Mountain View College
DALLAS COUNTY COMMUNITY COLLEGE DISTRICT

Dallas County
Community College District

BROOKHAVEN
NATIONAL LABORATORY

Solubility of Perfluorocarbons Tracers used under Geothermal Conditions

Jesse Fox
Professor of Chemistry
Mountain View College
July 13, 2015

- Who am I (introduction)
- Who do I represent (MVC)
- How did we get here (intention and fruition)
- Now that we are here, what are we doing (research)
- Where do we go from here (funding and future research)

Who am I ?

- I am currently a Professor of Chemistry at Mountain View College of the Dallas County Community College District in Dallas, Texas
- Teaching 19 years, 11 years as full-time professor
- I have done Academic Cooperatives with
  - Los Alamos National Laboratory (2011 & 2012)
  - Lawrence Berkeley National Laboratory (2014)
  - Brookhaven National Laboratory (2015)
- As an undergraduate and graduate student, I have interned at:
  - University of Oklahoma (1989)
  - NASA Space Life Science Training Program (1990)
  - Oak Ridge National Laboratory (1990)
  - Los Alamos National Laboratory (1991-1994)
- My vision is to do what I can to get our students exposed to things outside of their community and neighborhood.
- Mountain View College is <u>not</u> a research-based institution. Therefore our students are not exposed to research, unless they intern on their summer breaks.

How did we get here

- An intention… to get our students exposed to the realm of research by any means necessary. The birth of the Academic Cooperative.
  - 8 students to LANL in 2010 (on HSI-STEM grant from NSF)
  - 8 students to LANL in 2011 (on HSI-STEM grant from NSF)
  - 2 students to LBNL in 2014 (on grant from Dept. Of Education grant)
  - 2 students currently to BNL (on grant from Dept. Of Education grant)
    - Yassien Fadul
    - Juan Sosa
- Correspondence with Noel Blackburn (over 4 years) and the Personnel in the Office of Educational Programs
- Came to BNL for a Spring Break visit with a group of students in 2011
- We have sent students to the BNL Minimester the BNL through CCI program.
  - Eric Torbellin
  - Jereamy Riggs
  - Rubi Peña
  - Altramiese Tippie
- Students to participate in BNL CCI Program
  - Altramiese Tippie 2013
  - Rubi Peña 2014
  - Jesus Ramos 2015

How did we get here

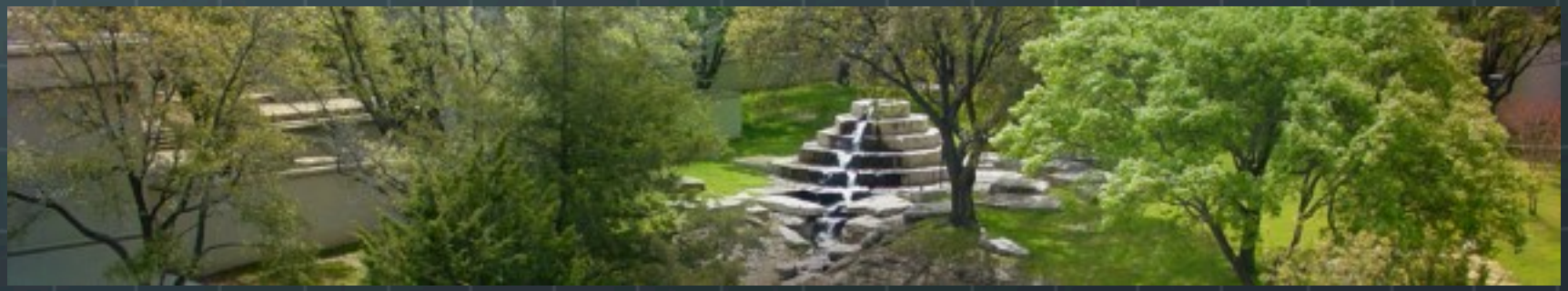
Who do I represent? Mountain View College

- Mountain View College is in Dallas, Texas
- Mountain View College is one of seven community colleges in the Dallas County Community College District which serves 85,000 students.
- Mountain View College is an open-access public community college.
- Mountain View College serves residents of southwest Dallas County, Texas (southwest quadrant of the city of Dallas, and the cities of Cedar Hill, Duncanville, and Grand Prairie.)
- Mountain View College currently serves 9,000 students, in which 53% Hispanic, 27% Black, 13% White and 4% Asian/Pacific Islander.
- Mountain View College is 58% Female and 42% Male. 66% of our student body is between the ages of 16-25.

