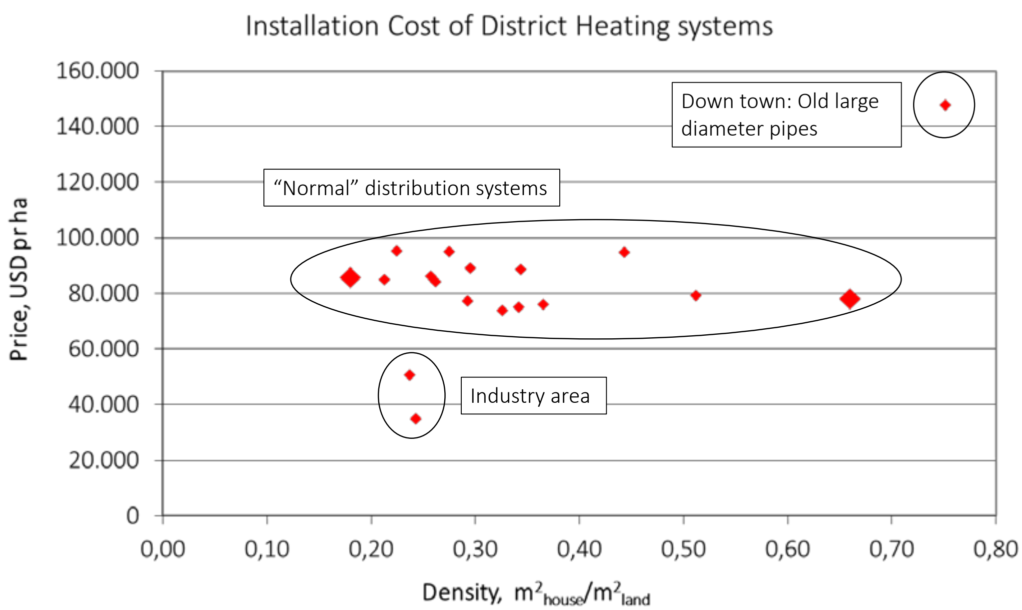

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House Connections and house heating systems

Which house heating system suites geothermal district heating?

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House heating systems

- Old radiator systems – bad for geothermal
  - Supply temperature 90°C
  - Supply temperature 70°C
- Modern radiator systems – good for geothermal
  - Supply temperature 75°C
  - Return temperature 35°C
- Floor heating – excellent for geothermal
  - Supply temperature 45°C
  - Return temperature 35°C

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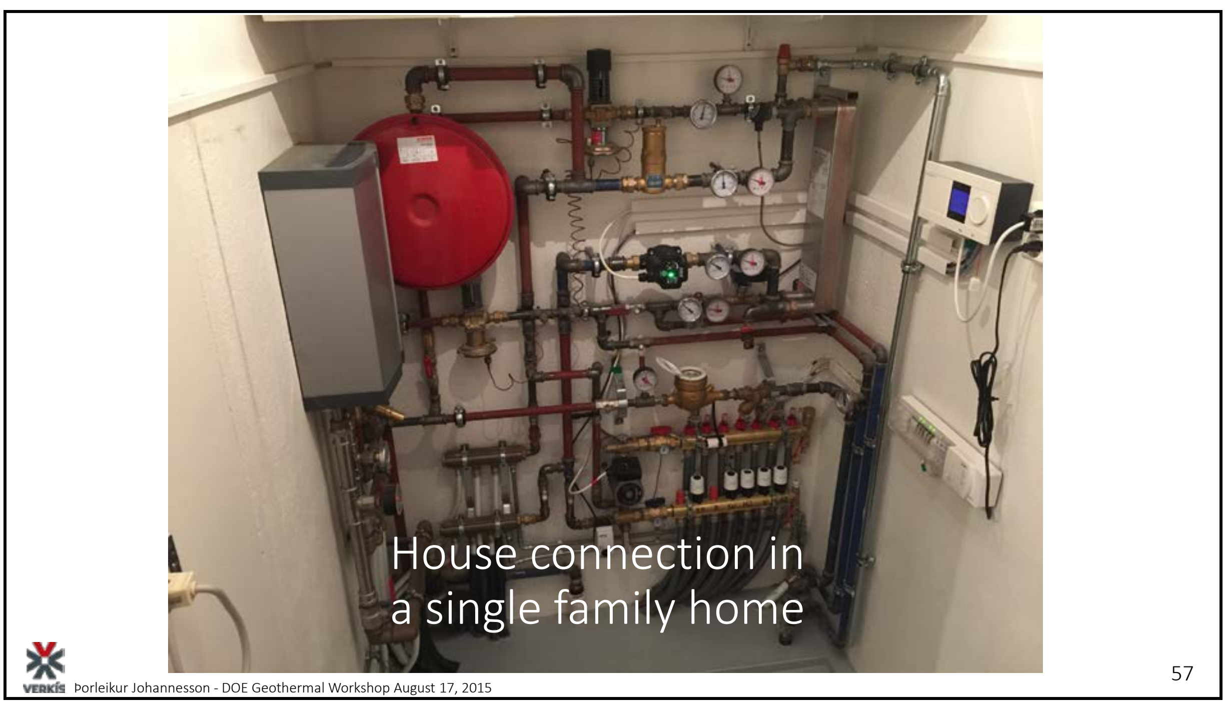

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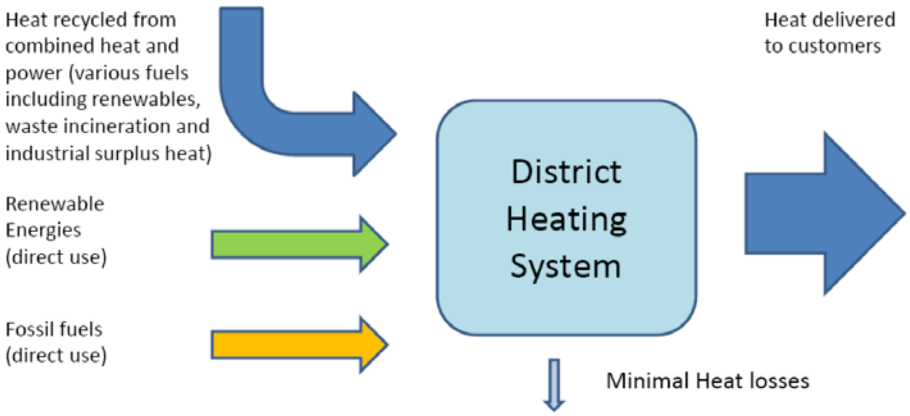
District heating is not only about geothermal



Þorleikur Jóhannesson - DOE Geothermal Workshop August 17, 2015 http://www.euroheat.org/Files/Filer/documents/Publications/District%20Heating%20in%20buildings_final.pdf 58

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Benefits of District Heating

- District heating is comfortable and effortless
- No need for individuals to purchase and handle fuels
- Limited servicing of equipment's for individuals
- Steady temperature at all times
- Pricing stable
- Reduces consumption, despite some heat losses in the network
- With access to geothermal heat as a base load, a win – win solution

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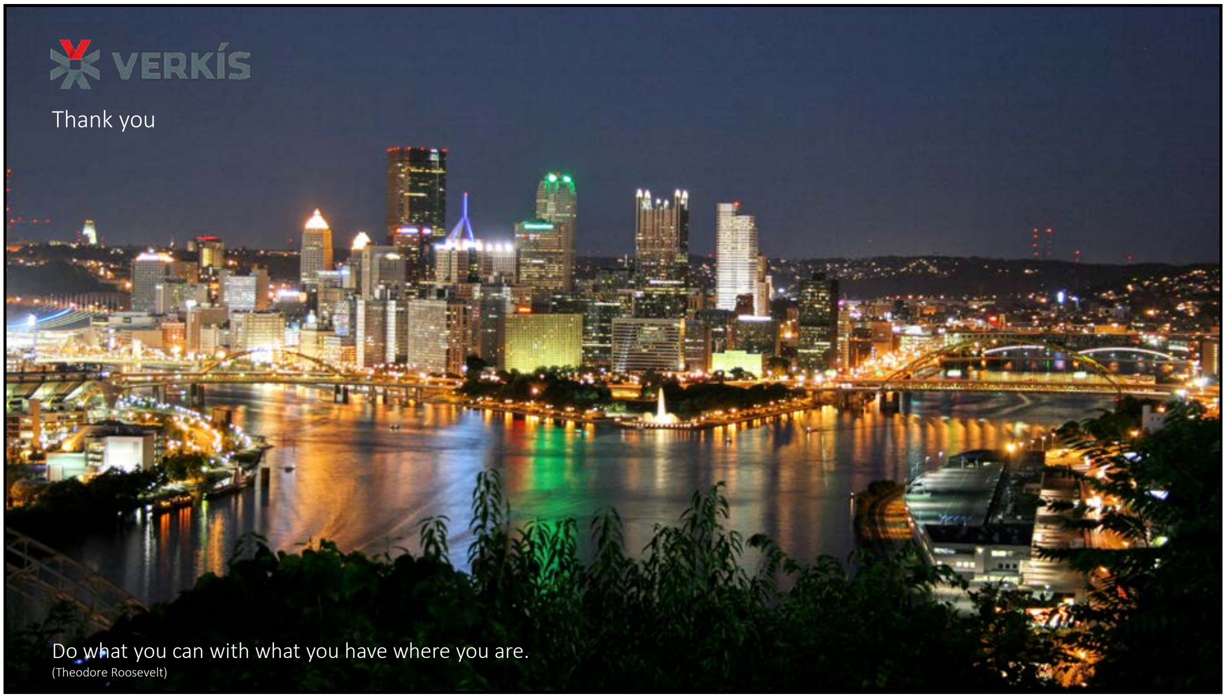

