Renewable Energy Siting and Transmission Resource Requirements

Ryan M. Yonk PhD & Randy T Simmons PhD
Renewable Energy Siting and Transmission Resource Requirements
Final Report
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Principal Investigators:
Ryan M. Yonk PhD
Department of Political Science and Criminal Justice
Southern Utah University
351 West University Blvd
Cedar City Utah 84720
ryanyonk@suu.edu

Randy T Simmons PhD
Department of Economics and Finance
Utah State University
3565 Old Main Hill
Logan Utah 84322
randy.simmons@usu.edu

Student Research Associates
Neal Mason
Rhett Busk
Mathew Coates
Amy McIff
Nicholas Hilton
Traves Bills
Kristen Dawson

Luci Griffiths
Joshua Blotter
Justine Larsen
Josh DeFrieze
Kayla Harris
Heidi Eysser
Richard Criddle
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Executive Summary

The term renewable energy can be misleading. Due to the presence of the word ‘renewable’ it is often assumed that renewable energy is easily produced, transmitted, and requires few inputs besides the respective natural resource. These inputs range from natural resources, to infrastructure, to man hours, and location requirements. An investigation of wind, solar, geothermal, hydropower, biofuels, and oil shale reveals, however, that each of these energy types have resource requirements for both production and transmission.

Requirements for siting, planning, and transmission differ according to energy type and size of the project. For example, while a geothermal plant must have geothermal fluid generally heated to at least 300º F, water requirements for biofuel production is negligible. Different types of renewable energy require different resource allocations, such as the water requirements for solar. Depending on the type of cooling required, water needed for solar energy plants varies from 450 gallons/day per MW to 13,500 gallons/day per MW. There are also resources that are specific to certain types of renewable energy. While wind energy must have wind ≥ Class 3 (~15.7 mph at 50 meters) for an economically viable wind project, wind is not necessary for hydro, biofuel, solar, or geothermal energy.

Included in this reports are the siting, construction, and transmission requirements for the above mentioned fuel types. The first half of this report is composed of summary charts noting the basic requirements for the siting and remission of the respective fuel type. That section will be followed by a detailed report for each energy type discussing the siting of the energy from the planning to transmission stages. Each section may be read alone or together with all sections to create a comprehensive overview of renewable energy siting, planning, and transmission resource requirements. Because of the unique status of biofuel among renewable energy sources, the biofuel section is broken into biodiesel and ethanol. The requirements addressed in the biofuel section differ from other sections because the producer of oil, rather than the producer of biofuel, customarily addresses resource requirements.
## Wind Energy Requirements: Summary Chart

### Siting

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Wind Speed ≥ Class 3 (~15.7 mph at 50 meters)</td>
<td>Minimum amount of wind for an economically viable wind project</td>
</tr>
<tr>
<td>Land</td>
<td>Total infrastructure impact 0.3-0.7 hectares/megawatt</td>
<td>Permanent Area Impact: 0.3-0.4 hectares/turbine Temporary Area Impact: 0.2-1 hectares/turbine</td>
</tr>
<tr>
<td>Water</td>
<td>51 grams/kWh</td>
<td>Estimate for a 3 MW Turbine</td>
</tr>
<tr>
<td>Employees</td>
<td>1 Manager, 2 Support Staff</td>
<td>Estimate for 60-100 Wind Turbine Generators</td>
</tr>
</tbody>
</table>

(Poore and Walford, 2008; Wilburn, 2011; Denholm et al., 2009)

### Transmission

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed/Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>2% of Direct Impact Area</td>
<td>Direct Impact Area estimated to be between 0.3-0.7 hectares</td>
</tr>
<tr>
<td>New Transmission Lines</td>
<td>$80-$150/kW</td>
<td>Estimates from infrastructure upgrades in the Netherlands</td>
</tr>
<tr>
<td>Money</td>
<td>$300/kW (Approximately 15% of the current cost of building a new wind project)</td>
<td>Median unit cost of wind transmission assuming a capacity factor of 0.25</td>
</tr>
</tbody>
</table>

(Denholm et al., 2009; EWEA, 2005; Mills et al., 2009)
## Solar Energy Requirements: Summary Chart

### Siting

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>16,689 gallons for PV Systems/2.61 million gallons for wet-cooled thermal plants</td>
<td>Amount Varies: Sample taken from article in <em>Las Vegas Sun</em> (Tevares, S. 2009)</td>
</tr>
<tr>
<td>Land</td>
<td>3,600 Acres</td>
<td>Amount Varies: Sample taken from the Ivanpah Solar Power Project</td>
</tr>
<tr>
<td>People</td>
<td>300 during construction/ 4-5 to operate</td>
<td>Amount Varies: Sample taken from Imperial Solar Energy Center West Project</td>
</tr>
</tbody>
</table>

