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CO-GENERATION OPPORTUNITIES FOR LOWER GRADE GEOTHERMAL RESOURCES IN THE NORTHEAST – A CASE STUDY OF THE CORNELL SITE IN ITHACA, NY

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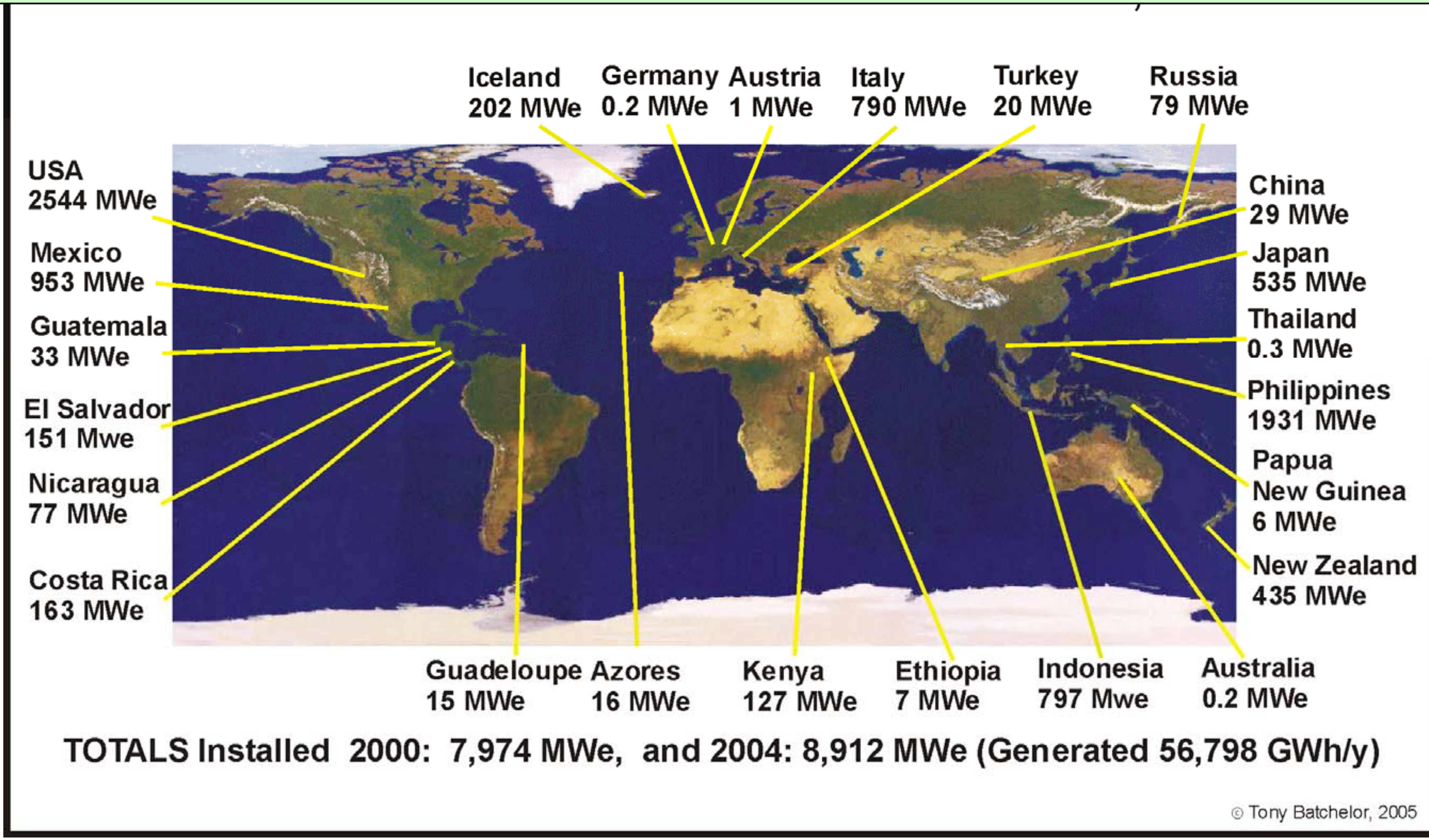
Outline

- **Introduction to geothermal energy**
- **Motivation from thermal spectrum of US energy use**
- **Rationale for direct use and combined heat and power using low grade geothermal**
- **Geothermal resource in the Eastern US and New York State**
- **Opportunities for a co-generation demonstration at Cornell**
  - **Commitment to sustainability – CCSF**
  - **Climate Action Plan**
  - **Existing District Energy and Co-generation**
  - **Hybridization of biomass with geothermal**
- **Path forward**

Utilization of Geothermal Energy

1. For Electricity -- as a source of thermal energy for generating 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

Today there are over 11,000 MWe on-line
USA at 4000+ MWe up from 2544 MWe in 2004



A.S. Batchelor, 2005; Bertani,2008; GEA, 2009; and IPCC 2010

Geothermal has enabled Iceland's transformation

Figure 1 - Cloud of smoke from space heating by coal over Reykjavik in the 1940 (Sturludóttir, 2007).

Figure 2 - Clear day in modern Reykjavik (Stone, 2006).

Geothermal has enabled Iceland's transformation

- In 50 years Iceland has transformed itself from a country 100% dependent on imported oil 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
- 2 world scale aluminum plants powered by geothermal
- Currently evolving its transport system to hydrogen/hybrid/electric systems based on high efficiency geothermal electricity