VERKÍS
Thank you
Do what you can with what you have where you are.
(Theodore Roosevelt)

SPEAKER PRESENTATIONS: **Jay Egg**

Geothermal Marketplace in the Eastern U.S.

Slide 1

Geothermal Marketplace (in the Eastern U.S.)

- **We will cover:**
  - GSHP Market Space
  - GSHP Payback Scenarios
  - GSHP Economics
  - Hybrid and Mini-grids
  - Geothermal Incentives
  - Renewable Energy Portfolio Standards
  - Renewable Energy Credits
  - Organizations
- **Break-out Session will feature:**
  - Geothermal Market Sizes
  - How GSHPs and deep direct use work together in cities
  - The real costs of operation of different fuel sources applied to CO2 factors

Slide 2

Low Temperature Geothermal

Geothermal Direct Use Technology & Marketplace

Hilton Garden Inn Pittsburgh/Southpointe

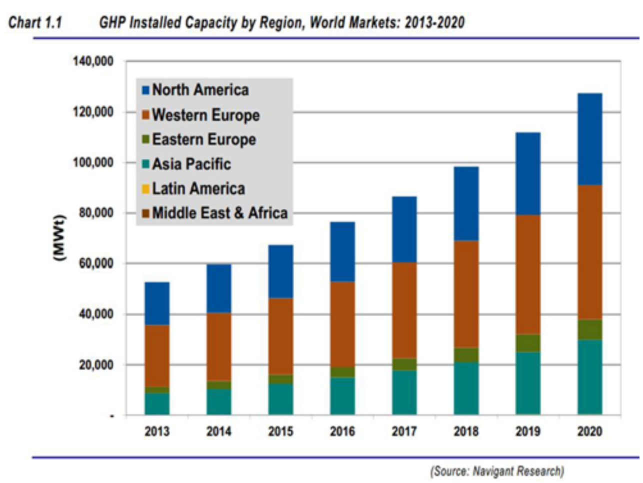
1000 Corporate Dr, Canonsburg, PA 15317

Workshop Agenda – Monday August 17, 2015

This workshop is a forum to exchange information on low temperature geothermal applications. To that end, participants will be asked to provide recommendations and information based on personal experience, individual advice, information, or facts regarding this topic. The objective of the workshop is not to obtain any group position or consensus; rather, the DOE is seeking as many recommendations as possible from all individuals at this meeting.

Slide 3

GSHP Market Space



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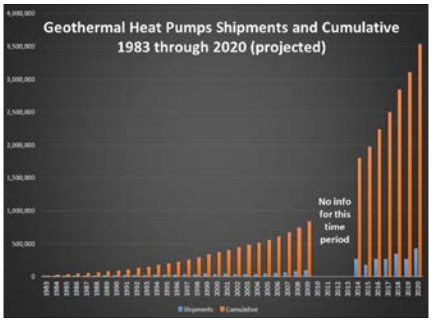
GSHP Market Space



As of 2009:

- "Hot Rock" Geothermal (Electricity):
  - Installed capacity: 3,048 MW_e,
  - Production Rate: 16,603 GWh_e/year
- Direct Use (Thermal):
  - Installed capacity: 611.5 MW_t,
  - Production Rate: 2,542 GWh_t/year
- Geothermal Heat Pumps (Thermal):
  - Installed capacity: 12,000 MW_t,
  - Production Rate: 13,167 GWh_t/year

Figures on Geothermal market size are hard to find since EIA stopped measuring the GHP market in 2009. But, the National Academies of Science recently published a report that includes an estimate of the Geothermal market in 2009. See page 43 in: "Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action." –Bob Wyman, Geothermal Consultant

Slide 5

GSHP Market Space

- Austin, TX-7500 Homes
- Community geothermal

- Clearwater District Energy Plant 6,580 tons

Slide 6

Potential Growth in Geothermal Market

Future energy system on the Cornell University campus as envisioned by the Climate Action Plan (Cornell University, 2014). When fully converted to a carbon-neutral campus, a large part of the heating and electricity consumption would be supplied by a hybrid geothermal–biomass co-generation system.

Cornell University; Verizon Data Centers; Cayuga Lake-Source Cooling Plant

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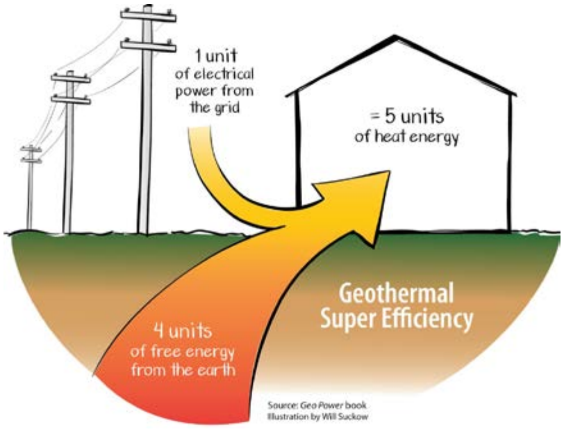
500% Efficient; Simply Put



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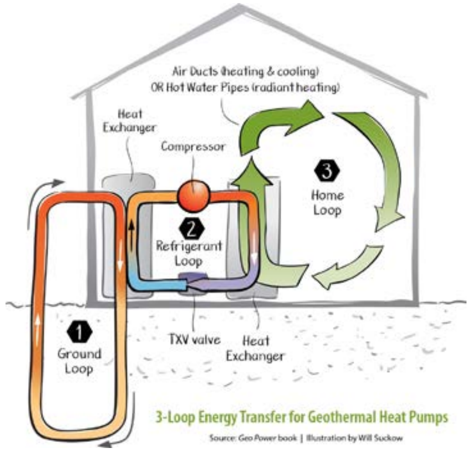
Usable Temperature Range: 25F-110F



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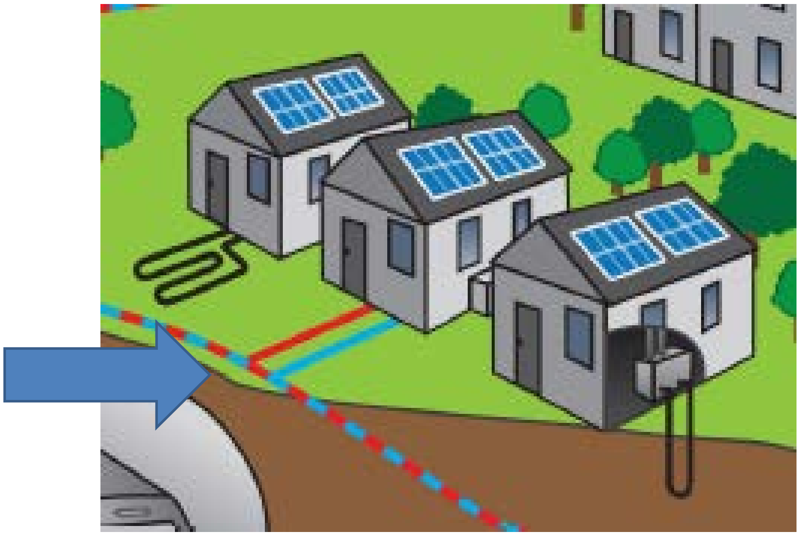
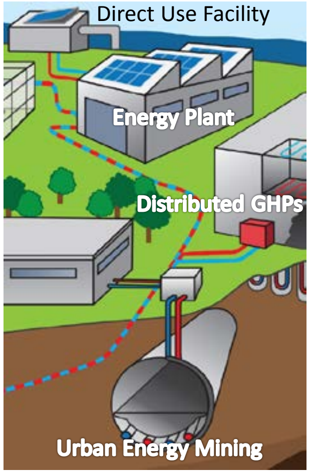
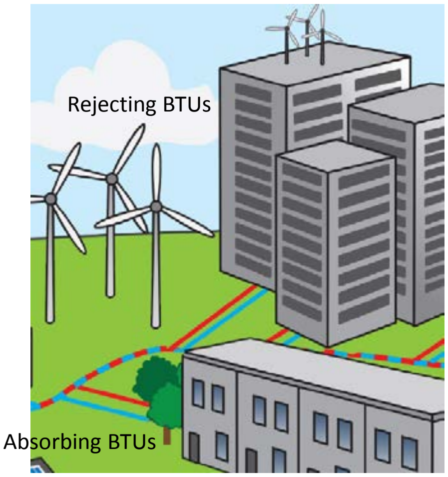
Part of a Bigger Picture