### Transmission

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
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<td>16,689 gallons for PV Systems/2.61 million gallons for wet-cooled thermal plants</td>
<td>Amount Varies: Sample taken from article in <em>Las Vegas Sun</em> (Tevares, S. 2009)</td>
</tr>
<tr>
<td>Land</td>
<td>230KWh transmission line across five miles of public lands to the Imperial Solar substation</td>
<td>Amount Varies: Sample taken from Imperial Solar Energy Center West Project</td>
</tr>
<tr>
<td>People</td>
<td>350 for construction/ 15 to operate</td>
<td>Amount Varies: Sample taken from California Valley Solar Ranch</td>
</tr>
</tbody>
</table>
# Geothermal Energy Requirements: Summary Chart

## Siting

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
</table>
| Land           | 50-350 acres  | Power plant= 15-25 acres  
Well field development/equipment=5-70 acres  
Transmission lines= 25-240 acres |
| Water          | Around 5 million gallons/day | For a 50-megawatt water-cooled binary-cycle plant |
| Employees      | 12-15 workers per day | During construction, a few hundred workers would be needed |

## Transmission

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>25-240 acres</td>
<td></td>
</tr>
</tbody>
</table>
## Hydroelectricity Energy Requirements: Summary Chart

### Siting

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>82,300 acres</td>
<td>Sample Size: This amount is used by the Grand Coulee Reservoir</td>
</tr>
<tr>
<td>Water</td>
<td>96,000 gallons per second</td>
<td>Varies according to project size: sample taken from the Hoover Dam</td>
</tr>
<tr>
<td>Employees</td>
<td>5,218 daily workers to implement/ security concerns prevented release of statistics verifying number of employees necessary on a daily basis</td>
<td>Sample Size: This figure is according to the Hoover Dam Project</td>
</tr>
</tbody>
</table>

### Transmission

#### Large Hydro

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>96,000 gallons per second needed to generate proper energy amounts</td>
<td>Varies by example: sample taken from amount of water flowing through penstocks of Hoover Dam</td>
</tr>
<tr>
<td>Employees</td>
<td>1,250 to maintain transmission lines</td>
<td>Varies according to project size: sample taken from HR dept. of Manitoba Hydro</td>
</tr>
</tbody>
</table>
### Small Hydro

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Less than 15 feet of elevation “head” needed to generate proper energy amounts</td>
<td>Varies by example</td>
</tr>
<tr>
<td>Employees</td>
<td>Automatic Operation Suggested Weekly Check-up</td>
<td>Varies according to project size</td>
</tr>
</tbody>
</table>

### Micro Hydro

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>At least 3 feet of elevation “head” needed to generate proper energy amounts</td>
<td>Varies by example</td>
</tr>
<tr>
<td>Employees</td>
<td>Automatic Operation Suggested Weekly Check-up</td>
<td>Varies according to project size</td>
</tr>
</tbody>
</table>
Oil Shale Requirements: Summary Chart

**Siting**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount Needed</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>4-5 barrels to produce one barrel of oil. 378,000 acres of feet of water per year</td>
<td>Depending on method of extraction, this amount can vary greatly.</td>
</tr>
<tr>
<td>Land</td>
<td>Maximum lease amount-5,760 acres, estimating 214 billion barrels in 5,200 kilometer area</td>
<td>Based on the CFR and the Uinta Basin area.</td>
</tr>
<tr>
<td>Employees</td>
<td>Estimations in construct-720 full time employees After construction-155 full time employees</td>
<td>Number may vary dependent on size of the operation</td>
</tr>
</tbody>
</table>

**Transmission**

Transmission issues and costs are dependent on local means of transportation and therefore requirement costs vary on the fuel required to power the trucks and the wages for the employees who drive them. Other variables may include storage and disposal.
## Ethanol Energy Requirements: Summary Chart