The Blue Lagoon in Iceland

But not every country has the geothermal resources of Iceland

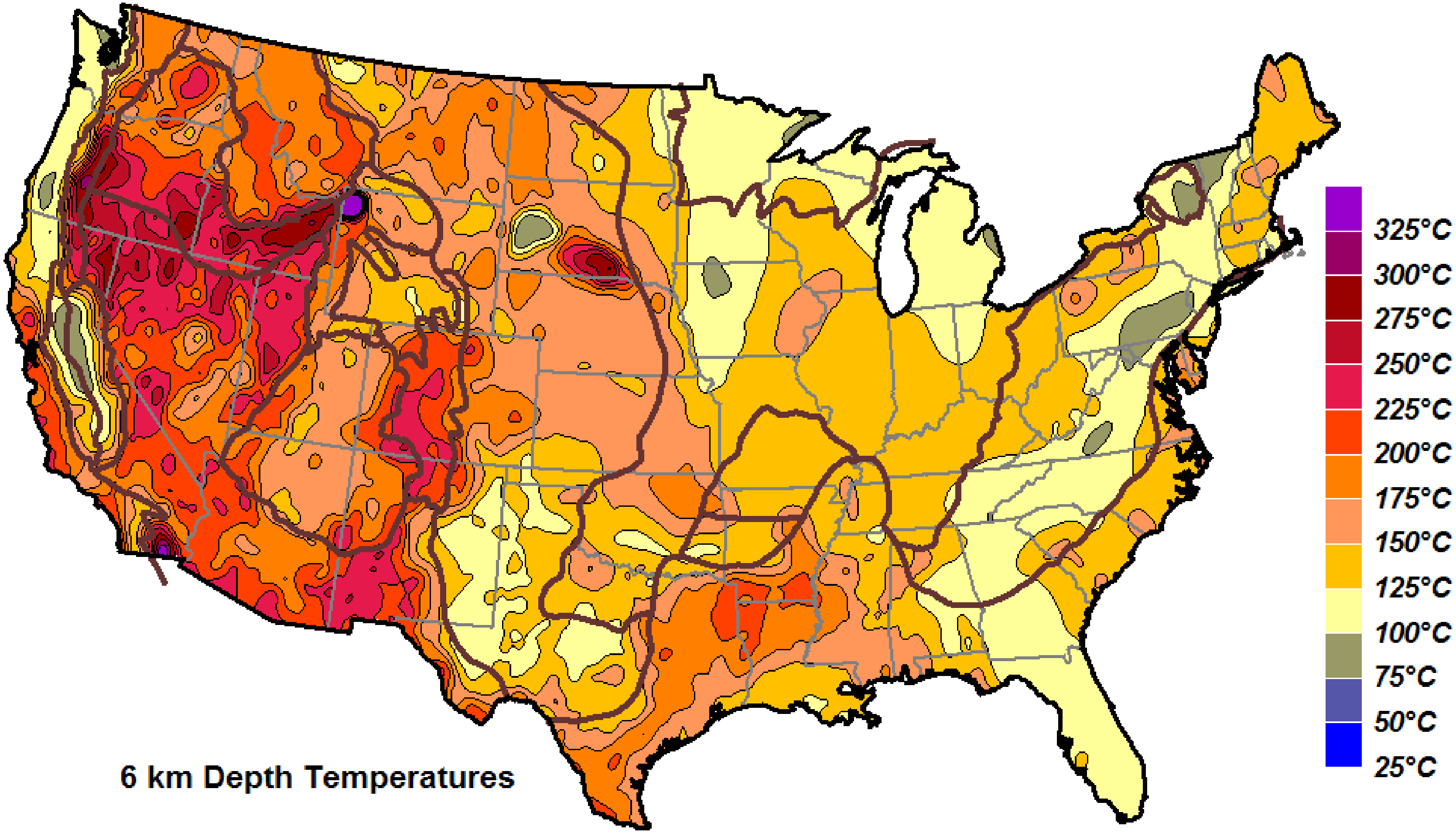
Geothermal energy today for heat and electricity

- From its beginning in the Larderello Field in Italy in 1904, more than 11,000 MWe of capacity worldwide today
- Additional capacity with geothermal heat pumps (e.g >100,000 MWt worldwide)
- Current costs -- 7–10¢/kWh
- Attractive technology for dispatchable base load power for both developed and developing countries

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

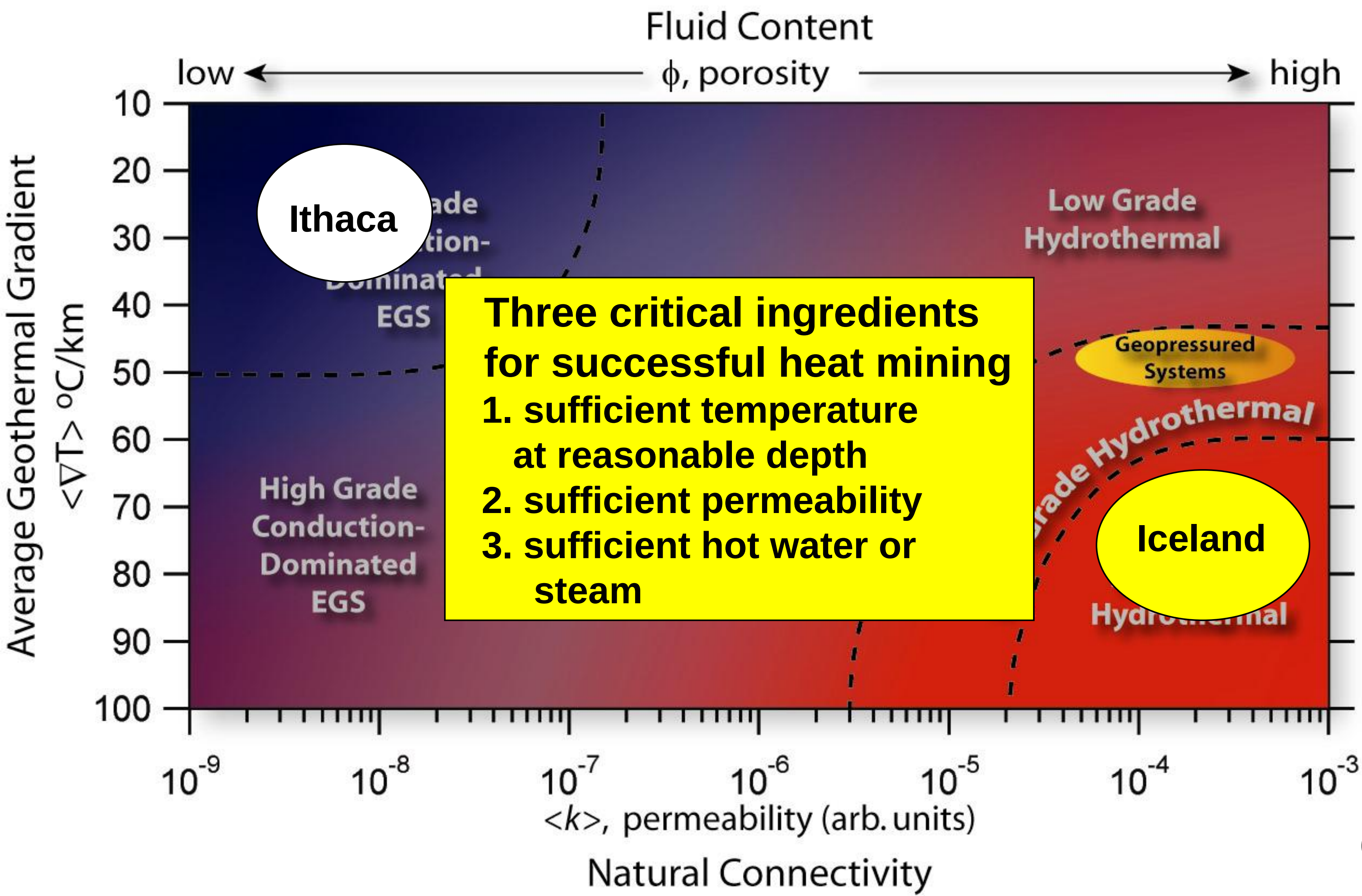
But geothermal today is limited to high grade, high gradient sites with existing hydrothermal reservoirs !!