Our Mission

- ***Mission Statement for College:***
- ***Mountain View College empowers people and transforms communities.***

- **Mountain View College is part of the movement to prepare future scientist and science professionals through STEM initiatives. Funding provided by these STEM initiatives allows Mountain View College to explore various venues to promote educational opportunities for its students, its faculty and its support staff**



Purpose of Academic Cooperative

- The purposes of the Academic Cooperative are
- to allow students in the southwest sector of Dallas county, the opportunity to become familiarized with research out in the field;
- to provide an environment conducive to influencing students to seriously pursue degrees in Science, Technology, Engineering and/or Math (STEM careers);
- to arrange collaborations between students at the community college level with those of research and STEM professionals;
- to participate in programs that allow students to experience stellar research opportunities at nationally renowned research institutions;
- to integrate on-campus study with practical hands-on work experience in the physical sciences or STEM fields. In conjunction with class seminars, the individual students will set specific goals with researchers and/or research fellows.

What are we doing

Solubility of Perfluorocarbons Tracers used under Geothermal Conditions

- Perfluorocarbons (PFC) are compounds that are composed solely of carbon and fluorine.
- Due to the electronegativity of fluorine, perfluorocarbon compounds have strong covalent bonds and are chemically inert.
- Perfluorocarbon compounds are appreciably soluble in water, and have been used for dissolving high concentrations of oxygen.
- Perfluorocarbons have high densities which make them heavier than water.

Synthesis of perfluorocarbons

- Two ways to synthesize perfluorocarbons
  - Fowler Process
    - $C_6H_{14} + 28CoF_3 \rightarrow C_6F_{14} + 14\ HF + 28\ CoF_2$
  - Electrochemical Fluorination
    - $2N(C_6H_{13})_3 + 90\ HF \rightarrow 6C_6F_{14} + 2NF_3 + 81\ H_2$

What are the uses of Perfluorocarbons?

- Perfluorocarbons have been used in:
  - Liquid Breathing
  - Blood Substitutes
  - Eye Surgery
  - Cosmetics
  - Liquid Dielectric
  - Tracers