<table>
<thead>
<tr>
<th>Country or Resource</th>
<th>Crop or its Requirement</th>
<th>Ratio of Energy Returned on Energy Invested (EROI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>USA</strong></td>
<td>Corn</td>
<td>1.3</td>
</tr>
<tr>
<td>Water</td>
<td>271,540 Gallons/Acre/Year</td>
<td></td>
</tr>
<tr>
<td>Tractor Rental</td>
<td>$50 per acre per trip, 4-15 trips required per year.</td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>1 person per 400 acres maintenance. 3 for mechanical harvest.</td>
<td></td>
</tr>
<tr>
<td>Tractor &amp; Equipment purchase</td>
<td>$100,000 base for new equipment per 400 acres. Will reduce per trip expense to roughly $20 per acre per trip.</td>
<td></td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>Sugar Cane</td>
<td>8</td>
</tr>
<tr>
<td>Water</td>
<td>Minimum of 651,696 Gallons/Acre/Year Note: Brazil receives more than double this in rain.</td>
<td></td>
</tr>
<tr>
<td>Tractor Rental</td>
<td>$50 per acre per trip, 4-15 trips required per year. $100-$200 dollar per acre per trip for specialized harvester. Usually 1 trip per year.</td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>1 person per 400 acres maintenance. 3 for mechanical harvest.</td>
<td></td>
</tr>
<tr>
<td>Tractor &amp; Equipment Purchase</td>
<td>$100,000 base for new equipment per 400 acres but $400,000 more for a specialized harvester. Will reduce trip cost to roughly $20</td>
<td></td>
</tr>
</tbody>
</table>
Biodiesel Energy Requirements: Summary Chart
(For soybean based production; estimated for 2012/13 costs, in 2002 dollars per gallon)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Per Gallon Usage</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land (For production of soybeans)</td>
<td>.00282 acres (.1226 bushels per gallon/43.5 bushels per acre)</td>
<td></td>
</tr>
<tr>
<td>Soybeans (Converted to oil)</td>
<td>7.35 pounds (.1226 bushels) (1 bushel of soybeans= 60 lbs)</td>
<td>2.17</td>
</tr>
<tr>
<td>Electricity and Natural Gas</td>
<td>.083 kwh, 38,300 Btu</td>
<td>0.16</td>
</tr>
<tr>
<td>Glycerol</td>
<td>Byproduct sold, offset to cost</td>
<td>0.15</td>
</tr>
<tr>
<td>Other (Methyl Alcohol, Sodium Hydroxide)</td>
<td>Various units, total cost estimated by NREL</td>
<td>0.31</td>
</tr>
<tr>
<td>Plant Costs</td>
<td>Capital and financing costs (Assumes equity financed, annualized return of 10% over 15 years, annuitized at full capacity output)</td>
<td>0.136</td>
</tr>
<tr>
<td>Total Biodiesel Production Costs</td>
<td>Soybean based, in 2002</td>
<td>2.47</td>
</tr>
<tr>
<td>Petroleum Diesel</td>
<td>In 2002 dollars</td>
<td>0.77</td>
</tr>
</tbody>
</table>

(Radich, n.d; Combs, n.d.; U.S. Growers, 2011)

<table>
<thead>
<tr>
<th>Factor</th>
<th>6% of demand</th>
<th>25% of demand</th>
<th>75% of demand</th>
<th>100% of demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons of Diesel</td>
<td>2,671,980</td>
<td>11,133,250</td>
<td>33,399,750</td>
<td>44,533,000</td>
</tr>
<tr>
<td>Pounds of Soybeans</td>
<td>19,639,053</td>
<td>81,829,388</td>
<td>245,488,163</td>
<td>327,317,550</td>
</tr>
<tr>
<td>Acres of Land</td>
<td>7,535</td>
<td>31,396</td>
<td>94,187</td>
<td>125,583</td>
</tr>
</tbody>
</table>

The chart above summarizes the estimated required quantities of several factors of production and subsidies needed to satisfy portions of national diesel demand based on 2006 estimated consumption (Radich, n.d.; U.S. Growers, 2011; Combs, n.d.; EIA 2010).
Wind Energy Resource Requirements

One of the oldest forms of energy, wind energy harnesses the power of air convection from the Sun’s uneven heating of the Earth’s surface. Early windmills appeared two thousand years ago, though modern wind turbines are significantly larger and more efficient than their predecessors. Contemporary turbines are able to generate enough energy (7.5 megawatts per unit) to power as many as 6,000 homes. As the push for renewable energy has increased at the federal level, the demand wind energy production has also increased. By the end of 2011, nameplate capacity of wind energy turbines worldwide was 238 gigawatts, up 41 gigawatts from 2010 (GWEC). These numbers are predicted to continue to increase throughout this century. Several studies have indicated hundreds of terawatts could be economically generated from wind power, potentially meeting a large portion of energy needs (de Azua). Using wind as a resource carries several requirements, including land, energy, transmission, and resource requirements.

Siting Requirements

Land

One concern surrounding the development of wind energy is land. Though wind energy facilities often don’t require significantly more land than alternative methods of generating energy, the requirements can question the economic viability of wind farms. In addition, the turbines often have significant impact on their surroundings. One study evaluating 172 projects (collectively able to generate 80% of total US wind power) performed by the National Renewable Energy Laboratory found that, in practice, area requirements for wind energy
result in a total direct surface area disruption of about 0.3 to 1.7 hectares per megawatt. Permanent infrastructure impacts per turbine amounted to 0.3 to 0.4 hectares, and temporary impacts amounted to 0.2 to 1.0 hectares per turbine.

In terms of land impact, wind plants sited on cropland require the largest total land. Results from the study also highlight the variability of wind energy capacity; for total area requirements, excluding a handful of outliers, the range of values extends from 9 hectares/MW to 100 hectares/MW. The values range widely because the efficiency of a wind project depends on several variables, including plant size, geography, and the configuration of wind farms. Several of the 172 projects in the study provided detailed information about how land was used in the projects; most of the land used was dedicated to roads, with the remainder used for turbines (10%), substations (6%), and transmissions (2%) (Denholm et al 2009).