Demonstrating EGS in the Eastern US must deal with lower gradients and heat flows

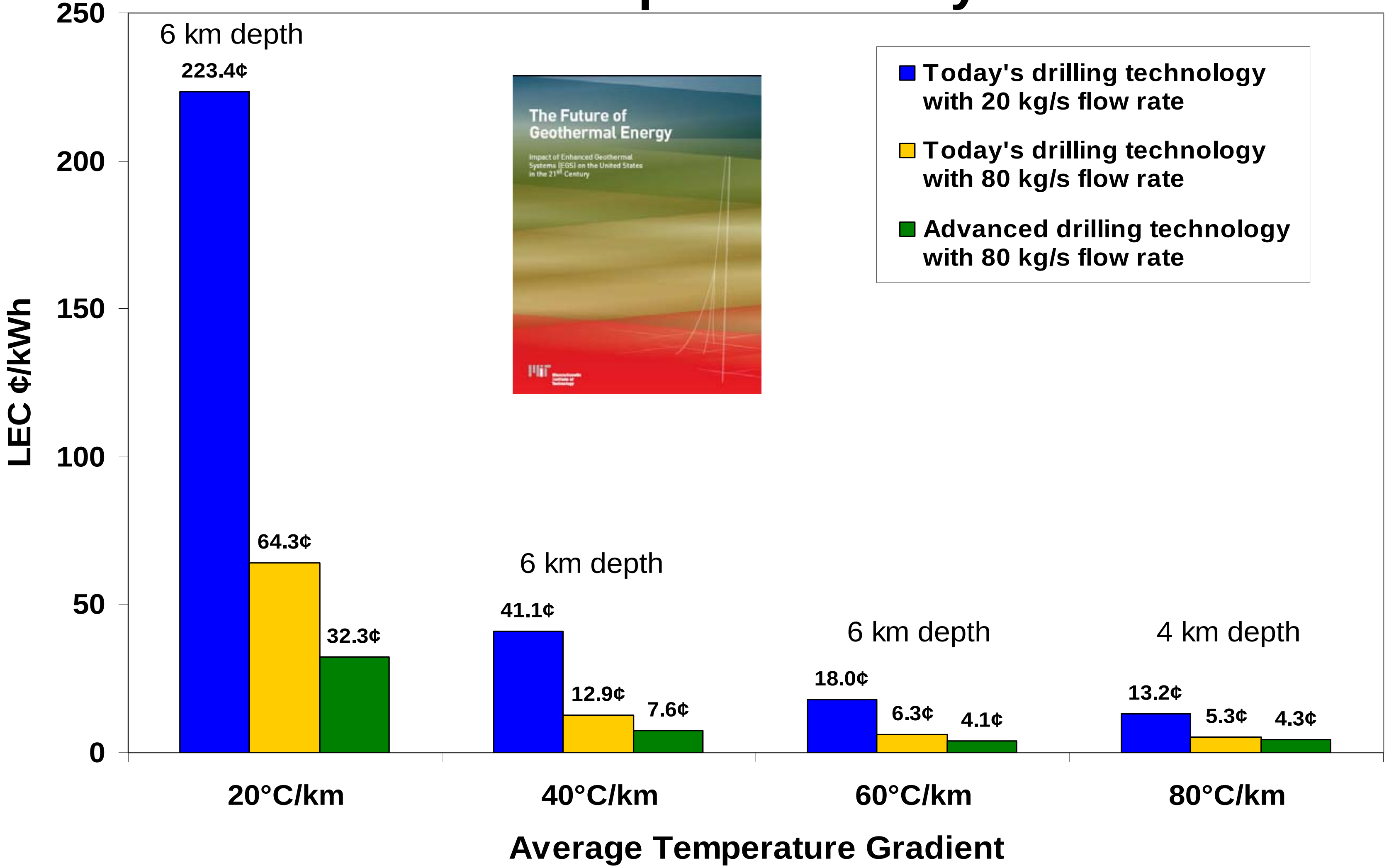


From Blackwell and Richards (June, 2007)

A range of resource types and grades within the geothermal continuum



EGS electricity in a low gradient region – not competitive today

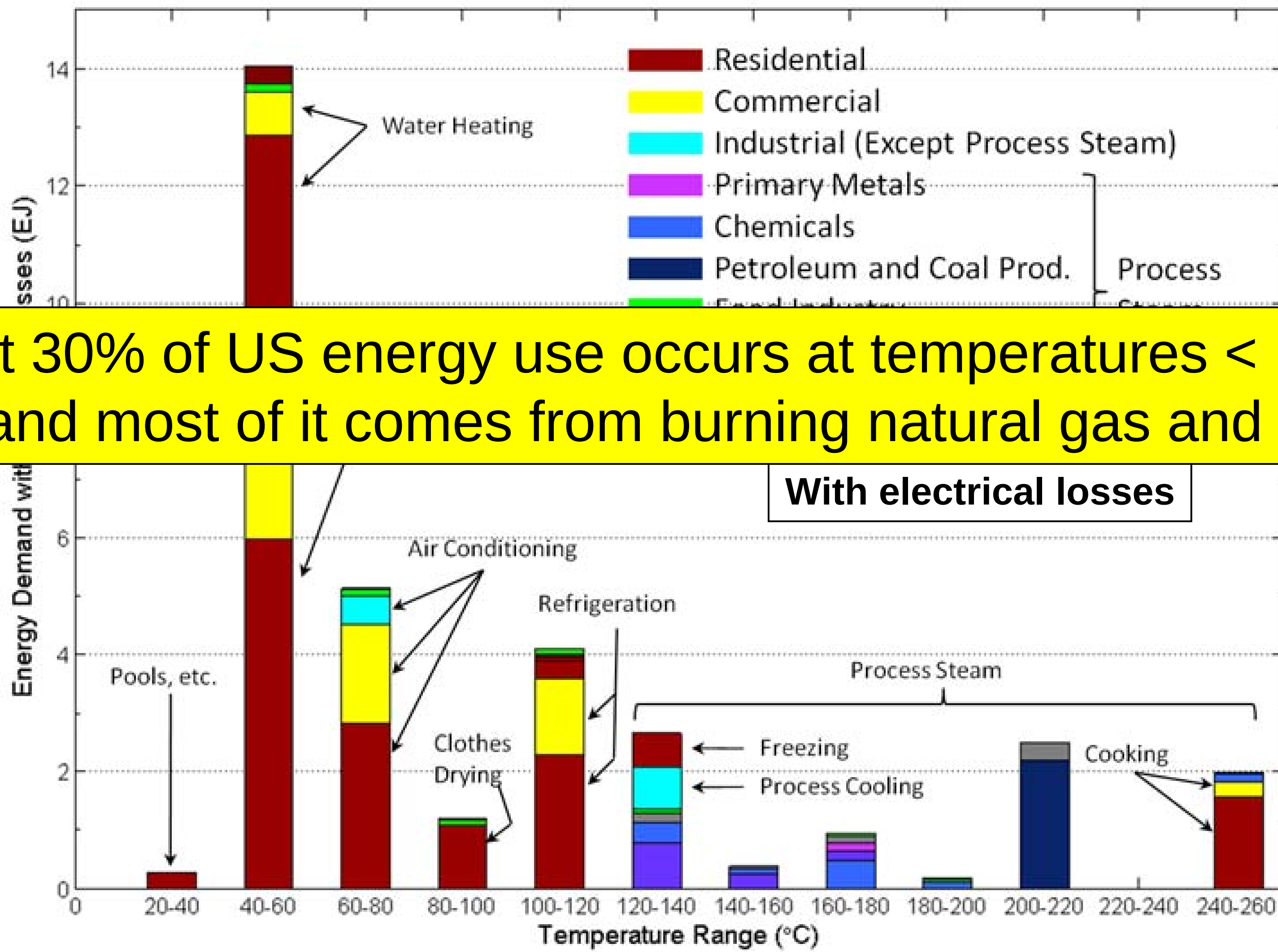


Leads you to direct use and district heating

The Thermal Spectrum of U.S. Energy Use

Energy consumed as a function of utilization temperature

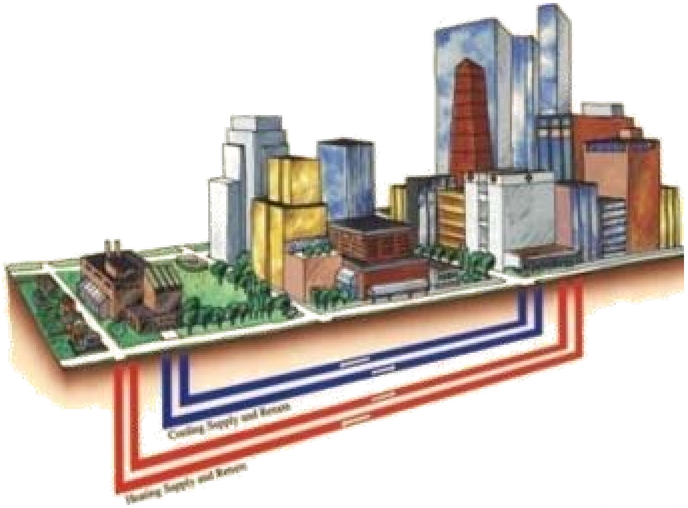
© by J.W. Tester, D.B. Fox and D. Sutter, Cornell University 2010



