Memo for Utilization Assessment

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Projected included members from Cornell University, Southern Methodist University, and West Virginia University.

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The Utilization effort for the Geothermal Play Fairway Analysis of the Appalachian Basin (GPFA-AB) included two broad types of data: 1) residential – community 'Places' and 2) site specific users with high heating demands such as universities, industrial users, government facilities, etc. to be considered as part of Phase 2. Below is a description of the data collected, and the programs used. For results and a discussion of the effort, see the Final Report for Phase 1 of the Low Temperature Geothermal Play Fairway Analysis for the Appalachian Basin, DOE Contract Award Number: DE-EE0006726.

The process for the GPFA-AB was primarily based on the previous research by students at Cornell University and West Virginia University. Below are main steps from this project and the last section includes the Chapter 3 details submitted by Tim Reber (2013) for his MS degree with every parameter described.

Steps in Determining the Surface Levelized Cost of Heat

The foundation source code used for the utilization risk assessment is the program GEOPHIRES, (GEOthermal Energy for Production of Electricity and Heat Economically Simulated). The software uses key data as input to calculate Levelized Cost of Heat (LCOH). Because we have characterized the subsurface as part of other tasks (thermal resources and natural reservoir quality), we modified GEOPHIRES to only focus on those remaining elements, which includes demand for heat as calculated from population and climate data, and the surface costs associated with delivering that heat to those in demand. Thus, in our implementation, the final output is a Surface Levelized Cost of Heat (SLCOH). The SLCOH includes the surface piping, heat exchange equipment (residential and/or commercial), operations, upfront capital cost, and maintenance costs over the lifetime of a 30 year project. A MATLAB[1] program serves as an interface between the Microsoft Excel files of collected input data and the GEOPHIRES program. The MATLAB code and Microsoft Excel files are included with the resulting data as part of the Catalog submission to the National Geothermal Data System (NGDS).

1. The U.S. Census Bureau maintains a database of information that includes state, county, and county subdivision, under the broader term 'Place.' A Place is used to identify all individual cities, towns, villages, boroughs, universities, and other Census-Designated Places (CDP's) defined as "settled concentrations of population that are identifiable by name but are not legally incorporated" (Census Bureau, 2012). The population and scope of a single Place may vary from the whole of New York City proper, with a population of over 8,000,000, to the smallest villages with populations as low as 10. In the New York, Pennsylvania, and West Virginia area we are using the 2010 Census data collection that includes 3,355 Places. These were downloaded via the FactFinder website (http://factfinder.census.gov).

2. Starting from the 3,355 places in New York, Pennsylvania, and West Virginia, using ESRI ArcGIS, the broader Place data were linked to their county and county subdivision. In order to complete this task, shapefiles of the Census Places and county subdivisions were loaded into ArcGIS. By using a spatial join and having the program find the Places within the county subdivision, this resulted in joining the attributes tables of the two files, allowing for the information for Places to have corresponding county subdivision data. Finally, all sites were checked and any places without a successful join had data manually added. This process was repeated to relate places with county information.

3. The place list was next limited to only those within this project's Appalachian Basin outline. We used the Golden Software program Mapviewer and ArcGIS for a comparison to confirm accuracy of locations within the project boundary. This reduced the number of possible Places for the project to 1,697.

4. To represent cooperation and coordination among smaller U.S. Census Places, which are generally townships or villages, we merged small places with their neighbors. Neighbors were determined by buffering around all of the U.S. Census Places polygons a distance of 50 m. Buffered polygons that intersected were neighbors. The small buffer was used because many of the places were quite close, but did not exactly share a border and this made neighbors for places that were within 100 m of each other. The U.S Census Places were sorted by population. Starting with the lowest population Place, it was checked to

[1] http://www.mathworks.com/products/matlab/

see if it had already been merged. If it had been merged, then no further action was taken for that place and the analysis moved to the next smallest Place. If the Place had not been merged, then we checked for neighbors. If there were neighbors, the Place was merged with all of its neighboring places. The analysis began again. If the Place had no neighbors, then the analysis continued to the next place. The merging stopped when all places below 10,000 population had already been merged or had no neighbors. Note that a Place was not merged multiple times. Below, these are referred to as "Cooperating Places" or, when the context is generic, simply as "places."

