Green Jobs Through Geothermal Energy

GEA
GEOTHERMAL ENERGY ASSOCIATION

October 2010

Green Jobs Through Geothermal Energy

By Dan Jennejohn

GEOTHERMAL ENERGY ASSOCIATION

209 Pennsylvania Avenue SE, Washington, D.C. 20003 U.S.A.
Phone: (202) 454-5261 Fax: (202) 454-5265
Web Site: www.geo-energy.org

October 2010

Acknowledgements

The Geothermal Energy Association (GEA) would like to acknowledge and express appreciation to the following people and organizations for their assistance and input in preparing and reviewing this report: John Pritchett, SAIC; Lou Capuano, Patrick Hanson, ThermaSource LLC; Kermit Witherbee, US Bureau of Land Management; Jim Faulds, University of Nevada, Reno; Curt Rich, Emily DeSantis, Pratt & Whitney Power Systems; Dan Fleischmann, Ormat Technologies; Kelsey Walker, Halley Dickey, Turbine Air Systems; Brian Fairbank, Nevada Geothermal Power, Inc.; Marshall Ralph, Bill Lewis, Power Engineers; as well as Industrial Cooling Systems, and Joel Renner,.

In addition to those people listed above, the author would like to acknowledge and thank Karl Gawell, Alison Holm, Leslie Blodgett, Kathy Kent, John McCaull, and Daniela Antonescu of GEA for their valuable input and support.

Cover Photo courtesy of Raser Technologies.

GEA
GEOTHERMAL ENERGY ASSOCIATION

Table of Contents

GEA
GEOTHERMAL ENERGY ASSOCIATION

1. Introduction and Background

The Geothermal Energy Association (GEA) is often asked: How many jobs will a new geothermal power plant create? What kind of jobs? Where? When? These questions are being asked about all new energy technologies. The answers you read about job creation can be confusing. Driving past an operating geothermal power plant, one would see few actual employees despite claims of thousands of new jobs being created through geothermal development! In this report the GEA breaks down the numbers that the industry uses in job generation statements, and provides a picture of the nearly one thousand people whose jobs are involved in a typical geothermal project.

1.2 Basic Findings from Previous GEA Analysis

GEA's *A Handbook on the Externalities, Employment, and Economics of Geothermal Energy* addresses some basic questions regarding geothermal energy jobs. This report was based on a detailed survey of the geothermal industry, also conducted by GEA: *Assessing total workforce involved in the Geothermal Industry: Employment Survey Results & Analysis,* completed in 2005. Both the report and the survey address topics related to employment in the geothermal industry such as current levels of employment, comparative industry employment, types of jobs, job quality, rural employment, and future job potential.

1.2.1 Commonly Used Terms

Employment levels and trends in any industry have their own lexicon. In order to better understand some of the findings presented in this and GEA's previous employment studies, a brief definition of some basic terms are provided.

Direct employment

Direct jobs are those associated with the construction and maintenance of geothermal power plants. During the construction phase, direct employment corresponds to the total jobs associated with power plant construction. During the operation and maintenance phase, it relates to all jobs associated with power plant operation and maintenance.

Direct jobs are not, however, all on the payroll of the company who is building or operating the power plants. A significant number of these jobs will be accounted for by contractors and subcontractors, particularly at the construction and manufacturing

stages. Of course, some companies may be vertically integrated with "in-house" operations, but most will contract out for many services related to exploration, drilling, construction and manufacturing.

Even for more permanent jobs, such as power plant operation and maintenance, this proves the rule. The GEA employment survey noted earlier found that subcontractors typically represent about 42% of the power plant operator's own workforce and 30% of total employment involved in power plant operation and maintenance (O&M).[i]

Indirect employment

Indirect employment refers to the jobs that are created in all the industries that provide goods and services to the companies involved in power plant construction or operation and maintenance. A drill rig, for example, might require 20 rig hands for its direct operation, but, according to the American Petroleum Institute, as many as 120 jobs may be required to support its operation.[ii] This larger number is comprised of direct AND indirect jobs, of which the latter are typically subcontracted out to other vendors and are necessary to support all activities of the drilling operation. The range of indirect jobs throughout all aspects of resource development is extensive, and would include government regulators, lawyers, architects, equipment service personnel, geologists, business management personnel, security guards, and many more.

Induced employment

Increased economic activity in a region with new direct and indirect jobs means additional new jobs that may not be directly related to the geothermal industry but are supported by it. Induced employment refers to jobs that are created to serve the workers, subcontractors and others that are counted in direct or indirect employment.