About 30% of US energy use occurs at temperatures < 160^{o}C and most of it comes from burning natural gas and oil

Framework for District Energy/CHP

- Underground thermal network of pipes "<u>combines</u>" heating and cooling requirements of multiple buildings
- Creates a "market" for valuable <u>thermal energy</u>
- Aggregated thermal loads creates <u>scale</u> to apply technologies not feasible on single-building basis



- District energy/CHP provides:
  - greater fuel flexibility
  - local grid support
  - increased fuel efficiency
  - reduced emissions
  - higher reliability
  - renewable/recycling energy (surplus heat)

Geothermal in the Eastern US – Challenges and Opportunities

- Lower grade Eastern geothermal resource leads to deeper, more costly developments.
- Lower rock temperatures will need to be utilized given lower gradients and high costs of drilling deep.
- Substantial economic barriers for generating electricity given the low 2ND law efficiencies of converting thermal energy into electric power at lower geofluid temperatures.
- Direct use and CHP provide attractive high utilization efficiency alternatives.
- Proximity to both high thermal and electric demand
- Small land use footprint of geothermal compared to other alternatives

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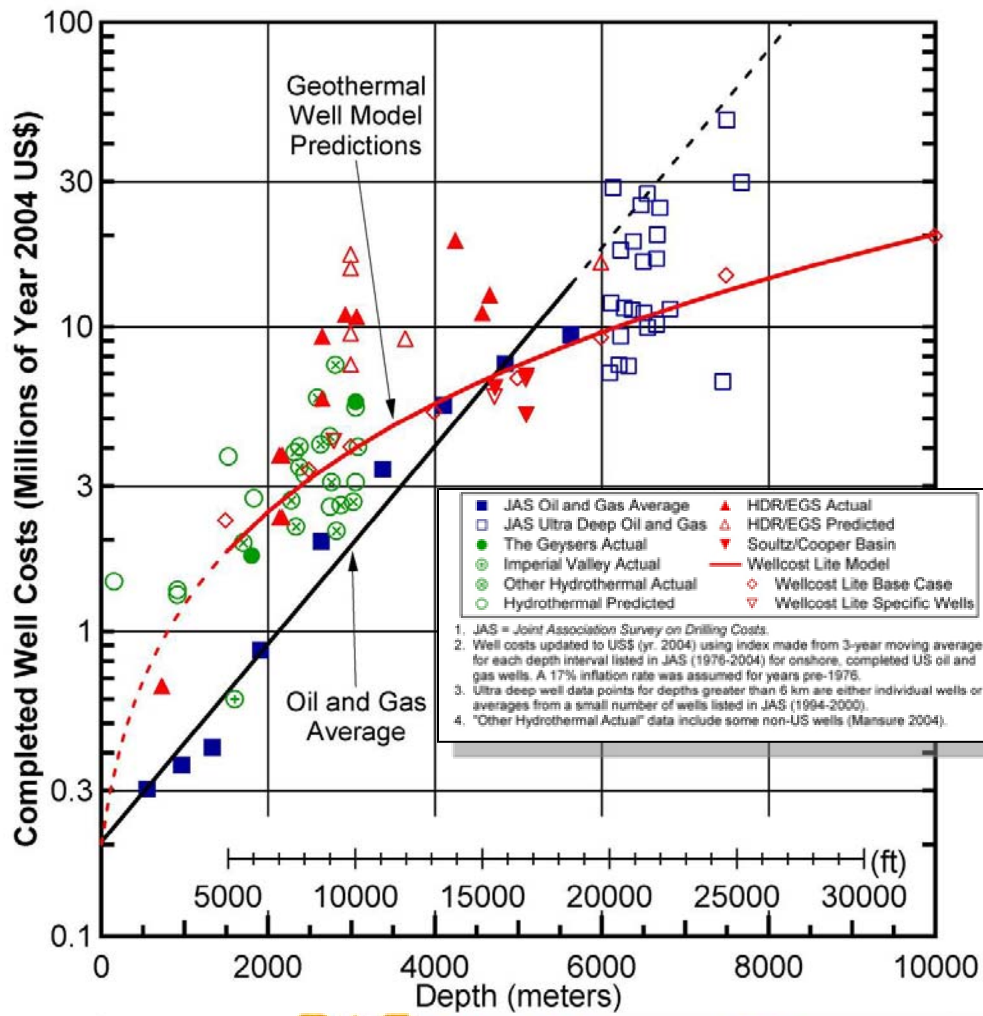
Economic modeling for utilization of low-grade geothermal

- Direct-use geothermal is able to capitalize on low-T resource
  - *T* = 110, 130, 150°C at
    2.5, 3.0, 3.5 km (40°C/km)
    3.4, 4.0, 4.7 km (30°C/km)
- Assuming \$300/kW_{th} for heat exchangers and piping
- Doublets (1 injector, 1 producer)
  - 2004 US\$ and 2·(2004 US\$)
  - 500 m separation
  - 7-inch diameter
- Debt/equity rates
  - 5%, 10%, 15%
  - 20-year project life
- Assume 80 kg/s in producer



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Economic Advantage of Direct-Use Geothermal

40°C/km Geothermal Gradient

- *T* = 110, 130, 150°C at 2.5, 3.0, 3.5 km
- Total costs include redrilling the reservoir

- 2004 US$ Drilling Costs/well
  - $3.5, $4.1, $4.7 million
- 2x2004 US$ Drilling Costs/well
  - $7.0, $8.2, $9.4 million

Electricity Production (¢/kWh)

	T (°C)	5%	10%	15%
2004 Drilling Costs	150	13	21	29
	130	24	40	55
	110	99	159	217

	T (°C)	5%	10%	15%
2X2004 Drilling Costs	150	18	31	42
	130	34	57	79
	110	135	228	315

District Heating ($/MMBtu)

	T (°C)	5%	10%	15%
2004 Drilling Costs	150	1.90	2.68	3.55
	130	2.12	2.93	3.85
	110	2.46	3.33	4.32

	T (°C)	5%	10%	15%
2X2004 Drilling Costs	150	2.75	4.06	5.54
	130	3.03	4.41	5.97
	110	3.45	4.95	6.64

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Economic Advantage of Direct-Use Geothermal

30°C/km Geothermal Gradient

- *T* = 110, 130, 150°C at
  3.3, 4.0, 4.7 km
- Total costs include redrilling the reservoir