How much land a specific wind harnessing facility requires depends significantly on the terrain where the turbines are constructed. For instance, turbines in forested areas usually require less total land area because of the economic cost associated with clearing forest, but they also have the most permanent impact on the land they occupy, as construction requires deforestation. Though most locations have similar balances between pros and cons, strategic placement of wind farms can generate increased monetary output. For example, because crops can be planted up to the base of turbines, and livestock can graze around them, many farmers could potentially lease their land to wind utilities while continuing to farm, creating multiple uses for their land. In fact, the Union of Concerned Scientists reports that developing wind energy on
farmed land alone could provide $1.2 billion in new income for farmers and rural landowners by 2020, as well as create 80,000 new jobs. Identifying similar niches for wind energy greatly reduces the amount of land required for wind farming (UCS, n.d.).

One final wind energy trend that should be addressed is the increasing interest in offshore wind developments. Research by BTM Consults (2010) indicates that currently 3.16 gigawatts (GW) of offshore wind farms have been installed, a number expected to increase to 75 GW by 2020. Though heavily implemented in Europe, no large-scale farms have yet to be completed in the United States, although several are in various stages of pre-construction (BTM 2010). Though off-shore wind developments run into many of the same problems that traditional wind farms do, it should be noted that turbines can be placed off-shore in relatively unobtrusive off-shore locations. Recent turbine designs have introduced turbines that can float, which could further reduce wind energy’s dependence on land requirement. Further, these turbines are not required to rest in permanent locations (The Guardian, 2010).

Energy

The potential for a wind farm generating electricity, and the cost per unit of that electricity, depends almost entirely on how much energy (in the form of wind) the turbines are exposed to. The power output of wind turbines increases as a cube of wind speed, and thus winds with higher speeds are much more economically viable. Wind speeds are separated into seven categories, with higher numbers indicating higher wind speeds. Generally, wind speeds of class three and above are necessary; in other words, wind speeds need to be at least
15.7 miles per hour at 50 meters for an area to be deemed economically viable as a potential wind farm location. A 2009 study performed by the National Renewable Energy Laboratory found that in the United States, most areas that meet these requirements can be found in the relatively less-populated Midwest, particularly in northern states like Montana and the Dakotas. The U.S. coasts are also rich with wind speeds above class 5 (Denholm et al., 2009).

Wind speed is merely one factor to consider, however. One of the largest drawbacks of utilizing wind energy, and easily among the most common issues presented by wind energy critics, is the volatility and intermittency of wind. Sometimes, the wind doesn’t blow, and often, the speed of the wind that does blow varies significantly by time, day, or season. Wind turbines are generally calibrated to maximize power production of the wind that usually surrounds them, and so such variance can reduce the amount of power that can be generated. Further, if wind reaches speeds that are markedly higher than normal, the turbines will in some cases be forced to shut down to avoid damage to the turbine. The number that relates the maximum capacity to the actual amount of energy generated is the “capacity factor” (UMass, n.d.). If the nameplate capacity (or maximum potential capacity) for a 5-megawatt turbine were 50%, then that turbine would generate, on average, only 2.5 megawatts. Typically, capacity factors for wind farms are roughly 20-40%, although some offshore sites where wind is more constant can achieve higher capacity factors.

There are a variety of other methods that are used to reduce the energy requirement for a wind farm site. For example, wind speed increases with altitude; for class 7 winds, wind blows at about 11.1 miles per hour at 10 meters,
but at 50 meters, wind blows at least at 19.7 miles per hour. Placing farms where there are few geographic or man-made features to interrupt the flow of wind also maximizes the amount of electricity that can be generated (UCS, 2009).

*Employees and Water*

Wind energy development requires a variety of workers for construction, maintenance, routine management, and operation. A 100-megawatt wind development project in Canada, called Greenwich Wind, estimated that the wind farm would bring 300 construction jobs during the peak construction phase; after construction ended the company employed eight to ten people in management and maintenance (RES Canada, n.d.). Operating costs for wind farms come from paying managers, technicians and specialized maintenance crews as well as new equipment. Routine maintenance, ordering and receiving inventory for turbine parts, generating status and production reports, and scheduling outside services for specialized maintenance are a few duties that require paid staff.

Since the most time-consuming activities for operations are linked to the number of turbines in a wind farm, Poole and Walford (2008) provide various manpower requirements based on the number of wind turbine generators in a facility. For a facility with less than 20 wind turbine generators (WTG), a single manager usually assumes routine tasks and maintenance (Poole and Walford, 2008). For large facilities with more than 60 WTGs, an administrative assistant and a support person are required in addition to a manager.

Compared to other forms of energy, wind energy uses little water. In arid climates, small amounts of water are used to clean turbine rotor blades to maintain performance (EcoGen, 2012). Citing a 2006 study by Vesta Wind
Systems looking at onshore wind turbines in Europe, Wilburn (2011) estimates freshwater consumption for a 1.65 megawatt turbine at 38 grams per kilowatt-hour, and 51 grams per kilowatt-hour for a three megawatt turbine. Wilburn writes, “These estimates include the resources used in raw material extraction, component manufacturing and transport, wind turbine installation and operation, and decommissioning and disposal of turbine components at the end of their life cycle” (2011).