Air Quality

Climate

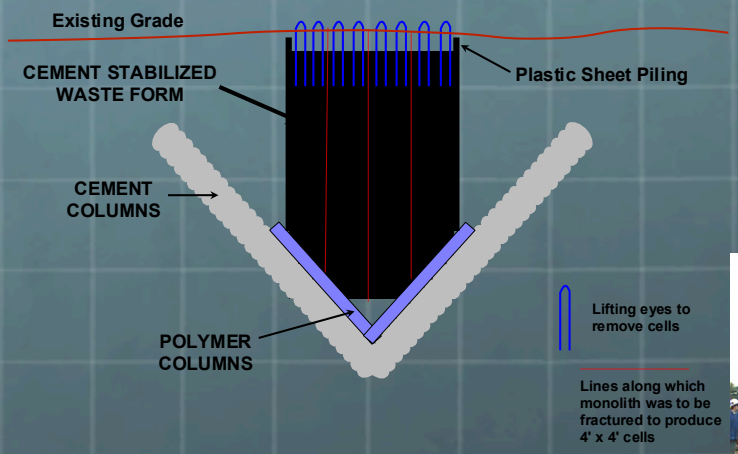
Toxic Releases

Emergency Response

Homeland Security

Building Ventilation

Underground Systems

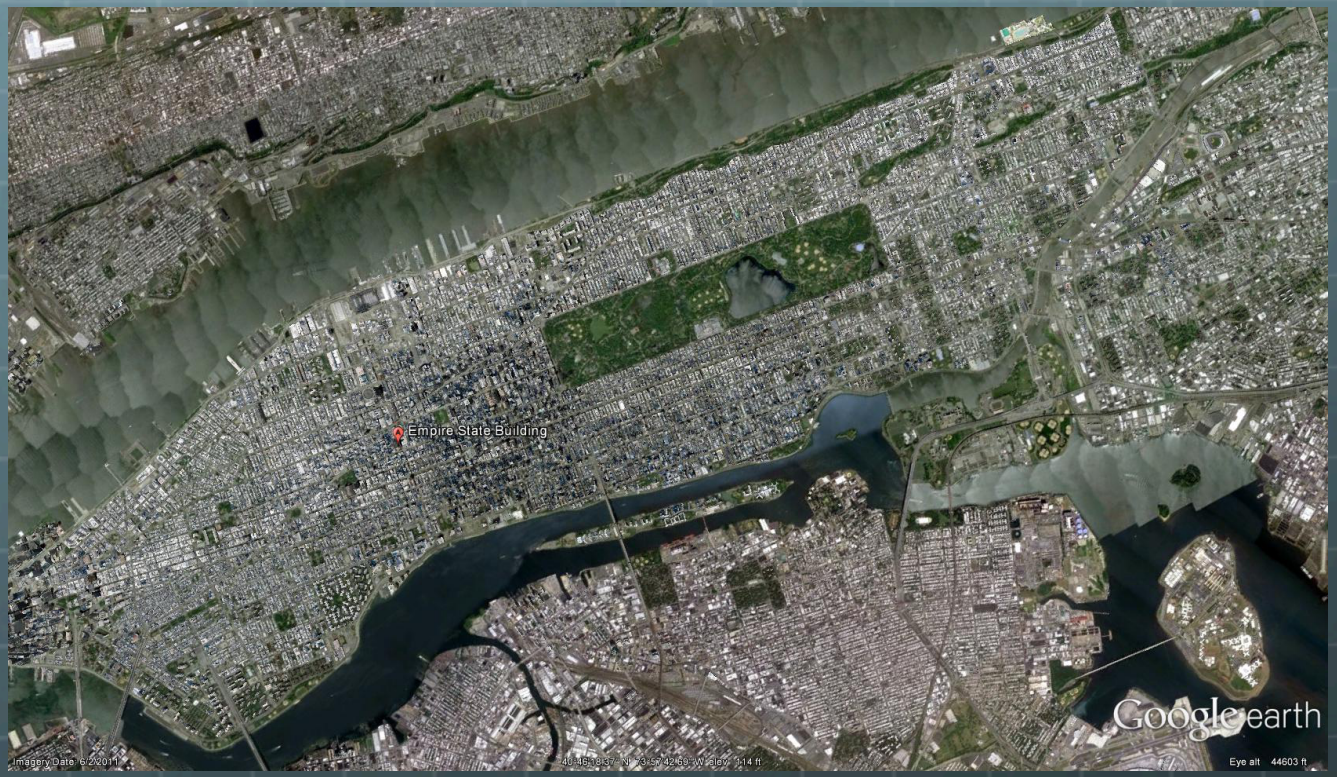


What are tracers

- A tracer is an indicator added to a system so that movement of mass can be easily detected.
- Have little or no background, and
- Are easily detected at background levels
- Natural Gas is an example of a tracer
  - Natural gas is odorless.
  - Mercaptan is added to natural gas so that leaks are detectable.
  - The smell of mercaptan is distinctive and unpleasant.
  - These compounds are detectable by the human nose at concentrations of only 10 parts per billion.

Perfluorocarbon Tracers (PFTs)

- PFT technique was developed at Brookhaven by Russ Dietz in early 1980s
- For atmospheric transport and dispersion research
- Six available compounds
- Present in the atmosphere at very low background levels:
  - From less than 1 to ~9 parts per quadrillion
- Detectable at background levels
  - Using specialized gas chromatography with electron capture detection