- 2004 US$ Drilling Costs/well
  - $4.5, $6.0, $6.8 million
- 2x2004 US$ Drilling Costs/well
  - $9.0, $12.0, $13.6 million

Electricity Production (¢/kWh)

	T (oC)	5%	10%	15%
2004 Drilling Costs	150	15	24	34
	130	27	45	62
	110	103	[illegible]	[illegible]

	T (oC)	5%	[illegible]	[illegible]
2X2004 Drilling Costs	150	21	36	50
	130	39	67	93
	110	147	250	347

10/25/10 NYMEX
$3.30/MMBtu

District Heating ($/MMBtu)

	T (oC)	5%	10%	15%
2004 Drilling Costs	150	2.13	3.06	4.12
	130	2.44	3.33	4.44
	110	2.90	3.75	4.95

	T (oC)	5%	10%	15%
2X2004 Drilling Costs	150	3.24	4.88	6.72
	130	3.53	5.26	7.21
	110	3.98	5.85	7.96

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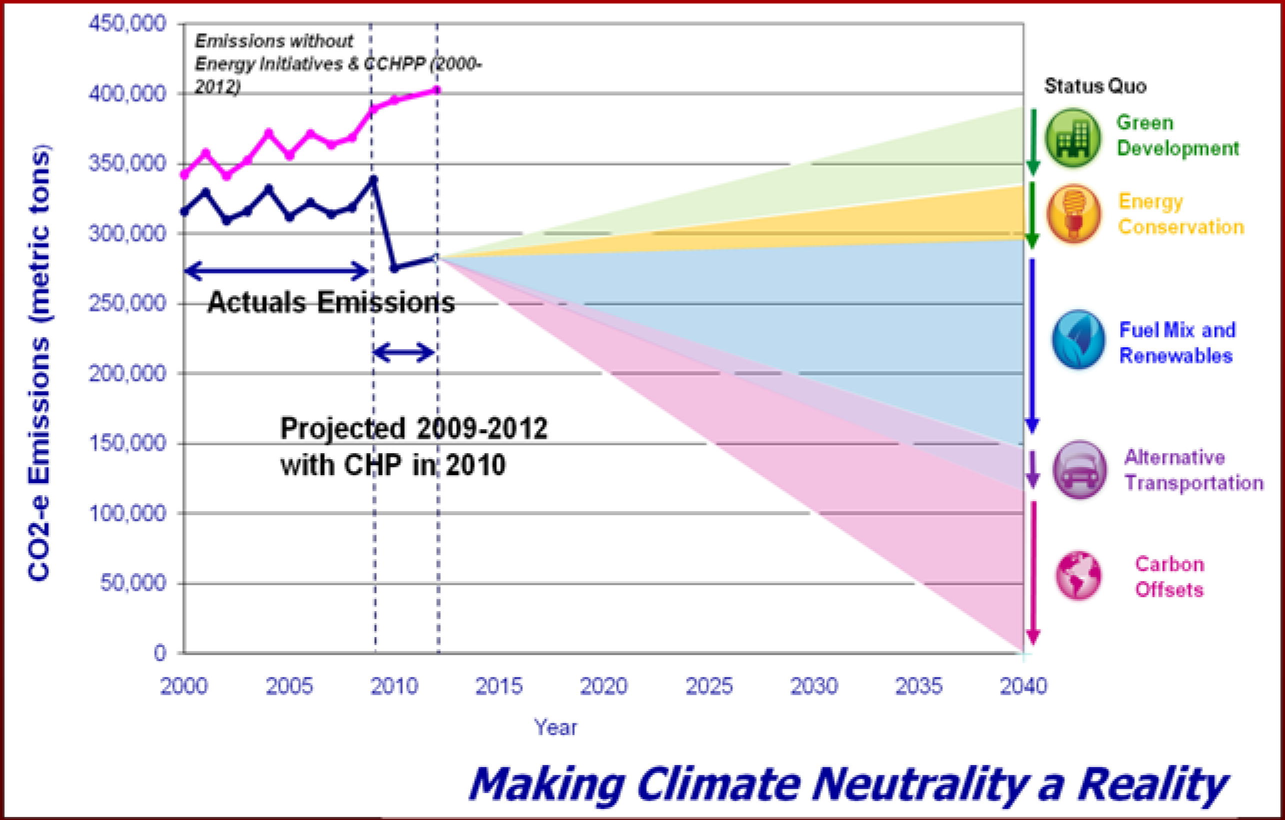
Cornell's transtion to a sustainable, low carbon energy future

Cornell Rises to the Challenge

Cornell Center for a Sustainable Future
www.ccsf.cornell.edu
and
Cornell Sustainable Campus
www.sustainablecampus.cornell.edu

Cornell's Approach includes:

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



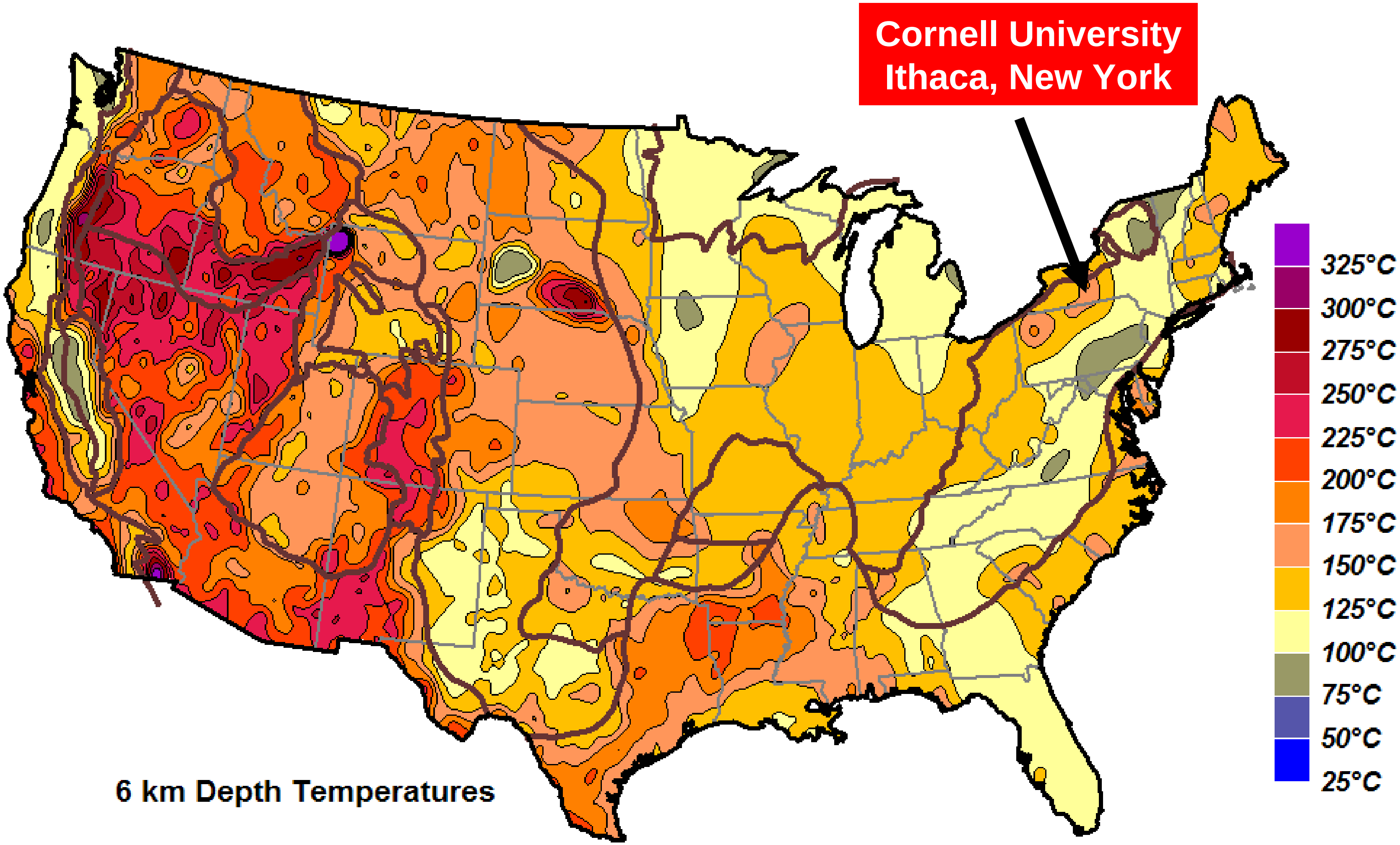
Transforming Cornell's Combined Heat & Power plant -- first from coal to gas to then to renewable energy sources