Slide 10

Usage of Thermal Imbalance
"Cascade"= Nearly Perpetual Reuse of Energy





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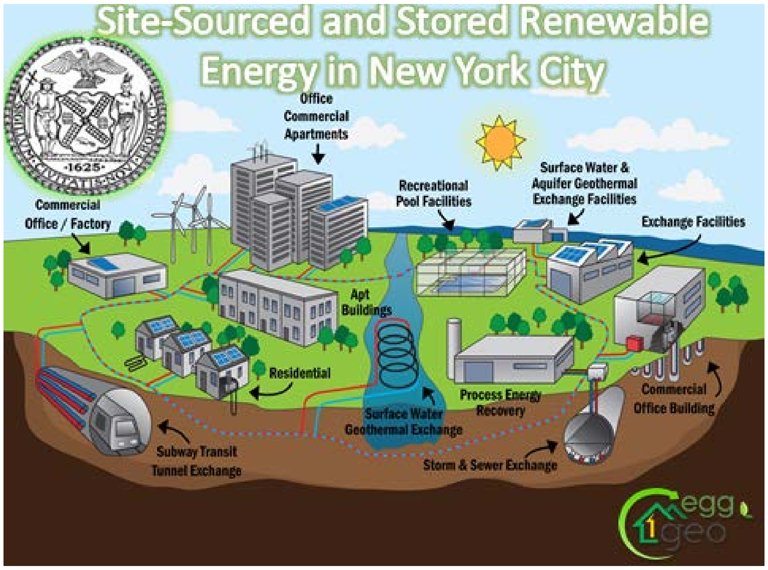
GSHP Market-NYC Council



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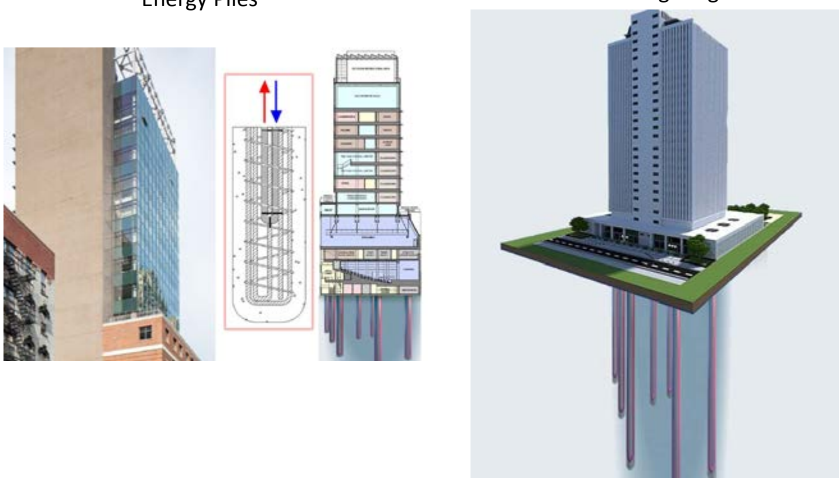
GSHP Market
Constructions Variations

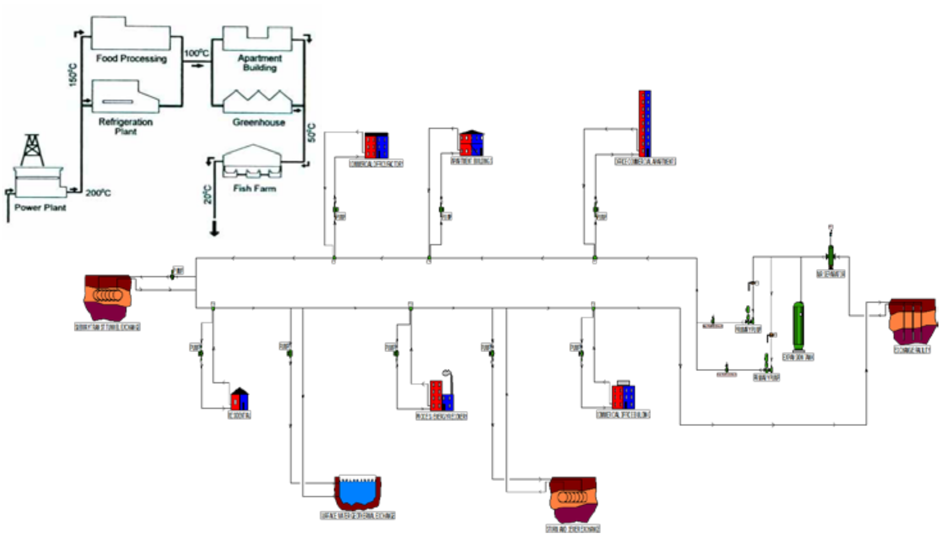
NY City Trevor Day School
“Energy Piles”

Salt Lake City
Fire Fighting



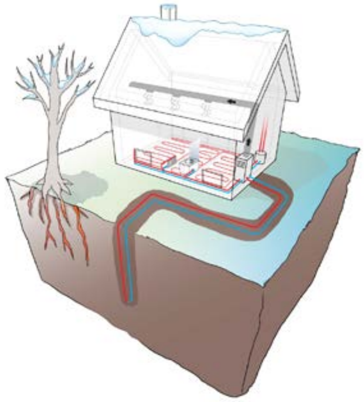
Slide 13

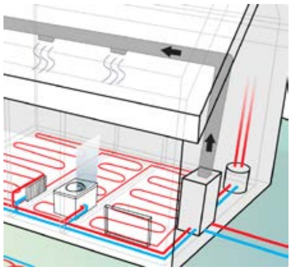
GSHP Market
Examples of a “Cascade” Mini-Grid



Slide 14

GSHP Payback Residential





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GSHP Payback Residential

Geothermal Investment Payb

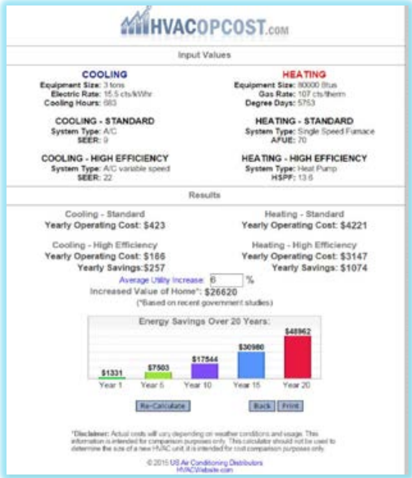
Builder:	
Home Owner:	Dan Gallogly
Job Info:	4 ton & 2 ton CM Tranquility

Geothermal Investment Information

Total Geothermal Investment: (includes supply and injection wells estimate $8,000)	$ 35,097.00
Florida Property Tax Rate (1.4% avg):	1.4%
1st Year Energy Savings vs 8 SEER:	$ 2,247.00
Estimated Yearly Hot Water Savings:	$ 200.00
Federal Tax Credit:	$ 10,529.10
Net Geo Investment (after tax credit):	$ 24,567.90

Geothermal System Payback

Net Geo Investment (after tax credit):	$ 24,567.90
Cost of High Efficiency Standard Eqp: (starting point as A/C system has to be installed)	$ 14,185.00
Total Additional Investment for Geothermal System Upgrade:	$ 10,382.90
Years to Recover Additional Investment:	Less than 4