**Transmission Requirements**

The intermittency of wind energy strongly affects the transmission requirements for power generated from wind turbines. Although significant problems generally don’t occur until wind power accounts for over 20% of all electricity, relying too heavily on wind energy could create grid shortages on days with inadequate wind. Many of the electrical transmission changes aren’t technological, per se, but rather require different large-scale energy management techniques.

The European Wind Energy Association lists certain general guidelines for an electrical grid relying on wind energy that should be addressed to consistently utilize wind energy. First, operation of the power system needs to be changed. Wind power generation isn’t dispatchable, which means that it’s impossible to start or stop generating as the need arises. Weather forecasting and statistical evaluation of wind variation is necessary to predict how much power wind can provide on the grid during any given time period. Second, utilizing wind energy often requires upgrading connection requirements to maintain a stable and secure supply. A study by Mills et al. (2009) estimated median transmission costs
for wind development at $300/kW (assuming a capacity factor of 0.25), or approximately fifteen percent of the current cost of building a new wind project. In the Netherlands, infrastructure upgrades to enable wind farms have cost the dollar equivalent of $80-$150 per kilowatt, while in Spain, upgrades have cost roughly $70 per kilowatt (EWEA, 2005). Despite these relatively small, one-time expenses, the cost of upgrading and enlarging a wind energy plant is much larger.

A final change is extending and modifying the grid infrastructure. Diversifying the geographic locations of turbines reduces the risk of a shortage, and many small suppliers from a variety of locations may want to participate. Both factors require longer grid connections. The offshore branch of wind farming also has unique requirements to connect to the grid, including cables installed underneath the seabed. One notable benefit of utilizing offshore wind farming, however, is that wind farms can be located close to coastal population centers. Despite these requirements, strategic wind energy siting can significantly reduce transmission costs (Holttinen et al., 2006).

Conclusion

Although wind energy has the capability to serve as a supplementary source of energy, it cannot serve as a primary source of power due to the unreliability of the resource from which it derives energy i.e. wind. And while wind energy requires minimal water resources for siting, there are few areas that qualify as economically viable wind energy sites. This is because wind must be greater than or equal to 15.7 mph at 50 meters in the air, a requirement that most areas do not meet. In addition, while an individual turbine only requires .3-.4 hectares of land, economically viable wind energy projects require several wind
turbines to generate electricity. Costs to link to the current power grid can be expensive, when a power grid is available and permission to hook up to the current power grid is granted. Finally, for a 60-100 wind turbine project, only one manager and 2 support staff are needed; while more are needed for the construction of wind turbines, the addition of wind turbines does not necessarily generate increased long-term employment opportunities in the communities where wind energy projects are found.
Solar Energy Resource Requirements

The 1973 OPEC oil embargo on the United States proved effective in crippling the U.S. economy. This denial of oil exports revealed the significant weakness of a country dependent on oil from other countries. Diplomacy began almost immediately as fears rose regarding the future of energy in the United States, leaving the United States in the meantime to depend on oil supplies from allied nations to keep the economy afloat (Office of the Historian, n.d.). Finally, in 1974 under the Nixon Administration, a sense of normalcy was reinstated as the embargo was lifted (Office of the Historian, n.d.).

Two Presidencies later, Jimmy Carter sat in the Oval Office during yet another energy crisis, in which the Iranian revolution affected the flow of oil to the United States and again threatened the economy. In response, President Carter pushed for more renewable energy use and development to prevent a similar situation in the future (Carter, J. n.d.). As part of his proposed energy reform, President Carter made the specific goal to “use solar energy in more than two and one-half million houses” by the end of 1985 (Carter, J. n.d.).

Solar power is unique among alternative energy resources in its versatility; it is neither confined to the traditional solar farm approach, nor to limited-impact home installments. Due to this variance in types of solar generating units, it is necessary to examine resource and land requirements in all areas before properly instating one of these facilities.

Types of Solar Plants

There are two main distinctions in types of solar plants; solar technology either uses concentrating solar power (CSP) to produce steam and turn turbines,
or individual cells used to transform solar energy directly into electricity. These two technologies are referred to as solar thermal and solar photovoltaic (PV) (Office of Indian Energy and Economic Development, A, n.d.). Solar energy generating systems vary in size dependent of the amount of energy needed and land availability. Some projects are small enough to fasten to the rooftops of homes, while others require vast mirror fields. Due to this variance, it is necessary for developers to first decide upon which type of solar energy to implement.

*CSP Systems*

Concentrating solar power collection facilities use mirrors to concentrate sunlight onto receivers, creating thermal energy. This heat is used to boil water, turning a turbine that produces electricity (Department of Energy, A, n.d.). CSP plants consist of two parts: one converting light from the sun into heat, and the other using the heat to create electricity.