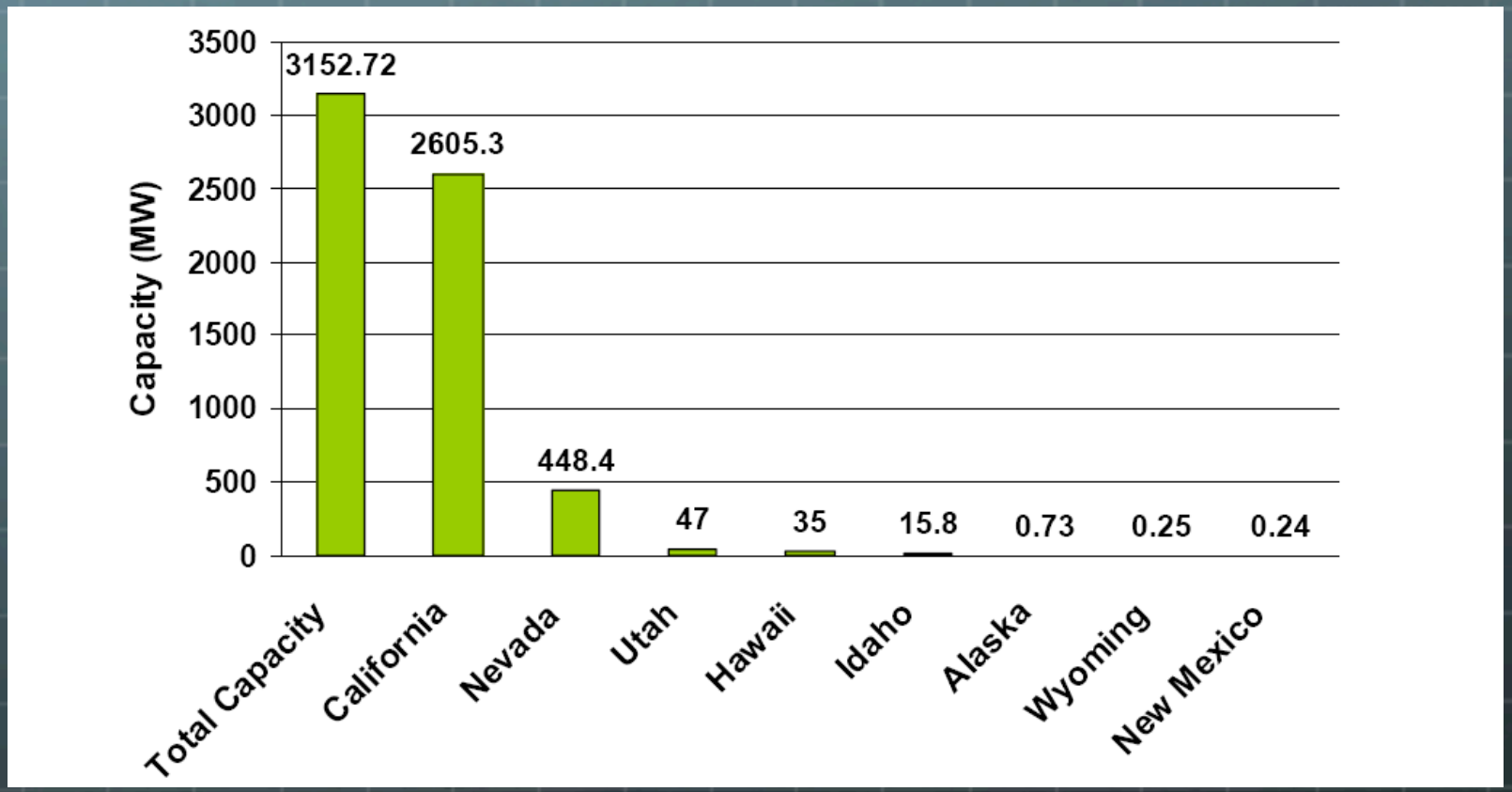


- 1 gram of a PFT can be detected in a volume as high as the Empire State Building over an area 3 times the size of Manhattan