1.2.2 Methodology

The direct jobs for geothermal projects were identified and accounted for by GEA as part of its examination of industry data, responses to a detailed survey, and other direct methods. Indirect and induced impacts were calculated with "input-output models" that provide a comprehensive picture of the economy considered. The result was an estimate of jobs that would identify the number of full-time jobs created per megawatt of geothermal capacity added, and the number of person-years of manufacturing or construction jobs created. Since manufacturing and construction jobs are not permanent, the use of person-years expresses the jobs in terms of employment on a full-time basis equivalent for one year. While construction and manufacturing jobs are expressed as full-time positions for one year (person-years), these jobs will be spread

out over several years depending upon the development time frame for new projects and may aggregate partial jobs.

The GEA analysis was widely reviewed by industry, academic, and government experts, and a more complete discussion of this process is presented in the two reports noted previously. Some of its major findings were:

- Direct employment results in 1.7 full time positions and 6.4 person*years per megawatt.

- Induced and indirect impacts were calculated assuming a multiplier of 2.5; for a total direct, indirect, and induced employment impact of 4.25 full-time positions and 16 person*years per megawatt.

These employment factors are broad industry averages, and employment at individual projects or companies may vary considerably.

1.2.3 Current Employment

Geothermal energy supports and generates a significant number of jobs when compared to other energy technologies. On a per megawatt basis, geothermal energy provides more jobs than natural gas as shown in Table 1 below.[iii]

Table 1: Comparative Job Creation

Power Source	Construction Employment (jobs/MW)	O&M Employment (jobs/MW)	Total Employment for 500 MW Capacity (person-years)
Geothermal	4.0	1.7	27,050
Natural Gas	1.0	0.1	2,460

Source: US DOE[iv]

The ability of geothermal energy to employ relatively high numbers of workers has enabled it to grow a diverse and expanding workforce. Using the employment factors at the end of section 1.2.2, GEA estimates that the industry currently supports approximately 5,200 direct jobs related to power production and management, while the total direct, indirect, and induced impact[v] of geothermal energy is approximately 13,100 full-time jobs.[vi] Employment is expected to increase in coming years as geothermal plant development and research expands. In the remaining months of 2010 and throughout 2011 GEA estimates that up to 660 MW of geothermal projects under development will enter stages of steamfield (production and injection drilling) and/or

power plant construction. The total direct, indirect and induced impact of these advanced geothermal projects would represent up to 2,805 full-time jobs.

1.2.4 Job Quality

Not only does geothermal energy provide more jobs than conventional energy technologies, it also provides quality, long-term jobs. According to the EIS/EIR for the proposed Telephone Flat geothermal development project located in the Glass Mountain Known Geothermal Resource Area in California, the average wage at the facility will be more than double the average wage in surrounding counties. According to the U.S. Census Bureau, the average per capita income in 1999 in the closest counties was around $21,000, with the average California per capita income nearly $2,000 higher.[vii] The average projected wage related to operation at the Telephone Flat facility would be higher than both the county and state averages, totaling between $40,000 and $50,000 (1998 $).[viii]

In addition to providing high average-wage jobs geothermal energy supports long-term employment. Geothermal developers, who typically negotiate 10- to 30-year agreements with purchasers, provide jobs that can be guaranteed for decades. The overwhelming majority of geothermal jobs are permanent (95%), and most are also full-time.[ix]

1.2.5 Rural Employment

Geothermal resources tend to be located in rural areas and require the support of the local workforce. For example, of the staff employed directly by one company at the Geysers Geothermal Complex in California, 425 full-time and 225 part-time employees are residents of the local community.[x] Rural communities face many unique challenges. The lack of stable, secure, long-term jobs in rural communities leads many young adults with "the most education and the greatest earning potential" to emigrate, leaving a poorer, older, and smaller population.[xi] Many rural communities, including those in which geothermal facilities tend to be located, suffer from significantly higher unemployment rates than the general population. In 2004, California's unemployment rate was 6.2%, but Siskiyou County, near the proposed Telephone Flat geothermal power plant, had an unemployment rate of 9.3%, more than one-third higher than the California average.[xii] The Center for Mental Health Services (CMHS) found that "many rural Americans are at or below the national poverty level."[xiii] Unemployment in rural communities makes residents particularly susceptible to high levels of social and health-related problems—more so than their urban counterparts.[xiv]

The development of geothermal resources provides not only income for rural communities but also a means by which to educate, train, and employ a diverse workforce. Rural communities tend to focus on a single source of revenue, such as manufacturing or agriculture, which can contribute to unemployment and economic instability. Geothermal offers a means of diversifying the economic base of local communities, thereby building on and sustaining established economies while attracting new business.[xv] Such diversification is a direct indicator of economic stability.[xvi]

1.2.6 Types of Jobs Created

The development of geothermal resources provides long-term income for people with a diversity of job skills. This includes welders; mechanics; pipe fitters; plumbers; machinists; electricians; carpenters; construction and drilling equipment operators; surveyors; architects and designers; geologists; hydrologists; electrical, mechanical, and structural engineers; HVAC technicians; food processing specialists; aquaculture and horticulture specialists; managers; attorneys; regulatory and environmental consultants; accountants; computer technicians; resort managers; spa developers; researchers; and government employees who all play an important role in bringing geothermal energy online.