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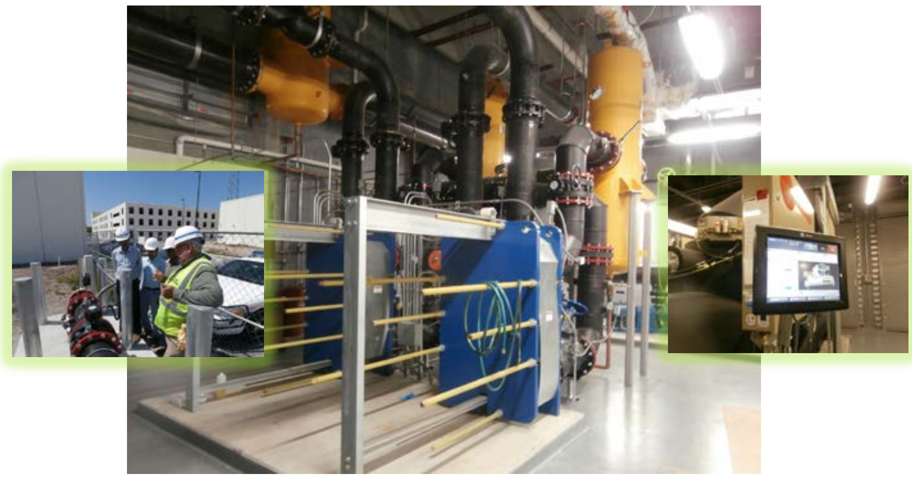
GSHP Energy-Plant Payback
Commercial/Industrial



Slide 17

First cost of 3 alternatives:

- Alternative 1: Option 20 Boilers and Cooling Towers
  - $11,637,334
- Alternative 2: Option 21 GW Exchange with Isolations Exchangers
  - $12,942,200
- Alternative 3: Option 22 GW Exchange WO Isolation Exchangers (Direct)
  - $12,564,200

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SUP Monthly Energy Consumption

The consumption of two utilities is affected by the Alternatives

Alternative	Option	System Type	Annual Electric Consumption (kWh per year)	Annual Water Consumption (Gallons per year)
1	20	Cooling Towers	15,646,900	77,893,000
2	21	Ground Water Cooling with Heat Exchangers	13,240,782	0
3	22	Direct Ground Water Cooling	11,763,350	0

Scaled Up Plant (SUP)

Slide 19

SUP Monthly Utility Cost

The cost of two utilities is affected by the Alternatives

Alternative	Option	System Type	Annual Electric Cost ($ per year)	Annual Water Cost ($ per year)	Annual Utility Cost Total ($/Year)
1	20	Cooling Towers	$1,024,872	$71,093	$1,095,965
2	21	Ground Water Cooling with Heat Exchangers	$867,271	0	$870,861
3	22	Direct Ground Water Cooling	$770,499	0	$783,662

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Payback Calculations

The simple payback for the Alternatives is summarized below

Alt.	Option	System Type	Annual Utility Cost ($ per year)	Annual Cost Savings ($ per year relative to BASE CASE)	Added Construction Cost ($)	Simple Payback[(1)] (yrs)
1	20	Cooling Towers	$1,095,965	BASE CASE	$0	BASE CASE
2	21	Ground Water Cooling with Heat Exchangers	$867,271	$228,694	$1,294,866	5.7
3	22	Direct Ground Water Cooling	$770,499	$325,466	$916,866	2.8

(1) Incremental Investment Simple Payback

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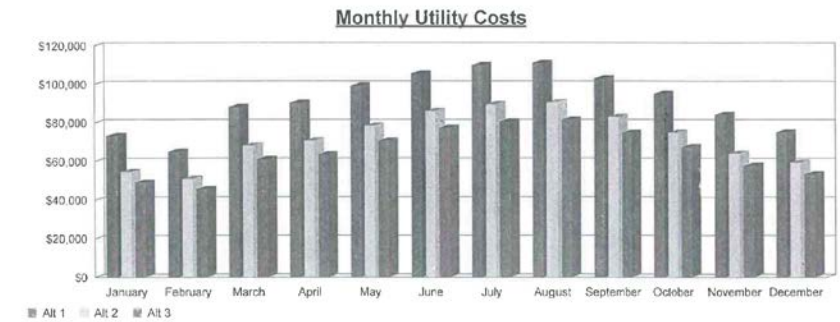
Life Cycle Cost Analysis Summary

Appendix J.6 has the year-by-year listing of annual costs for the four Alternative systems over a 30 year term. A summary of the LCCA is:

Alt.	Option	System Type	First Cost ($)	Life Cycle Cost ($)	Life Cycle Savings Over BASE CASE ($)	Added Construction Cost ($)	Simple Payback on Investment (yrs)	Internal Rate of Return (%)
1	20	Cooling Towers	$11,647,334	$29,187,314	BASE CASE	$0		
2	21	Ground Water Cooling with Heat Exchangers	$12,942,200	$26,832,534	$2,354,780	$1,294,866	4.3	24.9%
3	22	Direct Ground Water Cooling	$12,564,200	$25,357,951	$3,829,363	$916,866	2.2	45.3%

Slide 22

	Yearly Savings vs Alt 2	Yearly Total Operating Cost ($)	Yearly Utility Cost ($)	Yearly Maintenance Cost ($)	Plant kWh/ton hr
Alt 1	-304,388	1,573,498	1,099,598	473,900	0.736
Alt 2	0	1,269,111	870,881	398,250	0.623
Alt 3	95,499	1,173,612	783,662	389,950	0.560



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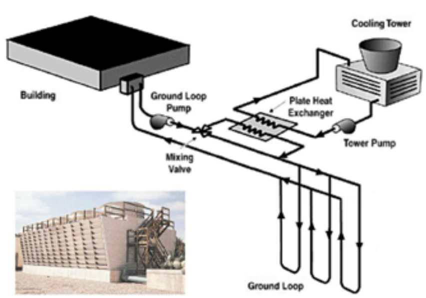
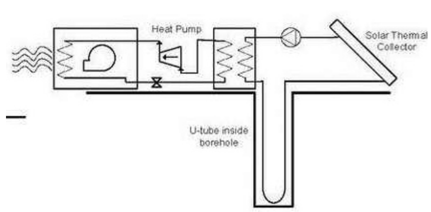
GSHP Economics; What about Hybrid?



Geothermal and Cooling Tower



Geothermal and Solar

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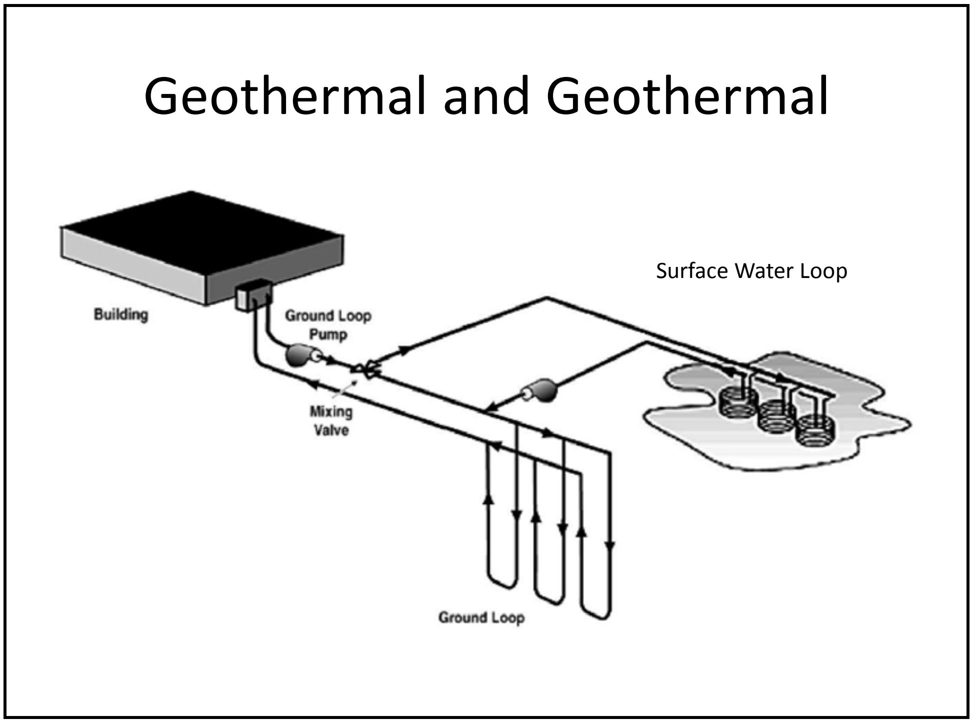