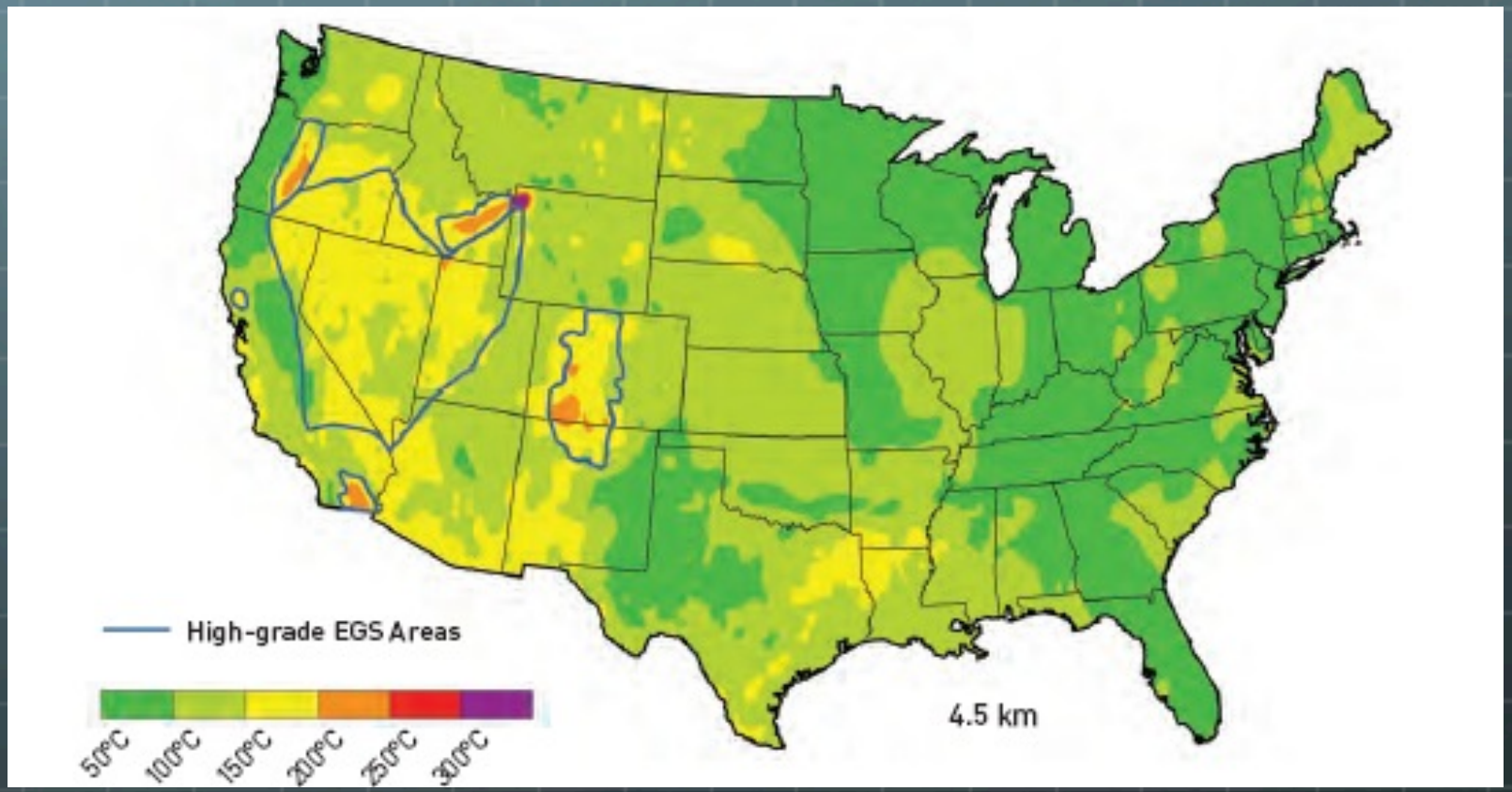
Engineered Geothermal System

- Current US electrical generating capacity is more than 1 X 10^{12} W (1 tera Watt)
- It is likely that 90 X10^{9} W (90 giga Watts) of generating capacity