While many of the types of jobs mentioned here are directly involved in developing a geothermal resource, growth in many of the industry's "behind-the-scenes" sectors has been picking up. The increase in on-line geothermal capacity over the last ten years has similarly spurred growth in geothermal research and development activity by academic and government institutions. While it is currently unclear precisely how many additional jobs have been created in these sectors as a result of geothermal growth, it is apparent that more and more people are becoming involved in areas beyond direct power plant development. A Federal Interagency Geothermal Working Group, for example, is composed of 13 representatives from various offices within six government agencies. Also significant are the numerous colleges and universities around the country that are engaging in geothermal-related research extending from geological assessment to Enhanced Geothermal System (EGS) development. The jobs involved in these areas are not within the scope of this report, but the increased attention being paid to geothermal energy in stages prior to and outside of resource development and construction are important to consider in characterizing geothermal employment.

In short, the development of geothermal resources requires the support of many skilled laborers and professionals from different sectors and during different stages of resource development. Section 2: Green *Jobs in Geothermal Resource Development,* will give a more extensive discussion of the wide range of jobs involved in a geothermal power project.

1.3 Future Potential and New GEA Analysis

The development of geothermal energy resources has the potential to generate and support numerous “green jobs” in the US. Geothermal projects that are currently in advanced stages of development in the states of Nevada, California, and Utah alone have the potential to create more than 2,500 permanent full-time positions and nearly 10,000 annual construction jobs. However, numbers don't always tell the complete story regarding the many and diverse jobs supported throughout the development of a geothermal resource. Section 2 will endeavor to walk through a geothermal project from start to finish, and will discuss both the types of jobs and the number of people involved at each stage in the development process. The information gathered by GEA for this analysis indicates that one typical 50-MW geothermal power plant can involve up to 860 different people with a wide range of skills over its development cycle. Some of these jobs will be "on-site" where the power plant is located, others can be in nearby major cities, and others can be found in manufacturing plants hundreds of miles from the actual geothermal resource.

2. Green Jobs Through Geothermal Development

The development of geothermal energy resources has the potential to generate and support numerous "green jobs" in the US. Geothermal projects that are currently in advanced stages of development in the states of Nevada, California, and Utah alone have the potential to create more than 2,500 permanent full-time positions and nearly 10,000 annual construction jobs using employment calculation methodology developed as part of the Western Governors Associations Geothermal Task Force Report.

The large number of jobs involved in the development of geothermal projects is not always obvious. Plant operation displays only a small fraction of the employment supported through developing geothermal resources. The road to completion of a plant begins well before construction, is comprised of many different stages, and requires the contribution and support of employees from a wide variety of backgrounds. Degreed professionals such as engineers, geologists, and geophysicists play an important role throughout resource development and operation. Technical "green collar" laborers such as drill rig operators, welders, mechanics, and safety managers are integral to the development of geothermal resources. An additional workforce of professionals such as lawyers, project managers, archeologists, sales people, assembly workers, and administrative staff work behind the scenes to support the development of renewable geothermal resources.

This section examines the phases in the development of a typical geothermal power project and identifies the many different types of workers who are involved. While this is not a quantitative analysis of the type prepared for the Geothermal Task Force Report, it is intended to show the broad range of different jobs involved in a geothermal. Today, a typical geothermal project can involve approximately 860 different workers.

Table 2: Jobs Involved in Geothermal Development (50 MW)

Stage of Development	No. of jobs
Start-up	10 – 13
Exploration	11 – 22
Drilling	91 – 116
Plant Design and Construction (EPC)	383 – 489
Operation and Maintenance	10 – 25
Power Plant System Manufacturing	192 – 197
Total	**697 – 862**