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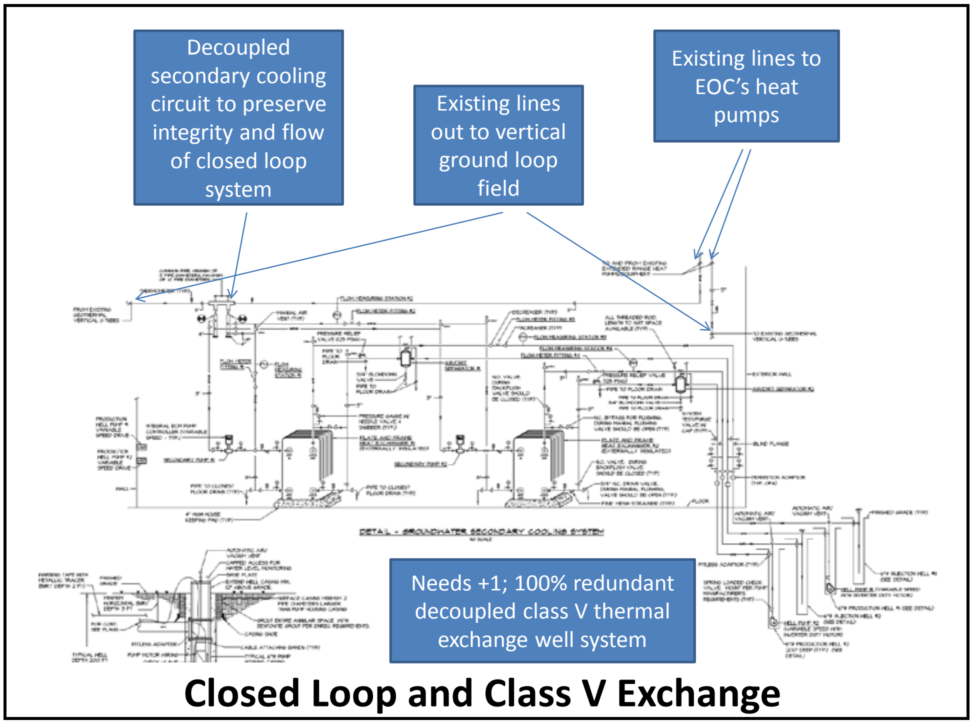

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Hybrid Example: Sussex County, DE Case Study

Sussex County, Delaware: Geo/Geo Hybrid

Geothermal Problems Could Shut Down Cooling System at Mission Critical Green Building

Stephen Del Percio | Jun 20, 2011 | 1 comment

Helps with thermal imbalance

A malfunctioning geothermal heating and cooling system at the Sussex County Emergency Operations Center in Georgetown, Delaware has officials scrambling for a temporary solution before the summer heat begins in earnest.

The $13 million, 18,000-square-foot facility opened in 2008 and was heralded as energy-efficient green building that could respond to large emergency events even during dangerous weather. The structure was designed to withstand wind loads of up to 120 miles per hour. But the facility is now in danger of its air conditioning shutting down and the oppressive Delaware summer damaging its millions of dollars of state-of-the-art electronics equipment.

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Sussex emergency facility may get backup geothermal cooling system

Problems with the cooling system at the 3-year-old, $13 million Sussex County Emergency Operations Center will require an additional $350,000 to fix.

County officials recently agreed to move forward with installing a new geothermal open-loop system to supplement the failing closed-loop system, which isn't keeping the building cool enough, said Steve Hudson, the county's director of technical engineering.

He said the current system is undersized and doing an inadequate job of servicing the complex, which contains $4 million in critical 911 electronics equipment.

term solution, he said.

"It was a very long summer," he said. "It's a very high-maintenance, high-dollar-to-operate piece of equipment."

Additionally, the cooling tower required a 24/7 service contract because no county staffers were qualified to keep it running.

Staffers researched two solutions, an open-loop well system and a traditional mechanical cooler system.

The mechanical cooler, though more widely used, was the more expensive option, costing $283,419 to run for 10 years. The supplemental geothermal system would cost more to install but have a 10-year cost of $29,754, Hudson said.

The open-loop system would pull well water from the ground, pump it into a heat-exchanger system and then discharge it back into the ground, Hudson said.

"I'd call this an innovative approach versus a

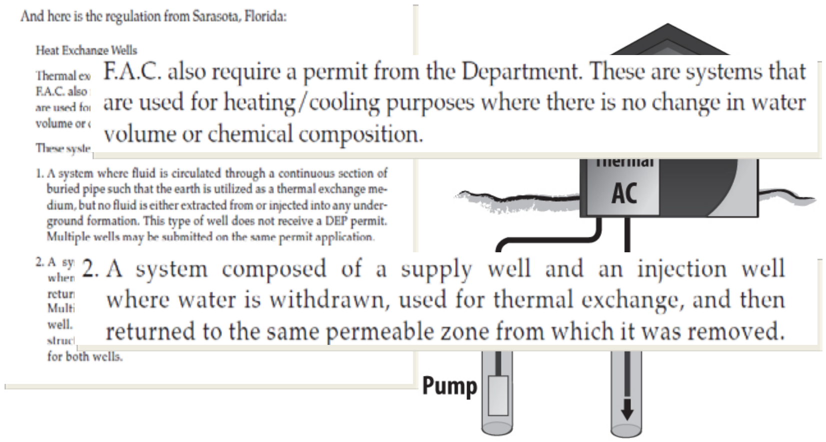
Why is a cooling tower "more expensive"?

Are there concerns with pulling from the ground and not returning?

What is a Backup Geothermal System? One option: Open Loop Geothermal

Slide 28

Nearly All Water Jurisdictions Have Verbiage…



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EOC accomplished temporary relief from a cooling tower…

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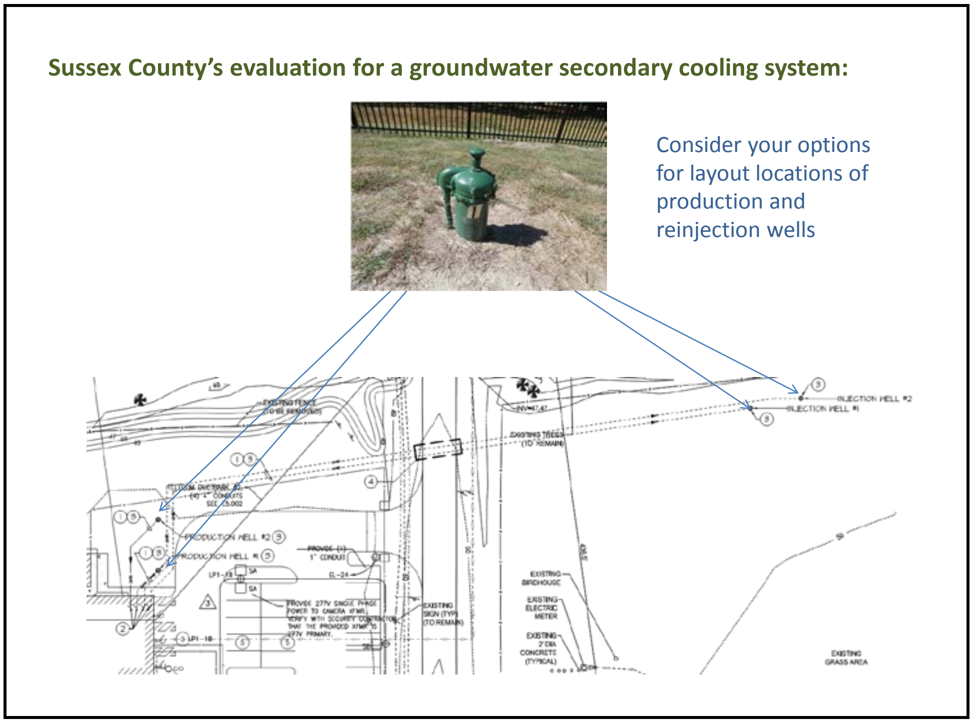