5. For this Play Fairway Analysis project, a minimum population threshold of 4,000 residents per Place or Cooperating Place was applied for all three states, to focus on those communities with a sufficient number of users to justify the initial capital investment associated with a district heating system. There were 1,442 Places with populations of less than 4,000, leaving the final number of Places for the SLCOH analysis to be 255. Thereafter, in order to have those Places and Cooperating Places with fewer than 4,000 people appear as red (unfavorable) on the final maps, they were assigned the same arbitrarily high SLCOH of $100/MMBTU. The actual input data associated with these places would lead to a different SLCOH and can still be calculated for future analyses as appropriate. The population threshold can be set as low as 1,500 residents per Place, and in doing so, makes the majority of the Places meet the criteria of good enough to consider. Although a positive outcome, we determined the 4,000 resident level for population of increased value in focusing the attention to sites most likely to be first users of this regionally new energy concept.

6. The next parameter is the building density and heating demand per building (i.e. detached single-family, attached single-family, 2 unit buildings, 3-4 unit buildings, 5-9 unit buildings, 10-19 unit buildings, 20-49 unit buildings, and 50+ unit buildings). These detailed data are included within the Census Factfinder under "American Community Survey" using the 2010 5-year estimates and code B25024, representing the number and type of housing units per residential building category. The Energy Information Agency (EIA) performs a Residential Energy Consumption Survey (2009) that we used to determine average square footage of each designated unit and related heating load on a Census region basis.

7. Within many Places are commercial buildings, which can be put into 12 categories: 1) Accommodation, 2) Food, & Other Services, 3) Administrative and Waste Management and Remediation Services, 4) Arts, Entertainment, and Recreation, 5) Educational Services, 6) Health Care & Social Assistance, 7) Information Geographic Area Series, 7) Manufacturing, 8) Other Services, 9) Professional Scientific & Technical Services, 10) Real Estate & Rental and Leasing, 11) Retail Trade, and 12) Wholesale Trade.

a. In order to determine the heating loads for commercial sites within our Place dataset, we combined the energy consumption for building types, the square footage of a building, and the type of commercial application based on the 12 categories above. Three datasets were used: the EIA manufacturing *energy consumption* data (http://www.eia.gov/consumption/manufacturing/), the EIA's 2006 report of Commercial Buildings Energy Consumption Survey (CBECS) for the *floor space*, and the US Factfinder 2007 'Economic Data' for categories.

b. From these files, the number of establishments and number of employees were collected for each "economic place". Unfortunately, the term "economic place" did not equate to that of the census definition of Place. The "economic place" can be related to the census classification of "county subdivision", which we did have linked to each Place. Following the methodology of (Reber, 2013) and Tester et al. (2015), in the instance where a single "county subdivision" (i.e. "economic place") contained multiple Places (typically around metropolitan areas) the data on commercial establishments for that county subdivision was divided amongst the Places within that county subdivision based on the relative population of each Place. In addition, due to the potentially identifiable nature of the reported economic data, some employment sizes were represented by a letter which stood for a range of values (ex. "A" meant an establishment had less than 20 employees, "B" meant an establishment may have between 20 to 99 employees, "C" means 100 to 249 employees, etc.). For these sites, the average of the range rounded up to the next integer was used for the model (ex. "A" would have 10 employees, "B" would have 60 employees, "C" would have 175 employees, etc.). This allowed for the MATLAB/GEOPHIRES model to have a numerical value to perform the calculations.

8. Another dataset included was the location of roads (Road shapefiles from the TIGER dataset). The total length of roads within each Place was used as a method to estimate the required piping length required to service a given location (Reber, 2013) and Tester et al. (2015). Based on Reber's conclusions, the GEOPHIRES program uses 75% road coverage to provide adequate piping density required to reach all buildings for geothermal district heating system.