will be retired as Nuclear and coal fired plants are retired
- Goal of 1 X 10^{11} W (100 GW) electrical energy from Geothermal Sources by 2050

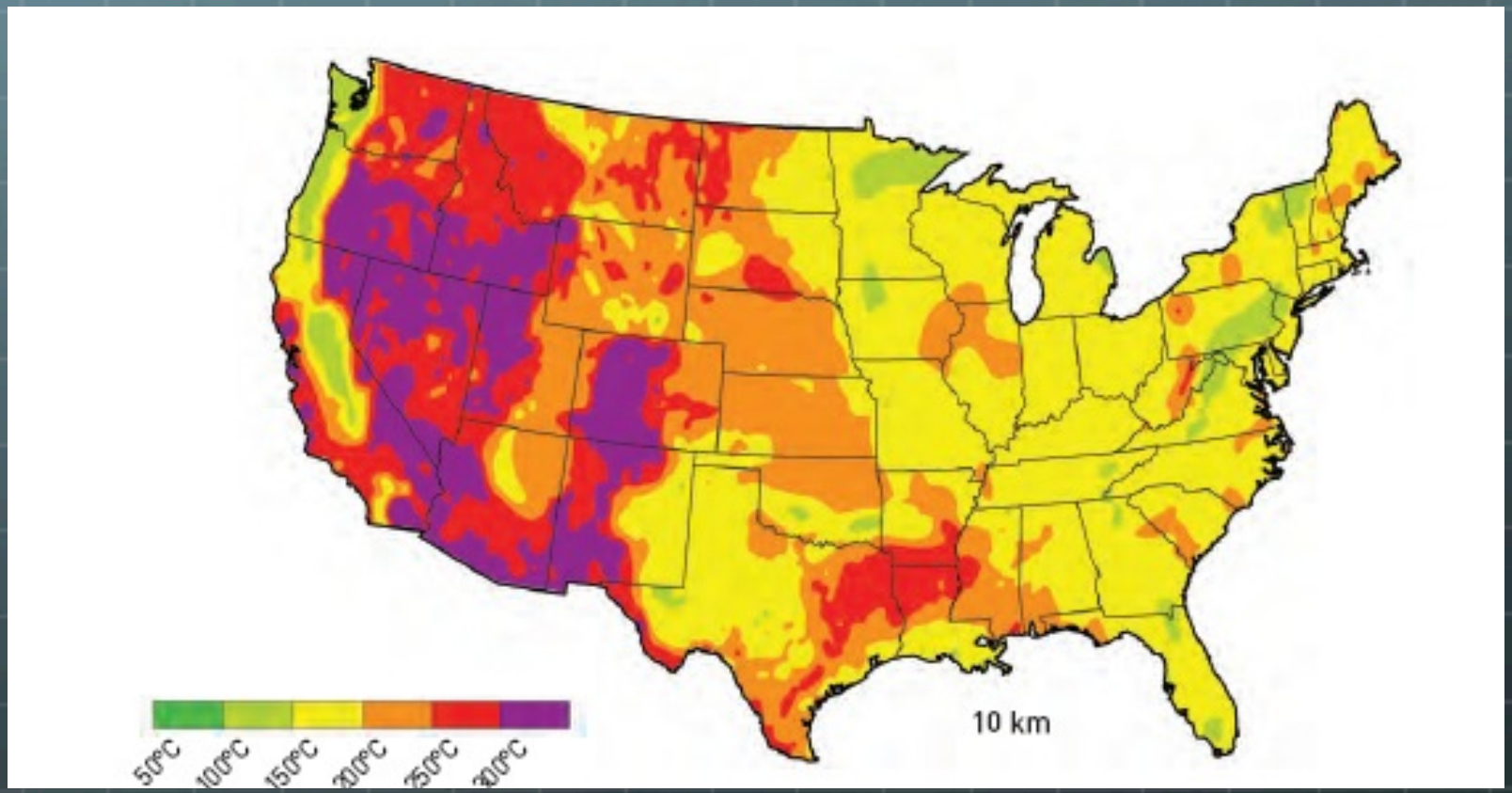
Current Geothermal Electrical Production