Extensive district energy infrastructure

Renewable Energy Options for Cornell's campus with 30,000 students, faculty and staff

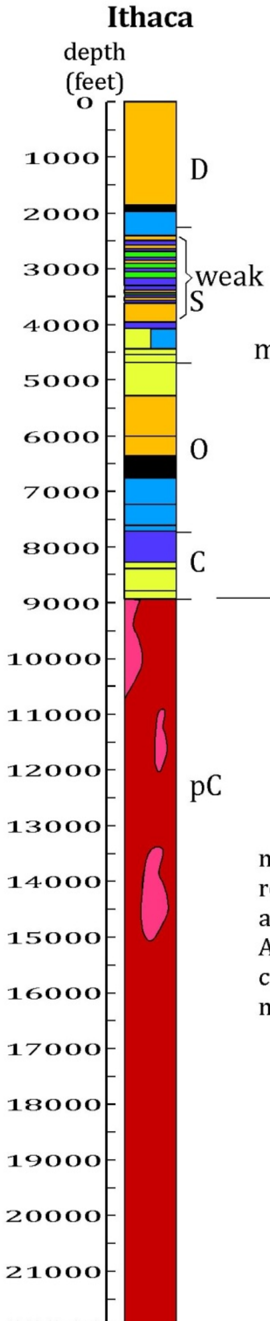
1. Lake source cooling implemented 10 yr ago
2. Cornell's hydro plant upgraded and operational
3. Solar not optimal for CHP at Cornell
4. Wind resource good - turbine siting faces issues
5. Biomass using Cornell's 14,000 acres of ag forest land
6. Geothermal of lower grade in the east -- useful for district heating

New York contains a large, representative region of higher Eastern heat flow



From Blackwell and Richards (June, 2007)

Geology -- Cover: 9,000 ft of Paleozoic Sedimentary Rocks and Basement: High grade metamorphic rocks in the Grenville province



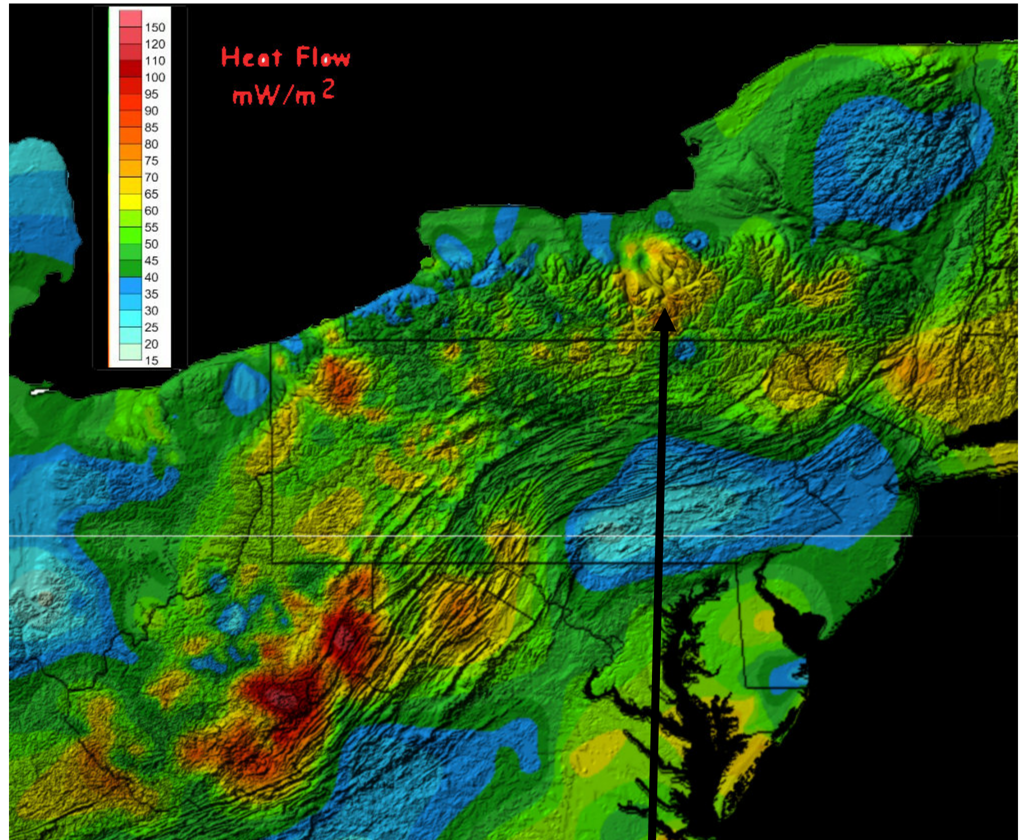
siliciclastic: sandstone, siltstone-shale, black shale
evaporite: halite
carbonate: limestone, dolomite
metamorphic: metasedimentary, granulite (charnockite)