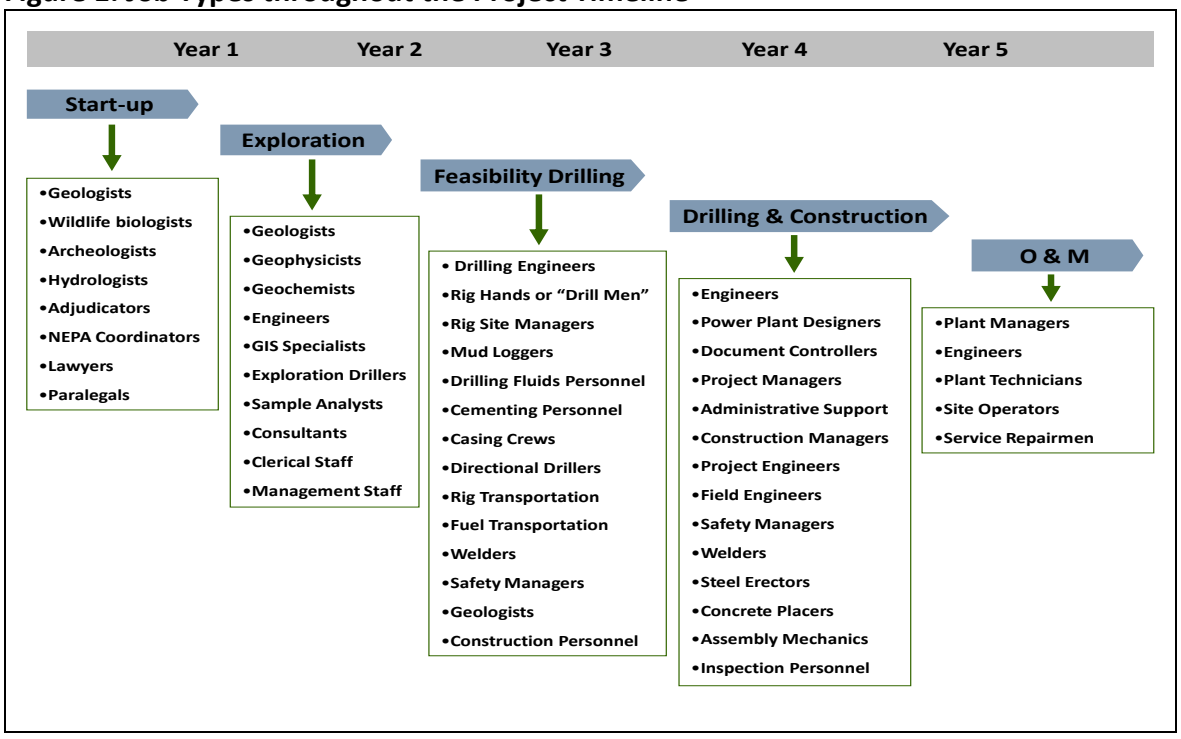
Source: GEA

2.1 Job Generation Throughout the Development Timeline

Currently, the US leads the world in installed geothermal capacity with approximately 3086 MW of geothermal power on line.[xvii] While this number is large, the vast majority of geothermal resources in the US remain undeveloped. In 2008 the US Geological Survey (USGS) estimated that potentially 73,286 MW of unidentified and 16,457 MW of identified conventional hydrothermal geothermal resources remain undeveloped in the US. When also including the development potential of enhanced geothermal systems (EGS) this number significantly increases.[xviii]

The development of US geothermal energy resources not only means the increased use of clean, baseload renewable energy to offset fossil fuel use in electricity production, but it also provides another important benefit: green jobs. The development of a geothermal resource is a significant undertaking requiring the input of degreed and technical professionals as well as the work and support of numerous green-collar workers. Many of the jobs supported during geothermal resource development play their most prominent roles in specific phases of the resource development timeline.

Figure 1: Job Types throughout the Project Timeline



Source: GEA

While a particular job may be featured during early or latter stages of resource development, it is evident that harnessing US geothermal resources will not only

support a large number of jobs, but will also support a large variety of jobs requiring professionals with different skills and educational backgrounds.

2.2 Project Start-Up

Before the exploration of a geothermal resource can begin, a flurry of preparatory activity occurs. A large portion of the work done at this start-up phase of geothermal development stems from working with state and federal permitting offices.

Approximately 248,672,710 acres of public lands in the Western US are areas of identified geothermal potential.[xix] If a developer suspects that a commercially viable resource exists in a publicly owned area, the developer must first obtain a geothermal lease from the US Bureau of Land Management (BLM).

The process by which a geothermal developer nominates and obtains a geothermal lease from the BLM can be relatively lengthy and involved. Normally, a nomination is filed with the BLM and enters a review process. The review can include, among other things, an environmental analysis of the impact of development on the proposed lease area, and can also permit future activities, such as drilling. Usually a team of 8 to 10 BLM staff will be involved in processing permits for geothermal development. This team is typically made up of geologists, wildlife biologists, hydrologists, archeologists, adjudicators, NEPA coordinators, and wildlife specialists. In addition to the BLM staff supporting the leasing and permitting process, the developer will also have 2 to 3 staff people involved in permitting. It should be noted that if any nominated land is located within a national forest, it is sent to the National Forest Service (NFS) for review. The NFS would utilize approximately the same number of professionals as the BLM.