9. The MATLAB script estimated the cost of a system for a lifetime of thirty years. The program uses a fixed annual charge rate (FACR), which allows the user to specify several factors, including discount rates. As reported by Shaalan (2001), this annual fixed-charge rate "represents the average or 'levelized' annual carrying charges including interest or return on the installed capital, depreciation or return of the capital, tax expense, and insurance expense associated with the installation of a particular generating unit"

(Shaalan, 2001). A FACR of 6% was used for this Play Fairway Analysis effort. According to the U.S. Department of Commerce it calculated an effective discount rate of 3% in 2011 for Federal and Public energy projects. Therefore 1% was also added to this value, resulting in a discount rate of 4% applied to SLCOH.

10. The GEOPHIRES result output of SLCOH is a spreadsheet (.csv format). The output was grouped by state and then sorted based on the population size and the resulting SLCOH in the units of dollars per one million BTU (British Thermal Unit). $/MMBTU. For all Places with a population of less than 4000 the SLCOH was assigned an arbitrary but high value of $100/MMBTU. This allows us to continue to keep smaller communities in the workflow as we get ready for Phase 2. We will be able to improve our cost estimates for the entire Place list, since the GEOPHIRES and MATLAB programs allow updates for a few or many sites with the same amount of effort.

For the resulting 255 Places assessed, the best case (least expensive SLCOH) is 7 $/MMBTU and the highest (most expensive SLCOH) is 65 $/MMBTU. The Places were differentiated into three thresholds with the best case scenario for the SLCOH between $7 and $13.5, good between $13.5 and $16, and low or unlikely potential as $16 to $25 SLCOH. Among the 255 Places, Table 1 shows the distribution of the 236 Places whose SLCOH is less than or equal to $25. In addition, there were 1,449 places assigned an SLCOH of $100 because of low population (< 4000 people).

Table 1: Distribution of 255 Census Places and Cooperating Places over 4,000 in population within the Appalachian Basin for NY, PA, and WV based on a three color ranking of the calculated Surface Levelized Cost of Heat (SLCOH).

State	Best Case (Green) $5 – $13.5/ MMBTU SLCOH	Good (Yellow) $13.5 - $16/ MMBTU SLCOH	Unlikely (Red) $16 - $25/ MMBTU SLCOH
New York	30	27	30
Pennsylvania	37	52	27
West Virginia	21	10	2

A second set of values were assigned for the five-threshold risk assessment. Here the values were $5 to $12 (green - best), $12 to $13.5 (greenish yellow), $13.5 to $16 (yellow), $16 to $20 (orange) and $20+ (red - worst). The level of detail in this Phase 1 project does not provide enough site knowledge, even at the Place level, to assign increased levels of significance in the dollar amounts for the SLCOH. These were developed for the consistency of the combined risk task input files (see Catalog for the Combining Risk Factors Memo).

Error estimates for the Utilization risk factor were not calculated. Rather for the level of detail of Phase 1, the entire area is given a uniform uncertainty of approximately 5% based on changes in population and cost.

Steps for Inclusion of Site Specific Industrial Sites

In addition to the US Census 'Place' areas, this project researched low-temperature direct use geothermal energy applications for numerous industries, including aquaculture, green houses, and food processing such as dehydration and dairy processing (Lienau, et al., 1994). For the Appalachian Basin region and the anticipated temperatures at depths shallower than 3 km, potential users of the geothermal heat occur in the following industry categories: paper mills, wood drying kilns, dairy processing (includes yogurt and milk pasteurization products), college and university campuses, and select military locations. Typical temperature ranges for these applications are listed in Table 2.

Table 2: Site-Specific industries of interest and required temperature ranges.

Industry	Temperature Range
Dairy	Butter/Yogurt production 80 – 90 °C Traditional pasteurization 72 – 75 °C
Wood Drying	43 – 82 °C
Paper/Pulp Mills	66 - 150 °C
University/College Campus	100 - 150 °C
Military Bases/Stations	100 - 150 °C

Each industrial site was located using a Google Map search for each category, except for the locations of the diary processing sites found on the Dairy Plants USA website. All of these potential industrial users have a component of their process(es), which could benefit from incorporating a geothermal element into their system, either by preheating or reducing electrically heated steps.

References

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Detailed documentation of the MATLAB implementation of this model is available from:

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