D - Devonian
S - Silurian
O - Ordovician
C - Cambrian
pC - Precambrian basement

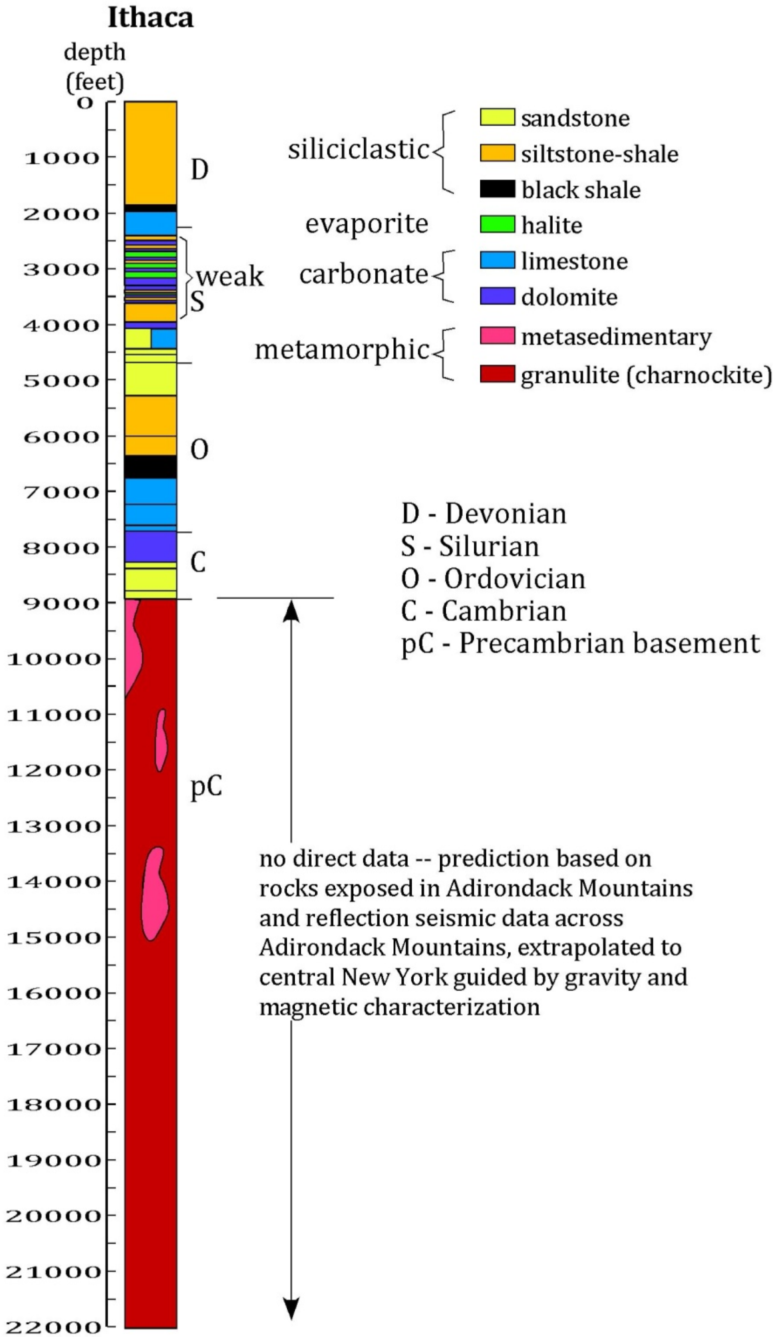
no direct data -- prediction based on rocks exposed in Adirondack Mountains and reflection seismic data across Adirondack Mountains, extrapolated to central New York guided by gravity and magnetic characterization

Ithaca underground to 22,000 ft

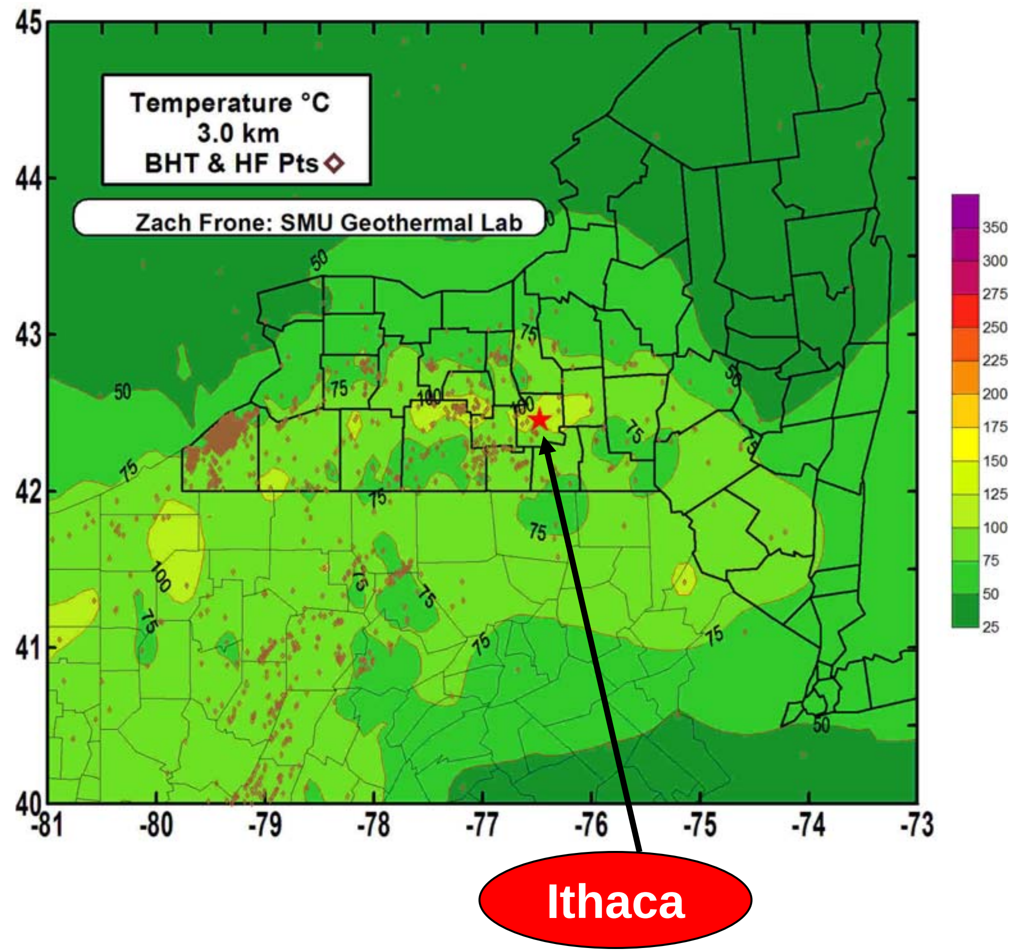
To reach rock at 120-200°C well depths of 10000 to 15000 ft are needed