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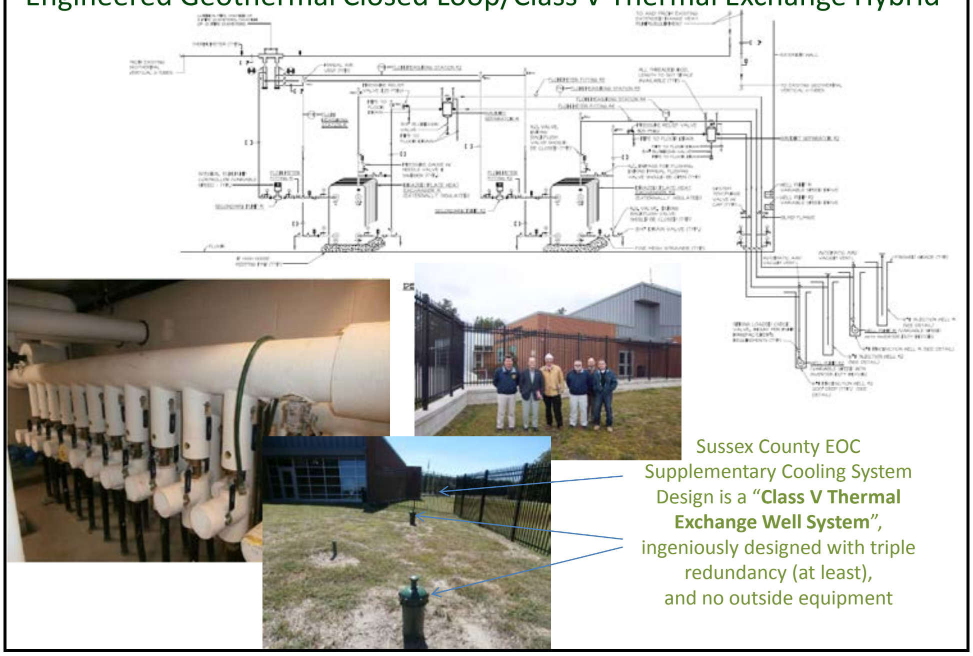
Engineered Geothermal Closed Loop/Class V Thermal Exchange Hybrid



Sussex County EOC
Supplementary Cooling System
Design is a "**Class V Thermal Exchange Well System**",
ingeniously designed with triple redundancy (at least),
and no outside equipment

Slide 33

News story from October 4, 2013

Sussex County building sets industry standard

Local engineers design fix for geothermal cooling system

By Ron MacArthur
ronm@capegazette.com

RON MACARTHUR PHOTO
SUSSEX COUNTY'S Emergency Operations Center in Georgetown is cooled by a state-of-the-art geothermal system.

Work to fix a geothermal system at Sussex County's Emergency Operations Center has attracted national attention and set a standard for the industry.

The center's geothermal system was not keeping the facility cool; interior temperatures reached in the high 80s and into the 90s, jeopardizing the heat-sensitive technology in the building. The ground was retaining heat through a process known as thermal retention.

When that occurs, most users abandon the underground loop geothermal system and put in a cooling tower, said Jay Egg of Egg Geothermal. However, Sussex County engineers worked with Egg to design a supplemental cooling system tied into the existing geothermal system. What the county needed was a new geothermal system to fix its existing geothermal system.

The temporary fix back in 2011 was to install a cooling tower at the cost of $50 per day, but county engineers realized quickly they needed a better, more cost-effective solution. "The cooling tower was too expensive, and maintenance was intense," Hudson said.

Because of the heat generated by computers and other high-tech equipment in dispatch and emergency centers, cooling issues are not uncommon, Egg said. He said the problem first surfaced in Florida, where the temperature is constantly warm.

The county's geothermal system is supplied by 24 wells, each one a 600-foot closed loop system.

A mechanical cooler, although more widely used, was a more expensive option in the long run, said Sussex engineer Steve Hudson, costing more than $280,000 to operate over 10 years. The supplemental system cost more to install but will cost less than $30,000 in utility bills over a decade.

A supplemental pump-and-injection geothermal system turned out to be the permanent fix. The supplemental open-loop well system, which cost more than $470,000, has turned out to be state-of-the-art, costing less than $4 a day in electricity to operate.

The idea for the fix came from an unlikely source. During a discussion about the problem, Councilman Sam Wilson, R-Georgetown, said driving a new well and pouring cool water over the underground system might help. "Why not use water from another well to cool the system," Wilson said.

The water used to cool the system is then injected back into the aquifer so no water is wasted, Egg said.

The work could qualify for a $250,000 FEMA grant. If that occurs, the system will pay for itself within 10 years, he said.

"It's operating better than we could have imagined," Egg said during a Sept. 24 presentation to county council. "This is now the model how to properly implement geothermal technology throughout the country."

Hudson said the temperature dropped 10 degrees immediately

Continued on page 43

Slide 34

Sussex County replies to system operations query

From: George Wilburt [mailto:GWilburt@gipe.net]
Sent: Thursday, March 20, 2014 11:41 AM
To: Steve Hudson
Subject: Quick Follow up on Sussex EOC

Steve,

Just curious on the open well system, now that we have had a pretty cold winter. Did you guys shut off the wells and go all well field to pull heat from the ground or did the building stay in cooling all winter? If you did end up pulling from the wells, just curious what kind of water temps. you may have seen for winter.

Hope all is going well.

Thanks.

George A. Wilburt, P.E., LEED AP
Mechanical Engineer

GIPE ASSOCIATES, INC.
Consulting Engineers
Mechanical - Electrical - Plumbing
8719 Brooks Drive - Easton, MD 21601
office 410.822.8688
fax 410.822.6306
mobile 410.443.1302
web www.gipe.net
Going Beyond the Expected

GAI #:11161

From: Steve Hudson
Sent: Thursday, March 20, 2014 2:43 PM
To: 'George Wilburt'
Subject: RE: Quick Follow up on Sussex EOC

George,

We left the Open loop system in Auto all Winter, but it has only run occasionally. The building itself has been in Cooling Mode all Winter, operating from the Closed Loop Wells.
The present Loop Temps are 79 degrees to the Wells, with a return Temperature of 75 degrees……4 degree DT….not bad for 70 degree range ..

We recharged the $*@!! out of that closed loop area last fall…..

We presently have the open loop system to start at 74 degrees and stop at 71 degrees, not about to let that Well Area heat to the upper 90's again…LOL

To sum it up, the system is working great…..I wish all of our projects could turn out so well…

Thanks George…

> To sum it up, the system is working great…..I wish all of our projects could turn out so well…
>
> -Steve Hudson, Sussex County Director of Engineering

Slide 35

Understanding "Class V Thermal Exchange Wells"

DEP 2012 UNDERGROUND INJECTION CONTROL 62-528

lowermost formation containing, within one quarter mile of the well bore, an underground source of drinking water.

2. Other industrial and municipal (publicly or privately owned) disposal wells which inject fluids beneath the lowermost formation containing, within one quarter mile of the well bore, an underground source of drinking water.

3. Radioactive waste disposal wells that inject fluids below the lowermost formation containing an underground source of drinking water within one-quarter mile of the well bore.

(b) Class II. Wells which inject fluids:

1. Which are brought to the surface in connection with conventional oil or natural gas production and may be commingled with waste waters from gas plants which are an integral part of production operations, unless those waters are classified as a hazardous waste at the time of injection.

2. For enhanced recovery of oil or natural gas; and

3. For storage of hydrocarbons which are liquid at standard temperature and pressure.

(c) Class III. Wells which inject for extraction of minerals, including:

1. Mining of sulfur by the Frasch process;

2. Solution mining of minerals; (Note-Solution mining of minerals includes sodium chloride, potash, phosphate, copper, uranium and any other mineral which can be mined by this process).

(d) Class IV. Wells used by generators of hazardous wastes or of radioactive wastes, by owners or operators of hazardous waste management facilities, or by owners or operators of radioactive waste disposal sites to dispose of hazardous wastes or radioactive wastes:

1. Into or above a formation which, within one quarter mile of the well, contains either an underground source of drinking water, or an exempted aquifer, or

2. Which cannot be classified as a Class I well under Rule 62-528.300(1)(a), F.A.C., or as a Class IV well under subparagraph 1. above.

(e) Class V. Only injection wells not included in Class I, II, III, or IV are Class V wells, which are grouped together for the purpose of permitting:

1. Group 1 - Thermal Exchange Process Wells.

a. Air conditioning return flow wells used to return to any aquifer the water used for heating or cooling. An air conditioning supply well, heat pump, and return flow well used to inject water into the same permeable zone from which it was withdrawn constitute a closed-loop system;

b. Cooling water return flow wells used to inject water previously used for cooling;

2. Group 2 - Aquifer Recharge Wells.

a. Recharge wells used to replenish, augment, or store water in an aquifer;

b. Salt water intrusion barrier wells used to inject water into a fresh water aquifer to prevent the intrusion of salt water into the fresh water;

Effective 2-16-12

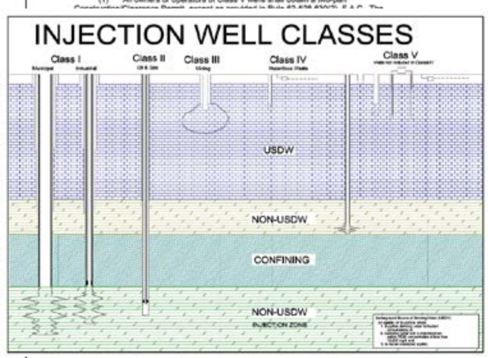
11

DEP 2012 UNDERGROUND INJECTION CONTROL 62-528

(12) A separate underground injection control permit shall be obtained for a Class V well which is constructed and operated as part of a fluid treatment or disposal system permitted by the Department.
Specific Authority 373.309, 403.061, 403.087 FS. Law Implemented 373.308, 373.313, 403.021, 403.061, 403.062, 403.087, 403.088, 403.161 FS. History - New 4-1-82, Amended 5-8-85, Formerly 17-28.61, 17-28.610, 62-28.610, Amended 8-10-95, 6-24-97, 7-15-99, 11-20-02.