Average Temperature Map at 6.5 km (3.9 miles)

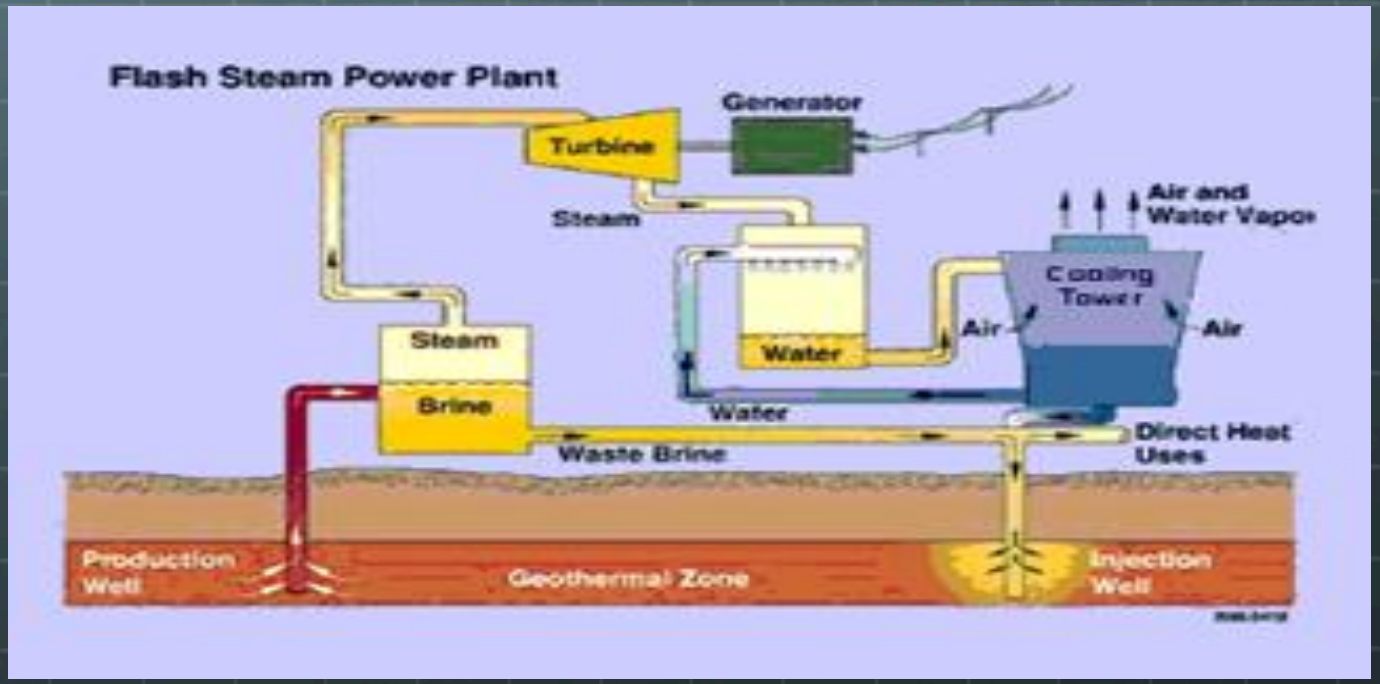


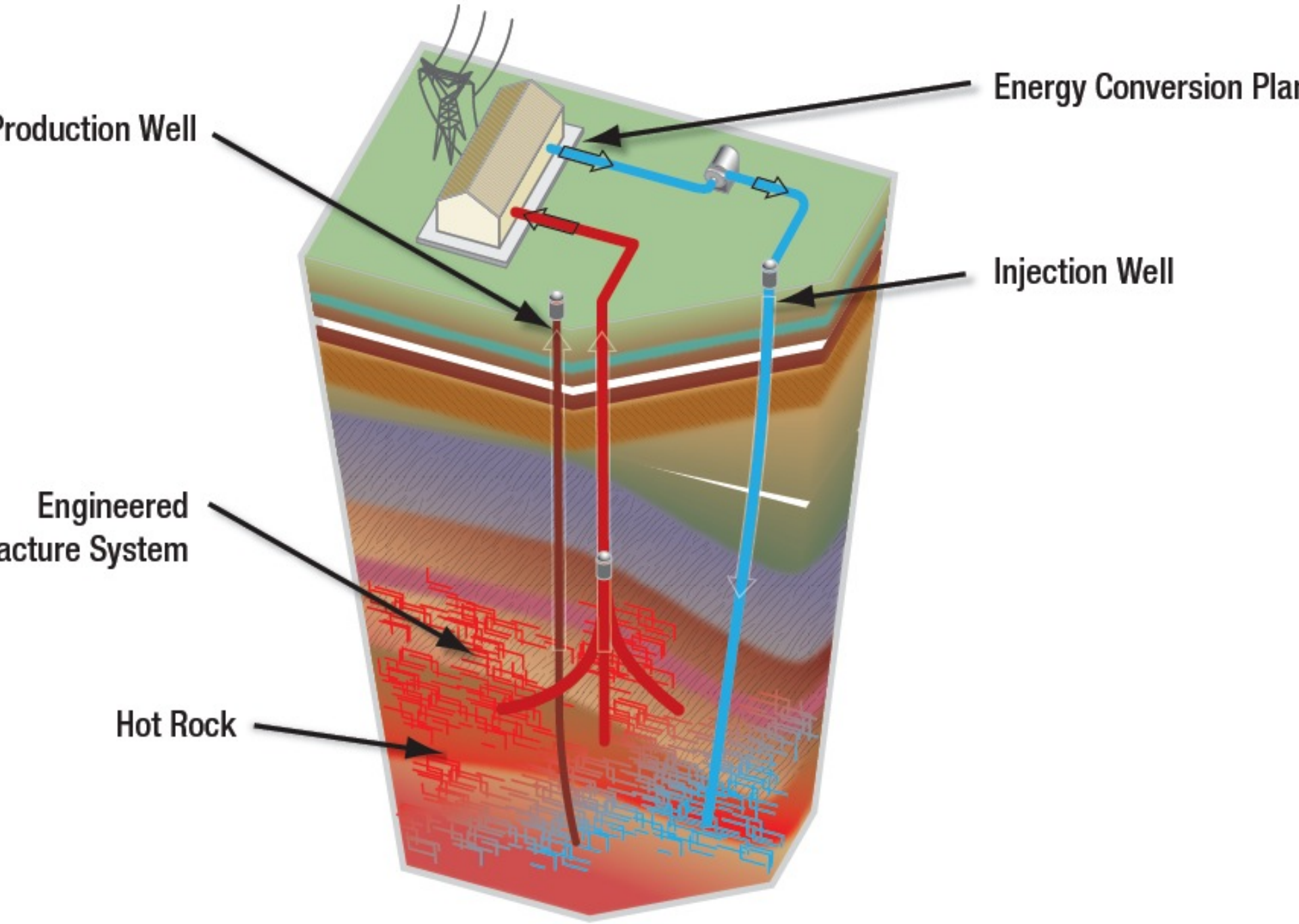
Average Temperature Map at 10 km (6 miles)