There are four types of CSP systems: linear concentrator, dish/engine, and power tower systems (Department of Energy, A, n.d.). Linear Concentrator systems use mirrors to concentrate sunlight into linear receiver tubes containing liquid. As the sun heats the liquid, a “superheated steam” is created, which is used to drive turbines and produce electricity. Linear concentrating power plants are the most common type of CSP system in the United States, which consist of parallel rows of panel-shaped mirrors aligned to maximize exposure to the sun (Department of Energy, B, n.d.).

Dish/Engine systems, on the other hand, use a system of parabolic mirrors shaped like a satellite dish, reflecting the light into a receiver to create steam.
These systems are the least productive of CSP systems in terms of kilowatts (Department of Energy, C, n.d.). Power tower systems use mirrors that are arranged circularly around a large tower, allowing them to collect light from the sun at any angle, and reflect light to a receiver at the top of the tower, subsequently superheating liquid to turn turbines. Power tower systems have proven especially effective at providing electricity during bad weather, and even at night. In one instance, a power tower operation provided uninterrupted electricity 24 hours per day for 7 consecutive days (Department of Energy, D, n.d.).

*Photovoltaic Systems*

PV systems use the light from the sun to directly create electricity. As the sun’s light is absorbed into photovoltaic cells, electrons in the semiconductor material absorb the light; the energy absorbed causes them to escape normal rotation patterns in the atom and become part of an electrical current. These cells range in size, but average only a few inches across. Grouping many PV cells together then forms a solar panel. PV solar electric systems are versatile in that they can be designed to fit any available space and provide the needed electricity. PV systems also generally contain a converter and batteries to transform power into usable electricity and then store it for future demands. These converters and batteries are referred to as *balance of system* (BOS) components.

There are only two types of PV systems: flat-plate and concentrator systems (Department of Energy, E., n.d.). Flat-plate systems organize solar arrays into flat plates that can be conveniently placed on rooftops or mounted on the ground. Flat-plate systems are convenient, but expensive. Because of their fixed
nature, they are also inevitably inefficient at times of day or in seasons when the angle of the sun changes (Department of Energy, F, n.d.). Concentrator systems use glass or plastic to concentrate sunlight onto smaller areas, using fewer cells more efficiently to create more electricity. However, concentrator systems run higher costs in light-concentrating optics and generally need to be mounted so that the system can track the sun; otherwise, the system is ineffective.

**Siting Requirements**

*Land Requirements*

PV systems are more diverse in application than CSP systems, which need large amounts of land. PV systems can be small enough to power a road sign or large enough to power a community (Department of Energy, G, n.d.). The diversity of solar projects necessitates varying amounts of land and resources for each facility. Because there is not a set list of requirements needed to develop solar energy facilities, insight to basic requirements for each can be gained from looking to existing examples of solar energy.

The Ivanpah solar power plant in California is currently under construction and was named the 2012 Energy Project of the Year (Blog Brightsource Ivanpah, n.d.). Ground was broken in 2010 for the plant, which is expected to double the amount of solar energy generated in the US when completed. The system will be composed of three power towers surrounded by mirror fields, and is the largest thermal solar energy plant currently under construction (Blog Brightsource Ivanpah, n.d.). Although land requirements vary according to project size and terrain, the Ivanpah project properly reiterates the vast amount of land needed for commercial-scale solar facilities through its use of
3,600 acres - revealing the far end of the spectrum in relation to land required for implementation (About Brightsource Ivanpah, n.d.).

Solar energy is not limited to large-scale productions; the Solar America Cities Partnership Program, implemented by the U.S. Department of Energy, is a competitive means to promote increased use of solar energy in cities throughout the country (Powering Our Future, October 2010). Salt Lake City, Utah, a city participating in the program, uses small solar energy projects to reduce strain on the electrical grid (Powering Our Future, October 2010). As part of the program, Salt Lake City is one of fifteen different cities across the country that has made the goal of increasing solar-electric generation by 10MW by 2015 (Powering Our Future, October 2010). This will be done through small-scale solar systems, such as the installation of solar panels on rooftops. Select solar projects, such as this one, require minimal areas for implementation - some of which aren’t in use anyway (as is the case in rooftop space).

A comparison of the Ivanpah Solar Power Plant and the many smaller systems being implemented in Salt Lake City, indicates that there are many different possible area requirements for solar energy systems. The 3,600 acres needed to run the Ivanpah project varies in size from not only with the rooftop space needed for small PV systems, but also with other large solar projects. Land type, weather characteristics, and energy demands all cause differing solar projects to vary in the amounts of area needed for their implementations. Variety in land needs can be seen in the projects approved by the Bureau of Land Management (BLM): “projects range in size from a 45 MW photovoltaic system
on 422 acres to a 1,000 MW parabolic trough system on 7,025 acres” (BLM Fact Sheet, 2012).