62-528.635 Construction/Clearance Permit for Class V Wells.

(1) All owners or operators of Class V wells shall obtain a two-part



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The Variables of Ground Water

Table 3.4 Potential Interactions Between the GHX, the Surrounding Environment, and the Geothermal Heat Pumps*

Potential Impact	Types of GHX**	Environmental Consequence	GHP System Consequence
Geologic and Hydrogeologic Impacts			
Could wellfield penetrate karst geology?	C, O, S, H	Subsidence, potential groundwater contamination from surface pollutants or from closed-loop fluid	Requires specialized drilling to stabilize wellfield; potential for wellfield collapse over time
Is wellfield sited within a principal aquifer?	C, O, S, H	Risk of contaminating potential drinking water supply	Declining head within aquifer may reduce exchange capacity; reduced system effectiveness
Could system alter groundwater level and flow?	O, S, H	Water logging, desiccation, impact on neighboring water supplies and systems	Potentially reduced GHP capacity/efficiency directly and/or in neighboring systems
Could system affect the capture zone of nearby wells?	O, S, H	Pollution, increasing vulnerability of nearby wells and planned system	Reduced flow in nearby wells; reduced system performance
Could wellfield penetrate a flowing artesian aquifer?	C, O, S, H	Uncontrolled overflow, groundwater depletion	Reduced system performance or failure
Could wellfield penetrate separate aquifers?	C, O, S, H	Alteration of flow and quality of connected aquifers, potential for pollution/degradation of one or more aquifers	Reduction in system performance
Thermal Impacts			
If system changes groundwater temperature	C, O, S, H	Changes in solubility of some minerals and bacterial growth	Altered heat transfer, potentially reduced GHP efficiency, precipitation/fouling on heat exchangers and pipes in open-loop systems
If system changes temperature of receiving water (surface water or reinjection aquifer)	O, H	Alterations to ecosystem, changes in solubility of some minerals, bacterial growth	Clogging/fouling in well, increased maintenance, reduced GHP efficiency, inability to reject into ground
If system changes ground temperature	C, H	Freezing/frost heave, thermal expansion, soil desiccation	Reduced GHP efficiency, damage to building structure, thermal interference with nearby GHP systems
Chemical and Microbial Impacts			
Could wellfield penetrate existing contaminant plume in soil or groundwater?	C, O, S, H	Mobilize and disperse contaminants further, contaminate groundwater	Potential to close down project
If antifreeze fluids or additives leak	C, H	Groundwater/water supply contamination from antifreeze, biocides, corrosion inhibitors	Reduced performance, pipe damage, increased cost
If surface contaminants migrate to groundwater via poorly sealed boreholes	C, H	Groundwater contamination	Unknown
If metals leach from installation materials (Cd, Cu, Cr, Ni, Pb, vinyl chloride)	O, S, H	Environmental contamination	Premature system degradation
If the microbiological population in groundwater changes	C, O, S, H	Unknown	In O, S, and H, potential fouling of well screens, pumps, heat exchanger plates, and pipes; reduced system efficiency, increased system maintenance
If pathogens are introduced or mobilized in system	O, S, H	Change in ecosystem balance	Potential human hazards, required disinfection
If biodegradation increases	O, S, H	Increased nutrients, inorganic and organic micro-pollutants; increased anaerobic bacteria with potential for increased gases and acids in well	Potential fouling of well screens, heat exchanger plates, and pipes; reduced system efficiency; increased maintenance

* Information adapted from Table 1 in a 2011 paper by M. Bonte et al., *Underground Thermal Energy Storage: Environmental Risks and Policy Developments in the Netherlands and European Union*, www.ecologyandsociety.org/vol16/iss1/art22/. Additional information from D. Banks, *Introduction to Thermogeology* and from personal communication with J. Schnieders, Principal Chemist/Microbiologist of Water Systems Engineering Inc.

** C=closed-loop GHX, O=open-loop GHX, S=standing column well GHX, H=hybrid system GHX

Nina Baird, Ph.D., Carnegie Mellon University
John Rhyner, PG, P.W. Grosser Consulting Inc.

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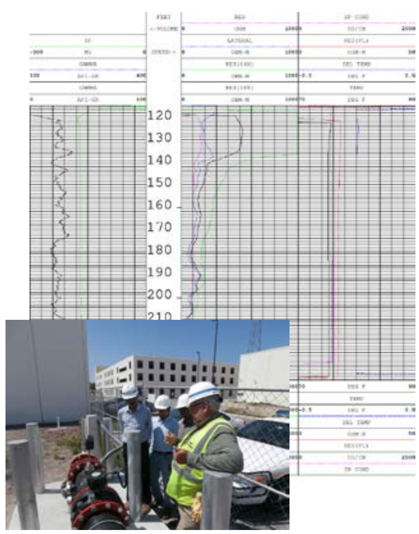
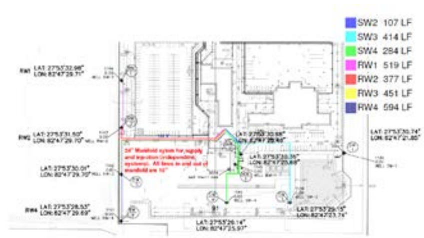
Testing and Layout





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Pittsburgh's Energy (NRG) Goals

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Hidden Benefits of Geothermal

- Elimination of outdoor equipment
- Elimination of Water Consumption
- Elimination of Legionnaires threat (from cooling towers) NYC Headline
- Increased efficiency in cooling and heating
- Longer life (all inside)
- Storm and weather proof (NYT article)

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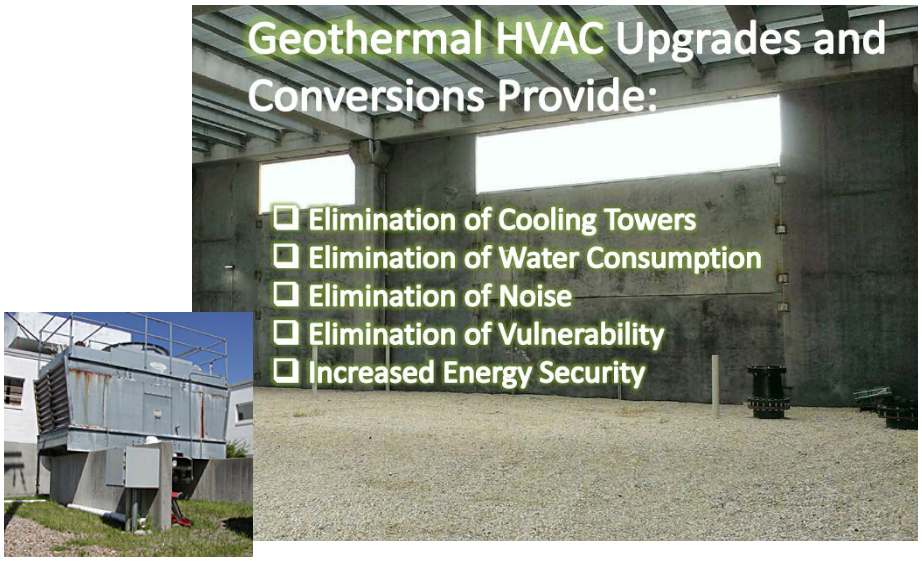
Hidden Benefits of Geothermal



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Reduces Various Challenges

New York City Council Passes Law to Curb Legionnaires' Outbreak

The New York City Council voted unanimously on Thursday to pass legislation that mandates strict regulations of cooling towers, a move that comes in response to the current outbreak of Legionnaires' disease in the South Bronx. The Council voted 42-0 in favor of new regulations that will require all cooling towers be registered, tested and then disinfected if they're found to contain *Legionella* bacteria. Cooling towers are used to regulate temperatures indoors and are part of ventilation systems in many modern residential

The New York Times

BUSINESS DAY | SQUARE FEET

Geothermal Designs Arise as a Stormproof R

By ALISON GREGOR NOV. 6, 2012

Advocates for geothermal energy say that the path of destruction cut by Hurricane Sandy, which unearthed fuel tanks, ravaged cooling towers and battered air-conditioners, has already persuaded some building owners to switch to geothermal systems that use underground pipes to harness the earth's energy for heating and cooling buildings.