Enhanced (or Engineered) Geothermal Systems

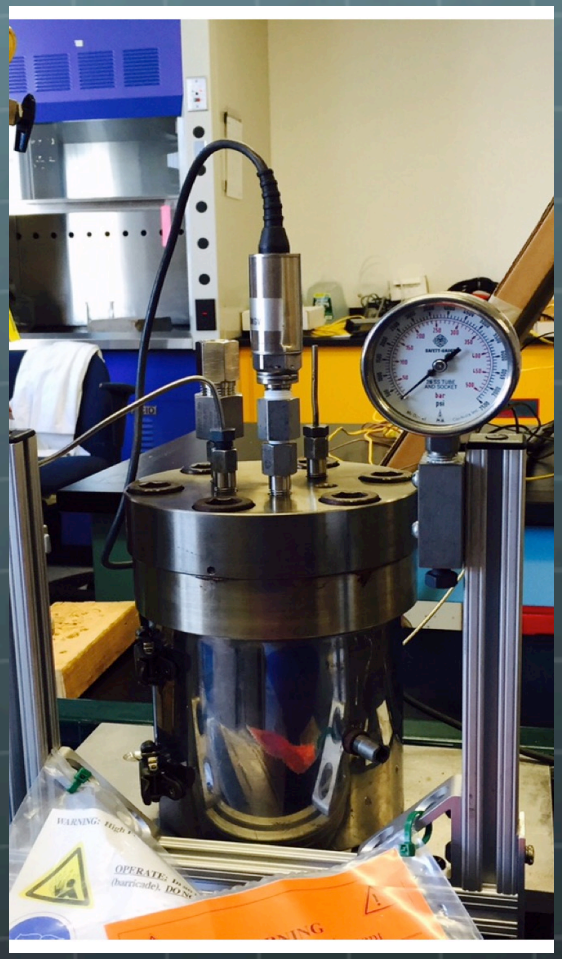
- EGS are defined as reservoirs that have been created to extract economical amounts of heat from low permeability geothermal resources




Energy Conversion Plan
Production Well
Injection Well
Engineered
acture System
Hot Rock

- Quantitative characterization of temperature distributions and surface area available for heat transfer in EGS is necessary for commercial development of geothermal energy.
- The goal of this project is to provide integrated tracer and tracer interpretation tools to facilitate this characterization. PFTs will be tested as conservative tracers.
- They are thermally stable at temperatures over 500°C and will not degrade in the geothermal environment.
- We will characterize the solubility and transport behavior of PFTs in geothermal systems

The Vessel



Replication of geothermal conditions in the laboratory

- Experiments shall be carried out replicating geothermal conditions (~200°C @ 30 psi) in the vessel.
- The vessel will be filled with 5 cc of PFT and 300 cc of water.
- 5 cc of gas will be collected at different temperature and in triplicate to determine and quantify PFT concentrations
- This will be done with six perflurorcarbon compounds
- Quantified with Gas chromatography with an electron capture detector (ECD).
- The GC/ECD methods has the sensitivity to quantify background levels of PFT if the material in 1.5 liters of ambient air is collected.

Future work

- Continue with testing of each of the six perfluorocarbon tracers to see which gives a better ECD reading in GC-MS.
- Explore the use of stones or rocks similar to those used for geothermal energy and test for changes in PFT concentrations
- Explore the possibility of packaging PFTs in micro-beads and other forms using materials that will release the tracers at specific temperatures.
- Acquiring funding from my home institution to continue the research started at BNL with more students

Acknowledgements

- Brookhaven National Laboratory
  - Office of Educational Programs
    - Visiting Faculty Program (VFP)
      "This project was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Visiting Faculty Program (VFP)."
  - John Heiser
  - John Watson
  - Rick Wilke
- Dallas County Community College District
  - Dr. Stephen Jones, Interim Dean of STEM Division and STEM Program Director
  - Dr. Preston Pulliams, Interim President of Mountain View College
  - Dr. Quentin Wright, Vice-President of Instruction
  - Joyce Larkin, Administrative Assistant to STEM Program Director
  - Mountain View College
  - Joe May, District Chancellor
- Department of Energy
- Department of Education

Acknowledgements

Composition of Air

- 78% nitrogen (N_2)
- 21% oxygen (O_2)
- 1% trace gas species including
  - Water (H_2O)
  - Argon and other noble gases (Ar, Ne, Kr, Xe)
  - Methane (CH_4)
  - H_2
  - CO_2 : January 2012: 393.09 ppm
  - CO_2 : 10th May, 2013 : >400 ppm

Perfluorocarbon Compounds Used as Tracers

Acronym	Formula
PDCB **perfluorodimethylcyclobutane**	C_6F_{12}
PMCP **perfluoromethylcyclopentane**	C_6F_{12}
PMCH **perfluoromethylcyclohexane**	C_7F_{14}
o-PDCH **perfluorodimethylcyclohexane**	C_8F_{16}
i-PPCH **perfluoroisopropylcyclohexane**	C_9F_{18}
PTCH **perfluorotrimethylcyclohexane**	C_9F_{18}