The team of 8 to 10 BLM staff selected to facilitate the early leasing and permitting processes surrounding the development of a geothermal resource will continue to work on other permits (i.e. production well drilling and power plant permits) associated with the project as development progresses. Additionally, planning and building transmission connecting the project to the grid requires a right-of-way, which requires both the developer and the BLM to have their own realty staff of lawyers and paralegals working to aid in transmission permitting and planning.[xx]

While a large portion of geothermal projects in the Western US are located on federal land, there is a significant potential for geothermal development on state and private lands. Although BLM employees do not process and permit privately managed land, professionals involved in these types of geothermal developments include real estate professionals, title companies, land-men, and legal support. Whether located on public

or private land, state and local governments perform their own permitting activities similar to those of the BLM.[xxi]

2.3 Exploration

Prior to initiating subsurface development of a geothermal reservoir, a developer will conduct a series of geothermal exploration activities in order to improve the chances of drilling successful production wells. Exploration activities may include airborne, geological, geochemical, and geophysical surveys. The drilling of temperature gradient wells, core drilling, or other drilling operations are examples of other exploration activities. The variety of skilled professionals and laborers needed to support geothermal exploration activities is summed up in Table3.

The exploration of a geothermal resource requires the expertise of professionals with both undergraduate and advanced degrees in geology, geophysics, geochemistry, engineering, and geographic information systems (GIS). The work also calls for the technical expertise of green-collar workers to support exploration drilling and the gathering of geophysical data.

Consulting and management professionals are also needed to support development efforts. At least one to two consultants from an outside company will usually be contracted by a developer to review and provide a professional assessment of geothermal exploration data.

Table 3: Jobs Types Involved in Geothermal Exploration

Job Title	Educational Background	Number Employed
Geologist	Grad. Level	1 – 2
Geophysicist	Grad. Level	1 – 2
Crew to Gather Data	Undergrad. Level, Technical	2 – 5
Geochemist	Grad. Level	1
GIS Specialist	Grad Level, Technical	1
Exploration Driller	Undergrad.-Grad. Level, Technical	3 – 7
Sample Analyst	Grad. Level	1 – 2
Consultants	Grad Level	1 – 2
Estimated Total		**11 – 22**

Source: GEA, UNR

Federal agency staff also play an integral role in permitting certain exploration activities as well as facilitating environmental assessments. Additionally, clerical staff and professional management from the development company are involved in geothermal exploration, the preparation of environmental assessments, and permitting.

While difficult to quantify, it is important to note the potential of geothermal exploration and development to positively impact the growth and support of indirect jobs in areas proximal to geothermal resources. Most geothermal resources are located in rural areas and the presence of geothermal exploration and development teams in these communities can significantly boost local economies. This can be especially important in rural areas where economic activity tends to be seasonal.[xxii]

2.4 Drilling

Once sufficient evidence has been amassed to indicate that a geothermal resource is commercially viable, a developer will begin drilling production wells. Usually, the developer will hire a company that specializes in drilling geothermal wells to begin the subsurface development of the targeted geothermal field. The drilling of a geothermal well is a complex and multi-faceted process requiring the support of multiple teams of specialized personnel such as engineers, geologists, welders, rig hands, cementing personnel, and drilling fluids personnel as well as site and safety managers (see Table 4). In short, the complexity of a geothermal drilling operation requires a large number of people from different educational and technical backgrounds.

Table 4: Jobs Types Involved in Geothermal Drilling

Job Title	Description	Number Employed
Drilling Engineer	Support on-site well drilling	2 – 3
Rig Hands or "Drill Men"	Operate geothermal drilling rig	15 – 20
Rig Site Manager	Manage drilling operations	1 – 2
Mud Logger	Sample and analyze fluid and rock cuttings from the wellbore	2 – 4
Drilling Fluids Personnel	Ensure the continual flow of drilling fluids into and out of the well	2 – 4
Cementing Personnel	Cement metal casings in place within the wellbore	6 – 10
Safety Manager	Ensure the safe operation and management of both the drill rig and employees	1
Welder	Weld equipment at drill site	3
Estimated Total		**32 – 47**

Source: GEA, ThermaSource

Table 4 outlines the job types involved in the construction of a single geothermal well, often employed directly by the drilling company. Additional supporting jobs are contracted out to vendors (see Table 5). Geologists, casing crew personnel, directional drilling personnel, and rig and fuel transportation personnel are just a few examples.