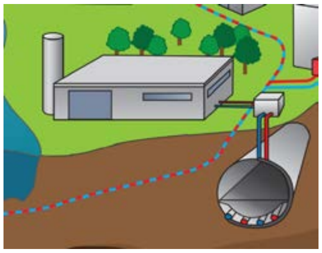
Slide 42

Frees Up Space

Slide 43

Potential for GHP Improvements…

- Piping
  - Conductivity
  - Versatility
- Drilling
  - Basements
  - Tight spaces
  - Configurations
- Sewer energy:
  - Thermal
  - Chemical Constituents



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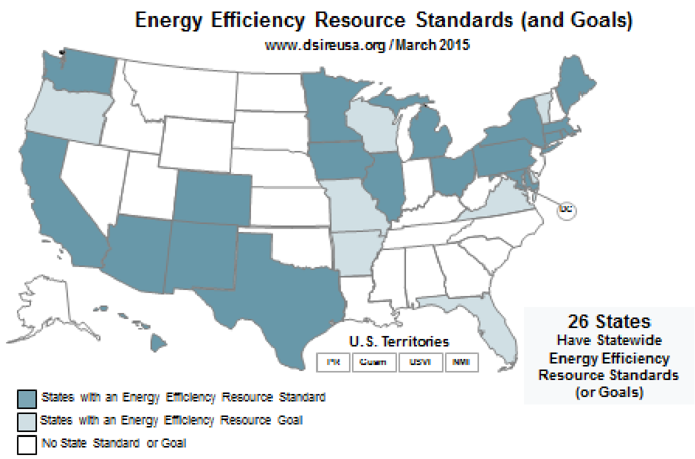
Database of State Incentives for Solar and Renewable Energy (DSIRE)

DSIRE® | NC CLEAN ENERGY TECHNOLOGY CENTER | U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



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Geothermal Incentives

- [DSIRE Website Navigation]
- Federal
- State
- Local
- Unusual and little known (for engineers and architects)

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Renewable Energy Portfolio Standards for Direct Use and GSHPs

- What are Renewable Energy Portfolio standards?
  - PA: Pennsylvania's Alternative Energy Portfolio Standard (AEPS), created by S.B. 1030 on November 30, 2004, requires each electric distribution company (EDC) and electric generation supplier (EGS) to retail electric customers in Pennsylvania to supply 18% of its electricity using alternative-energy resources by 2020.*

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Renewable Energy Credits

- What is a renewable energy credit (REC)?
  - A renewable energy credit (sometimes referred to as a renewable energy certificate or "greentag") is an environmental commodity that represents the added value, environmental benefits and cost of renewable energy above conventional methods of producing electricity, namely burning coal and natural gas. RECs help renewable energy facilities grow by making them more financially viable, thereby incentivizing development.

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Renewable Energy Credits

- How does the REC system work?
  - Renewable energy facilities generate renewable energy credits (RECs) when they produce electricity. Purchasing these credits is the widely accepted way to reduce the environmental footprint of your electricity consumption and help fund renewable energy development.

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Geothermal Exchange Organization (GEO) is the Voice of the Geothermal Heat Pump Industry in the United States

Advocacy • Partnerships • Outreach • Standards

OUR OBJECTIVES

- Sensible Public Policy
- Common Interests with Allies for Strength In Numbers
- Public Relations and Outreach
- Promotion of Quality in Training, Certification and Accreditation

Slide 50

Current GEO Initiatives

- Retention of Residential and Commercial Tax Credits
- Passage of Tax Extenders Bill for Bonus Depreciation, and Energy Efficient Homes and Buildings
- GHPs as Utility Compliance Option under EPA Carbon Dioxide Reduction Rules for Coal-Fired Power Plants
- Thermal (GHP) Technologies in Energy Efficiency Legislation
- Support of State-Level GHP Association Activities and Initiatives
- Support for Revived GHP Industry Data Compilation by the Energy Information Administration (DOE)
- Support for a U.S. Department of Energy GHP Office and Continuing Geothermal Heat Pump Research
- Partnering with Allied Organizations to Improve GHP Installation Training and Certification

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GEO State Geothermal Initiatives

GEO is Helping with Local Initiatives and Urges Formation of State Geothermal Associations

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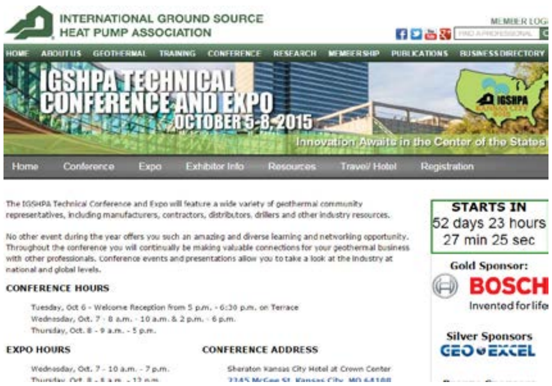
IGSHPA

- The International Ground Source Heat Pump Association (OSU)
- Research and development
- Training and certification



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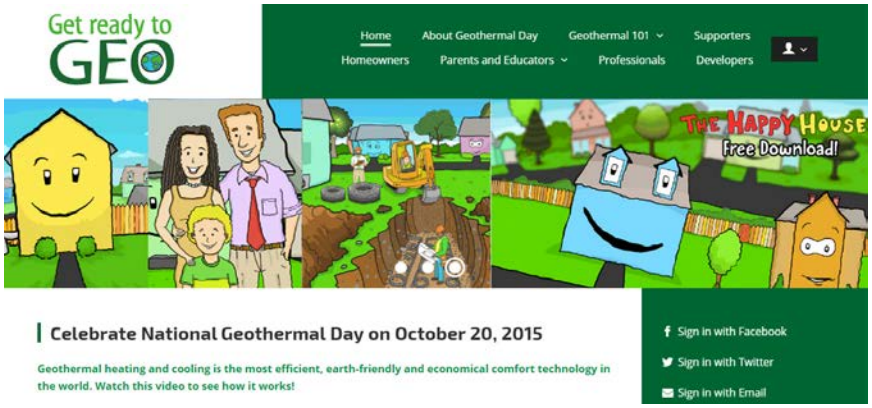
National Geothermal Day Supported by Industry Stakeholders



National Geothermal Day aims to raise awareness about environmental and economic benefits of geothermal energy and its vital role in building a clean and secure energy future. We are inviting industry partners, communities, businesses and educators to join efforts to advance further understanding and acceptance of geothermal technology as an unlimited, renewable form of energy. Join us by co-creating and sharing educational resources and participating in interactive activities in local communities and on-line.

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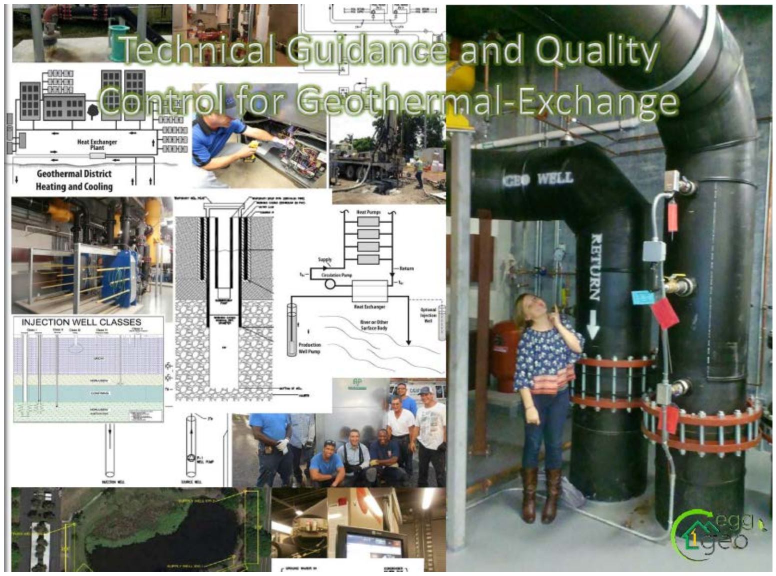
Geothermal Industry Advocacy



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EggGeothermal

Helping make geothermal work for ***<u>you</u>***.