Resource Requirements

Acreage, however, is not the only matter to take into consideration with site evaluation. The quality of the area is critical, and therefore evaluations of climate, meteorology, and topography are also important. To that end, the installation of meteorological towers and solar sensors are necessary during the site evaluation phase. Meteorological towers provide information such as wind speeds and temperature. They are lightweight and most often require no foundation. There is little maintenance or effort required to care for these towers (Solar energy site evaluation, n.d.).

Solar energy developers must consider two other essential needs in citing solar energy plants: water needs and workforce support. Solar energy sites are placed in sun-intensive locations; however, these locations are often located far from populations, increasing the overall cost. The most useful areas for solar development tend to be in rural desert areas, which complicate the ability to get water to the employees as water is scarce and employees are required to commute long distances. Because of these complications, larger power plants are most cost effective when compared with smaller facilities because they are able to serve larger volumes of individuals and therefore generate more income (NREL, 2011). Similar to the land requirement for instating solar energy generating systems, water needs also differ dependent on size and location. Each solar energy system requires water in one way or another; whether it’s used for dust control, or actually heated to generate electricity, water is a must.
An article that adequately gives a representation of water needed for PV systems surfaced in Las Vegas in 2009. The sunny areas of southern Nevada offered potential benefits to solar power; however, the implementation of these facilities received criticism at the large amounts of water needed to properly operate the plant (Tevares, 2009). Photovoltaic solar developers in the area hadn’t properly estimated their water usage, and estimated that the plant would require “only enough water to run the office bathrooms and wash the arrays of panels a couple of times a year” (Tevares, 2009).

Locals, however, argued that such an estimate was unfeasible, and that water needs would be much greater because of excessive dust in the area, thus creating a greater number of times the panels would need to be sprayed down. Dust on the PV panels could generate a decrease in efficiency by three percent, adding incentives for the project overseers to double-dip into water reserves (Tevares, 2009). Although PV systems use significantly less water (16,689 gallons per megawatt compared with 2.61 million gallons needed for wet-cooled solar thermal plants) the use of such large amounts of water remains a concern for residents of desert communities (Tevares, 2009).

Employment is yet another varying factor to look to in developing solar energy projects. Only minimal maintenance and regular checkup is required for small projects such as rooftop panels or those powering road signs. Larger projects on the other hand, require a significant number of employees to construct a facility, but afterwards then generally require fewer workers to tend to daily operations. An example of this is found in the upcoming California Valley Solar Ranch, where 350 construction jobs are made available through the
project- followed by 15 long-term positions to operate the facility that will generate 250MW (California Valley Solar Ranch, n.d.; CVSR Project Benefits Fact Sheet, n.d.).

**Transmission Requirements**

With advancing technologies, and growing contributions to the electrical grid from multiple renewable sources, solar energy developers need to keep transmission in mind when considering the construction of new facilities. Rural locations needed to create large-scale solar energy generating systems increase costs, as additional resources are needed to transmit the energy generated to the electrical grid. In focusing on solar transmission it is necessary to note the land, water and employee requirements needed to operate solar energy plants.

The process of transmitting the energy cultivated within the plant is not cheap. Many resources go into implementing an effective transmission system such as land, wiring, support structures, and transformers. After the energy is converted into electricity, it is sent through transformers, which increase the voltage in order to send it through the lines and into communities (NextEra Energy Resources, n.d.). Energy capacities, distance from the electrical grid, and land terrains all influence the size of transmission systems. Differing characteristics for each transmission system prevent the existence of an all-knowing spreadsheet with figures depicting the exact amount of resources needed during transmission. It is ideal, however, to look at similar solar energy facilities for ballpark numbers regarding transmission statistics. One such example is the Imperial Solar Energy Center West Project.
**Land Requirement**

The Imperial Solar Energy Center West Project is currently being constructed in Imperial County, California and when completed, is estimated to generate as much as 250MW (Imperial Solar Energy Center, n.d.). Lands once used for agriculture have been found to be un-economic and were therefore abandoned. These abandoned agricultural lands are being used for the facility, and cover an estimated area of 1,057 acres (Proposed: Imperial Solar Energy Center West, n.d.). Land needed for transmission varies from project to project. The Bureau of Land Management has authorized a 230KVh transmission line to cross five miles of public lands and connects the facility to the Imperial Valley Substation (Imperial Solar Energy Center-West Project, 2011). Lands needed for transmission in the project serves as a sample of potential lands needed by other similar solar energy facilities.