Table 5: Vendor Job Types Involved in Geothermal Drilling

Job Title	Description	Number Employed
Casing Personnel	Installs metal casing in the geothermal wellbore after drilling is complete	4 – 5
Directional Drilling Personnel	Operates and oversees the directional drilling of a geothermal well	5 – 7
Well Logging Contractor	Operate downhole well logging equipment	2
Geologist	Utilize geologic techniques and expertise to help mitigate drilling risk	3 – 10
Rig Transporter	Operates transportation needed to move the drill rig from one job site to the next	25
Fuel Transporter	Operates transportation needed to deliver fuel to the drill site	20
Estimated Total		**59 -69**

Source: GEA, ThermaSource

Drilling a geothermal well also includes important behind-the-scenes work of administrative and managerial teams that direct, manage, and support geothermal drilling operations. While difficult to quantify, these supporting personnel make up a significant number of employees working to develop geothermal energy.[xxiii]

2.5 Plant Design and Construction

Once the geothermal developer has determined the commercial viability of a resource and has accurately characterized the subsurface reservoir, they will often enter into an engineering, procurement, and construction (EPC) contract. The EPC contractor will utilize its own team of employees as well as subcontracted workers. As a result, geothermal power plant design and construction supports a diverse and significant number of jobs.

The planning and design of a geothermal power plant begins before construction actually commences at the plant site. During the power plant design and engineering phase of geothermal resource development, some 40 to 50 people of varying expertise and skill sets will be employed in the planning process (see Table 6 below).

Table 6: Jobs Types Involved in EPC Phase (Plant Engineering and Design)

Job Title	Description	Number Employed
Degreed Engineer	Engineers of various backgrounds (electrical, civil, mechanical) prepare equipments specifications, schematics, drawings, and general plant design	10
Plant Designer	Utilizes design software to prepare engineering designs for the geothermal power plant	30
Document Controller	Manages documents pertinent to the design of the geothermal power plant	1 – 3
Design Team Supervisor	Supervises and manages the overall geothermal power plant design process	1 – 3
Admin. Support	Assists the project team in document control, customer service, and other aspects as needed	1 – 3
Estimated Total		**43 – 49**

Source: GEA

There is extensive variation even within these categories. Engineers with expertise in mechanical, electrical, performance/systems, and project engineering are needed to support power plant engineering and design.[xxiv] Other management and document control positions are also integral to this process.

Once the actual construction of the geothermal power plant commences, the number and range of jobs needed to complete construction expands even further. Project overhead staff can number up to 40 people. Additionally, the EPC contractor will hire subcontractors to complete various aspects of geothermal power plant construction. Subcontractors or craftspeople involved in the construction of a 50-MW geothermal power plant can number from 300 to 400 workers during the final phases of plant construction when the amount of labor required to complete the project reaches its peak. There are various employment positions supported in this phase of geothermal project development as seen in Table 7.

Table 7: Jobs Types involved in EPC Phase (Plant Construction)

Job Title	EPC Team or Contractor
Construction Manager	EPC Overhead Staff
Project Engineer	EPC Overhead Staff
Field Engineer	EPC Overhead Staff
Project Superintendent	EPC Overhead Staff
Safety Manager	EPC Overhead Staff
Document Controller	EPC Overhead Staff
Admin. Support	EPC Overhead Staff
Welder	Subcontractor or Craftsperson
Assembly Mechanic	Subcontractor or Craftsperson
Inspection Personnel	Subcontractor or Craftsperson
Concrete Construction Operator	Subcontractor or Craftsperson
Steel Erector	Subcontractor or Craftsperson
General Construction Personnel	Subcontractor or Craftsperson
Estimated Total	**340 – 440**

Source: GEA

The plant construction stage typically takes around 2.5 years, and the number of subcontractors or craftspeople on the job site varies throughout this time. During initial phases these numbers remain small but peaks at around 300 to 400 employees toward the final stages. The number of people employed in constructing smaller geothermal power plants decreases but not necessarily proportionally to a decrease in power plant capacity; the number decreases only 25% for a 25-MW power plant compared to employment levels at a 50-MW plant.

2.6 Manufacturing

Geothermal power plants are made of many parts which, when assembled, make up relatively complex mechanical and electrical systems. For example, an organic rankine cycle geothermal plant will be composed of expanders, generators, pumps, heat exchangers, valves, refrigerant, steelwork, cooling towers, piping, switchgear, and transformers. These different parts must be individually manufactured prior to being incorporated into the overall power plant in a design and construction process that involves mechanical engineers, electrical engineers, performance/systems engineers, quality and manufacturing engineers, maintenance engineers, procurement specialists, mechanist, electricians, welders, assembly mechanics, inspection personnel, shipping personnel, maintenance technicians, and site operators.

The system that actually generates electricity, the power unit, is one of the central features of any geothermal power plant. The manufacturing of a single power unit requires the effort of a large team of professionals. One supplier estimates that some

165 jobs are supported in manufacturing the separate components of a standard 7-MW geothermal power unit. A single 50-MW geothermal power plant would require at least seven such power units to produce at full capacity. Like the power unit, the other major components of a geothermal power plant, such as the electrical, cooling, and piping systems, also support numerous jobs among their individual supply chains.