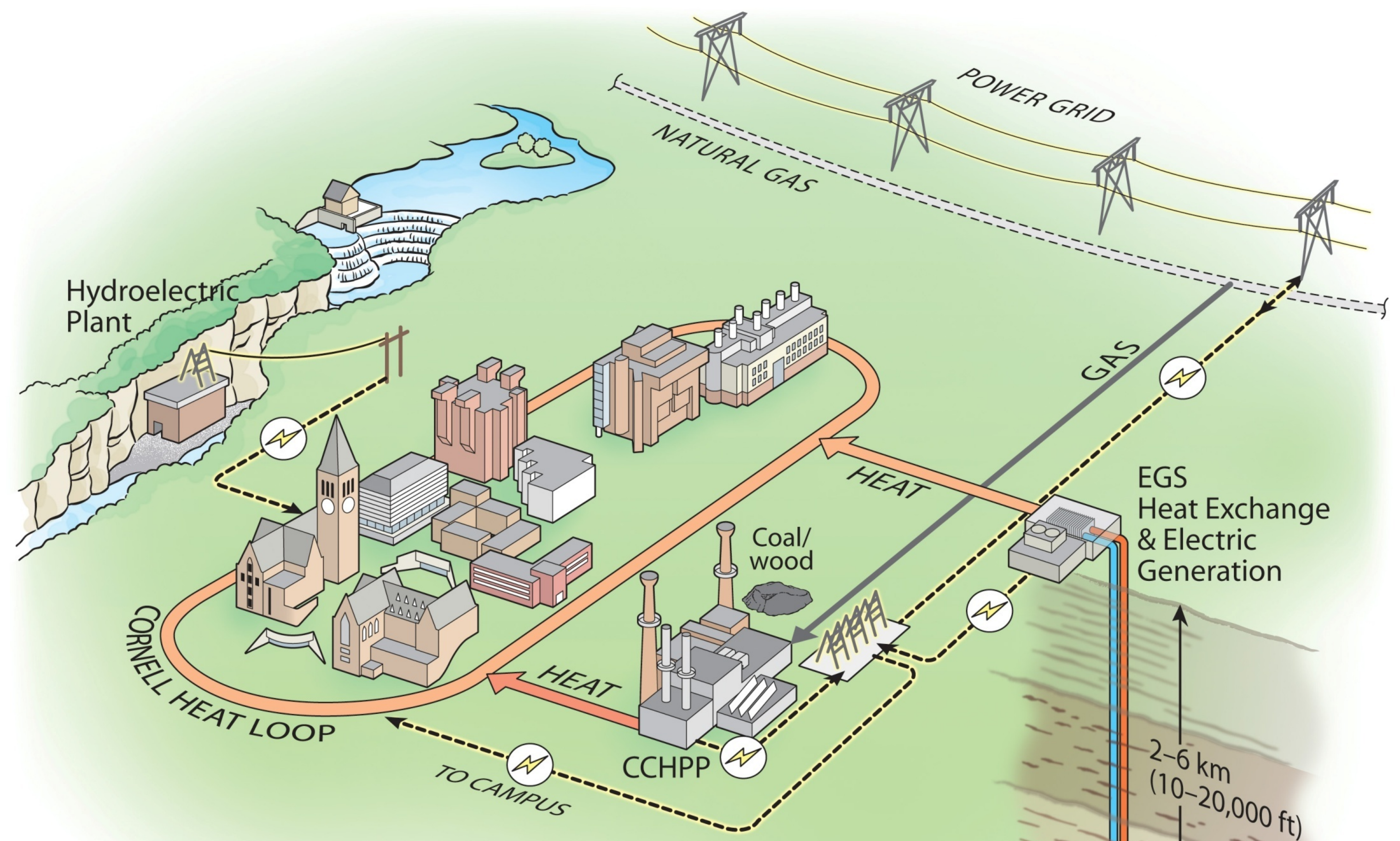
Ithaca



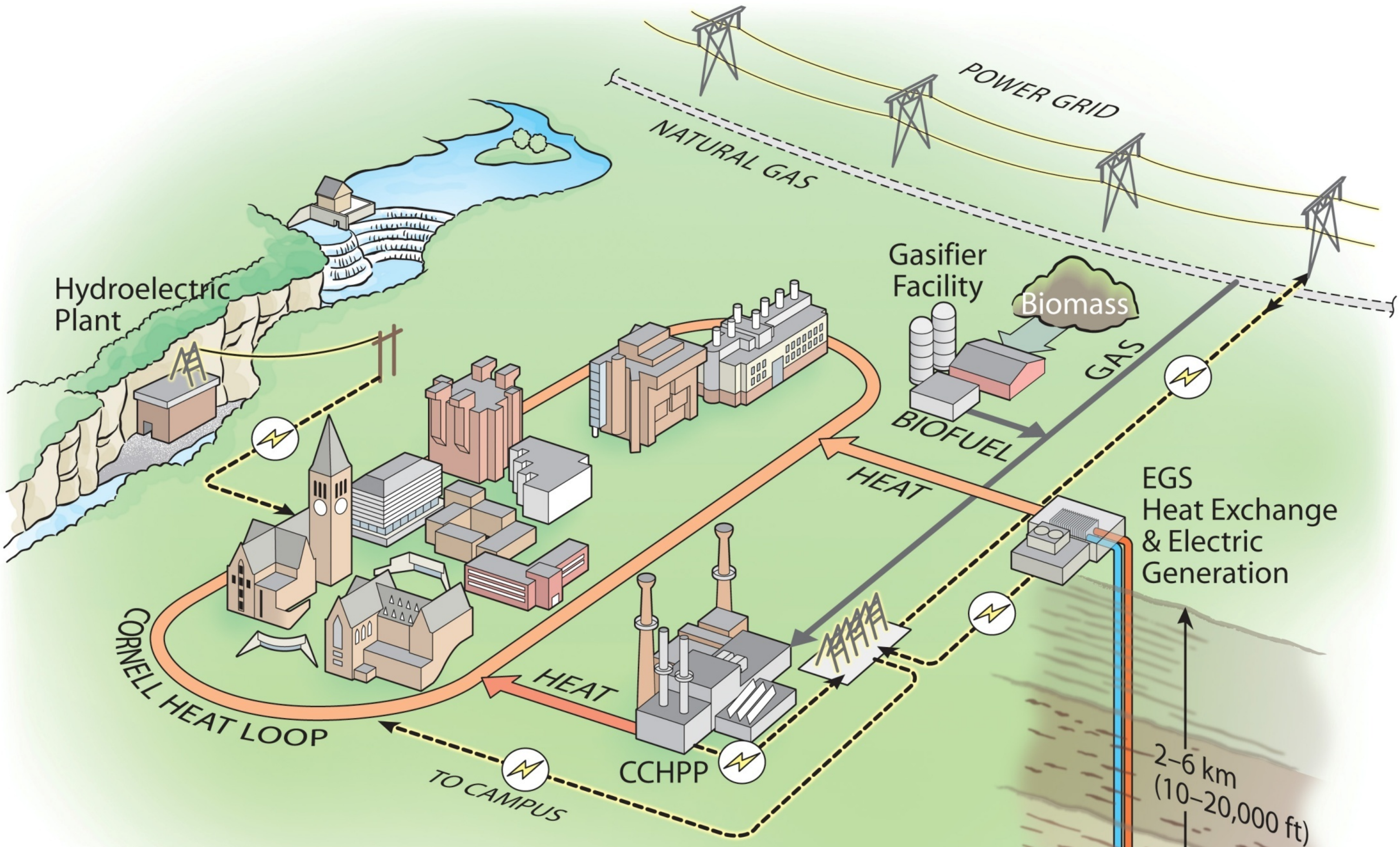
To reach rock at 120-200ºC well depths of 10000 to 15000 ft are needed



Source – Blackwell, Richards and Frone, SMU 2010



Integrating EGS Geothermal into Cornell's CCHPP



Integrating EGS Geothermal and Biogas into Cornell's CCHPP to achieve a zero carbon footprint

Cornell in Ithaca – Ideal site for demonstrating Low grade EGS technology in the Eastern US

- Higher heat flows than in other eastern sites.
- Ithaca location is representative of basement through much of the Eastern U.S.
- High heating demand, CHP plant, and district energy system for utilization of geothermal heat.
- Potential EGS sites on Cornell Property
- Significant drilling experience in region to ~ 3 km
- Considerable faculty expertise and interest in fields ranging from geology and engineering to social science relevant to meeting needs for research and community outreach
- Cornell's commitment to climate neutrality and the Climate Action Plan provides a teaching laboratory for workforce development.

Path Forward for a Geothermal Combined Heat and Power Demonstration at Cornell

Phase 1 Feasibility Study in Partnership with Ormat and Thermasource and NYSERDA

1. Detailed site assessment including subsurface geology, heat flows and gradients, seismic risk, water and land use, and infrastructure requirements
2. Exploratory drilling program design and plan
3. Regulatory oversight and permitting
4. Geothermal system design integrated into Cornell's district heating/distributed power supply from natural gas, biogas, hydro sources, and lake source cooling
5. ORC geothermal power plant design integrated into existing CCHPP for summer peaking use
6. Economic evaluation of drilling costs and power plant options

Thank you