Another example is the geothermal cooling system. The power plant cooling system uses either water or air cooling to transfer waste heat from the power plant to the atmosphere, enabling greater operational efficiency. Like power units, the cooling system is made of many different components manufactured in different locations by professionals with varying expertise and skill sets. Certain components are manufactured overseas, but a significant cooling system industry operates in the US. The increased development of geothermal resources represents an opportunity for manufacturers of cooling system components and technology to employ workers to meet market demand. One manufacturer of cooling systems for geothermal applications estimated that as many as 300 laborers would be involved in supplying fan stacks, gear boxes, drive shafts. While these may be drawn from the same cooling system supply chains as other steam-driven generation technologies, such as coal or natural gas, an increasing number of laborers are involved in manufacturing cooling systems for geothermal power plants.

What is certain is that the manufacturing operations required to support the construction of geothermal power plants further expands geothermal energy's employment footprint beyond the Western US. Suppliers of power and cooling systems components employ people in Arizona, Arkansas, California, Colorado, Connecticut, Kansas, Louisiana, Maryland, Nebraska, Nevada, Ohio, Oklahoma, Pennsylvania, Georgia, and Texas. Additionally, some US manufacturers of turbine systems manufacture products composed of greater than 90% US content, thereby supporting a geothermal manufacturing base in the US.

Steam turbine units and cooling systems are just two examples of the various systems needed to generate electricity in a geothermal power plant. An exhaustive list and analysis is beyond the scope of this paper. Still, as indicated by the examples of both the turbine and cooling system industries, the manufacturing of parts needed in the operation of a geothermal power plant can play a significant role in building a domestic green industry.

2.7 Operation and Maintenance

Once a geothermal power plant is operational, a number of professionals are employed by the owner and operator to maintain and operate it. Power plant managers, engineers, maintenance technicians, and site operators are employed at the site. The total number of people employed can range from 10 to 25 operation and maintenance personnel.

In addition to on-site and other O&M personnel employed by the geothermal power plant owner and operator, support and repair services are also required to maintain plant operations. For example, the supplier of the turbines used in a geothermal power plant will also provide repair services as well as new parts to ensure that the product they sold to the plant owner and operator runs smoothly. One supplier estimated that the continued operation of a geothermal power plant can support up to 19 service and repair jobs.

Turbines are just one example of the many working parts needing vigilant attention and maintenance in a geothermal power plant. Such a plant can be thought in three parts: the power generating unit, the steam gathering system, and the subsurface geothermal reservoir. The latter two parts also require regular maintenance over the life of the plant. Production and injection wells may need to be periodically reworked to ensure adequate fluid and steam flow and injection. As time goes on, it will usually be necessary to drill a new make-up well from time to time to maintain the flow of high-temperature geothermal. Additionally, the piping in steam gathering systems must be maintained and periodically replaced due to wear and tear. One geothermal developer noted that two of its power plants at The Geysers, California accounted for 67 production wells, 10 injection wells, 102 miles of underground well pipe, 8 miles of steam gathering pipe, and 5 miles of injection pipe. This constitutes a substantially large geothermal infrastructure, outside of the actual power plant, that not only requires a significant amount of manpower to construct but also a large number of professional workers to operate and maintain.[xxv]

2.8 Conclusion

The US has the potential to significantly bolster levels of employment by further developing its geothermal resources. From the early stages of leasing, permitting and exploration, to components of the geothermal supply chain, to later stages of production well drilling and plant construction, and finally, the continued operation and maintenance of a plant, geothermal project employs large numbers of professionals and supports a growing green collar industry. When considering the complex nature of the geothermal supply chain, as well as continued plant operation and maintenance, the

number of professionals employed via geothermal development increases even more. Just as important, geothermal resource development not only employs large numbers of people, it employs professionals from different backgrounds. While degreed professionals such as engineers, lawyers, and managers are important to the development of a geothermal power plant, the process would be impossible without the experience of technical green collar personnel such as drillers, welders, and machinists. It is difficult to quantify the exact number of jobs generated and supported by geothermal energy, but a closer look into the development process reveals geothermal development as integral to the nations clean energy portfolio in providing numerous stable and long lasting jobs.

3. References

[i] Hance, Cedric Nathanael. *Geothermal Industry Employment; Survey Results & Analysis.* Geothermal Energy Association. September 2005.

[ii] American Petroleum Institute. *Strategic Energy Resources: Bakken Shale, North Dakota.* Winter 2008. http://www.api.org/policy/exploration/upload/StrategicEnergyResources-BakkenShale.pdf

[iii] U.S. DOE (Jan 2006). *Employment Benefits of Using Geothermal Energy*, Geothermal Technologies Program. Retrieved March 17, 2006 from http://www1.eere.energy.gov/geothermal/employ_benefits.

[iv] This table is included for comparative purposes only. While these geothermal employment numbers are not consistent with GEA's updated employment information, GEA chose to include this table, endorsed by US DOE, in order to show how geothermal's employment figures compare with natural gas'. GEA has chosen to include these slightly outdated figures because they allow an even comparison between natural gas and geothermal. As we do not have updated natural gas figures, we cannot update only the geothermal figures for the purpose of comparison.

[v] See glossary for definitions

[vi] GEA Press Release (2005). *Expanding Geothermal Power Could Create 100,000 New Jobs*. Retrieved May 17, 2006, from http://www.geo-energy.org/publications/pressReleases/Expanding%20Geothermal%20Power%20Could%20Create%20100,000%20New%20Jobs%20September%207%202005.pdf.

[vii] Bureau of Economic Analysis (BEA). *Table 3.—Personal Income and Per Capita Personal Income by County*. Retrieved September 6, 2006, from www.bea.gov/bea/regional/articles/0700lap/tab3b.html.

[viii] Calpine Corporation (February 1999). *Telephone Flat Geothermal Development Project Final Environmental Impact Statement Environmental Impact Report*. California State Clearinghouse Number 97052078. pg 3.12-16.

[ix] National Geothermal Collaborative (NGC). *Geothermal Energy and Economic Development*. Retrieved March 14, 2006, from http://www.geocollaborative.org/publications/Geothermal_Energy_and_Economic_Development.pdf.

[x] National Geothermal Collaborative (NGC). *Geothermal Energy and Economic Development*. Retrieved March 14, 2006, from http://www.geocollaborative.org/publications/Geothermal_Energy_and_Economic_Development.pdf.

[xi] Fitchen, Janet M. (1991). "A Time of Change in Rural Communities: Implications for Rural Mental Health." *Rural Community Mental Health*, Vol. 18, No. 3. Retrieved April 5, 2006, from http://www.narmh.org/pages/culttwo.html.

[xii] Employment Development Department (EDD) (2005). *Siskiyou County, Snapshot*. State of California. Retrieved June 30, 2006, from http://www.calmis.cahwnet.gov/file/cosnaps/siskiSnap.pdf.

[xiii] CMHS (1993). *Taking Rural Into Account: Report on the National Public Forum.*

[xiv] Jackson, Glenn & Charles Cook, Substance Abuse and Mental Health Services Administration (1999). "Crisis Counseling Programs for the Rural Community," from *Disaster Mental Health: Crisis Counseling Programs for the Rural Community.* DHHS Publication No. SMA 99-3378. Retrieved April 6, 2006, from http://www.mentalhealth.samhsa.gov/publications/allpubs/SMA99-3378/crisiscounseling_ch2.asp.

[xv] Whitener, Leslie and David McGranahan (February 2003). *Rural America: Opportunities and Challenges*. AmberWaves, United States Department of Agriculture, Economic Research Service. Retrieved April 6, 2006, from http://www.ers.usda.gov/Amberwaves/Feb03/features/ruralamerica.htm.

[xvi] Sonoran Institute (2005). "A socioeconomic profile, Josephine County, Oregon." *Economic profile system (EPS)*. Sonoran Institute. Tuscan, Arizona.

[xvii] Jennejohn, Dan. *US Geothermal Power and Production Development Update*. The Geothermal Energy Association. April 2010. http://geo-energy.org/pdf/reports/April_2010_US_Geothermal_Industry_Update_Final.pdf

[xviii] United States Geological Survey. *Assessment of Moderate and High-Temperature Geothermal Resources of the United States.* September 2008. http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf

[xix] US Department of the Interior Bureau of Land Management, US Department of Agriculture United, United States Forest Service. *Programmatic Environmental Impact Statement for Geothermal Leasing in the Western United States, Volume I: Programmatic Analysis.* May 2008. Page 1-15.

[xx] Communication with Kermit Witherbee. BLM, August 10, 2010.

[xxi] Communication with Dan Fleischmann, Ormat, August 30, 2010.

[xxii] Communication with Jim Faulds, University of Nevada, Reno, August 12, 2010.

[xxiii] Communication with Patrick Hanson, ThermaSource, August 3, 2010.

[xxiv] Communication with Emily DeSantis, Pratt & Whitney Power Systems, August 10, 2010.

[xxv] Grande, Murray. *Northern California Power Agency's Approach to Meeting Renewable Requirements with Utility Scale Projects.* July 22, 2010.