**Employee Requirement**

Solar energy plants require differing numbers of employees, dependent on the size and location. As expected, the actual construction of the plant and transmission lines requires many more employees than does regular maintenance and daily operations. A sample size of necessary employees is shown through the creation of approximately 300 construction jobs and 4-5 long-term employment positions (Proposed: Imperial Solar Energy Center West, n.d.). Once in operation, transmission lines require minimal upkeep, which lessens the overall need for employees.
Water Requirement

As was seen in the water dispute in Las Vegas, residents near these developments often fear that water will be wasted in maintaining solar plants (Tavares, 2009). Many developers respond to this fear through using as little water as possible. In the case of the Imperial solar Energy Center West project, developers specifically chose PV systems to reduce water needs and gain further approval from residents near the area (Proposed: Imperial Solar Energy Center West, n.d). Contrary to CSP systems, which use heated water to turn turbines, PV systems transform sunlight directly into energy and therefore need water only for regular yearly cleanings.

Energy transmitted by PV systems is directly affected by the cleanliness of the panels, therefore creating a need for these regular cleanings. Amounts of water used to remove dust from the arrays can still be extensive, and vary according to the number of panels. Operators may plan around expected rainfall; however, areas with little rainfall may continue to require as much as 16,689 gallons of water per megawatt (Tavares, 2009). Additional water may also be needed to supply employee facilities, but dependent on the number of employees this amount may be rather small.

Diversity in types of solar plants facilitates a wide variety of transmission needs. Non-invasive rooftop installments used to power individual homes need far less land, water, and maintenance than large facilities that power entire communities. Although the amounts of resources needed may vary, the processes these projects follow in regards to transmission all follow the same pattern. Plant construction is a major undertaking, however, the plant is useless unless
connected to the electric grid to serve customers and generate income. Through looking at the examples of similar plants, developers can gain further insight as to the research and planning needed for transmission regarding solar energy.

**Conclusion**

A major concern in the construction and transmission of solar energy is the amount of water needed for solar energy. As a scarce resource, particularly in the West (where most of the potential solar energy development sites are located), there is concern that extensive water use for solar energy will take water from critical economic activities such as agriculture and grazing. While a somewhat large workforce is needed for construction of large scale solar energy plants, maintenance and operation of a solar energy plant does not require very many full-time, long-term employees. As with wind energy, the addition of solar energy plants does not necessarily generate increased long-term employment opportunities in the communities where solar energy projects are found. Large tracts of land are necessary for large solar energy projects, adding yet another difficulty to solar energy development.
**Geothermal Energy Resource Requirements**

Geothermal energy is harnessed from the heat of the earth. While there are different methods of obtaining energy from geothermal sources, the basic model uses steam and heated water to spin a turbine, which produces electricity. This electricity is then transmitted through transmission lines to its intended destination. The water is returned to the heat source as warm water to extend the life of the geothermal spot and can be reused after the earth reheats it. Geothermal energy plants have been in use since 1904 in Italy and have continued to improve and expand as technology advances (Geothermal Education Office, 2000).

**Siting Requirements**

**Land**

A good site for geothermal electric development must have shallow aquifers that produce heated geothermal fluid (generally at least 300º F, although some plants can utilize fluids as low in temperature as 210º F) and can be recharged by re-injecting the fluid. The site must also have access to extra water for evaporative cooling and ideally, to existing transmission lines and roads (Department of Energy (b), 2012).

Typically, about 2 to 7 acres of land are required for initial exploration and drilling depending on the size of the plant being built. Power lines connecting the power plant generator transmit the electricity to homes, buildings, and businesses. Once construction begins, the acreage requirements increase to 5 to 50 acres, so as to include land for access roads, actual construction, and the “drilling and installation of flow testing wells” (Department of Energy (a), 2012).
Construction requires about 50 to 350 acres of land; while most of the land will remain a part of the plant, some of the land will be reclaimed after construction (Department of Energy (c), 2012). Likewise, depending on the size of the geothermal system the operations and maintenance phase takes about 50 to 350 acres. “The power plant itself would account for 15 to 25 acres; the well field development and equipment (including the pipeline system) would account for 5 to 70 acres. The transmission lines would require from 25 to 240 acres, ranging in length from 5 to 50 miles with a corridor width of about 40 feet” (Department of Energy (d), 2012).

Assessing the Site

Before construction for a geothermal plan can begin, pre-construction surveys and studies must be conducted, including: “satellite imagery and aerial photography, volcanology studies, geologic and structural mapping, geochemical surveys, geophysical surveys, and electrical, magnetic, chemical, seismic, and rock studies” (Department of Energy (b), 2012). Following these surficial surveys and studies, more intrusive procedures must take place, specifically drilling for temperature gradient wells, and holes for seismic investigation, core drilling, and geophysical testing. While most of these assessment activities take place underground, the procedures require a significant amount of land obliteration: vegetation must be cleared around the site, roads built for easier access to project sites, drilling, explosions for seismic testing, and “sludge”, or slushy fluid remains, must be removed and disposed of (Department of Energy (b), 2012). The time it takes to perform the seismic surveys and surficial data collection is quite short, only lasting a few days.
A geothermal plant can be compared to a volcano: a relatively small amount of space can produce a significant amount of energy. Geothermal energy utilizes the least amount of land of any energy form: a geothermal energy plant requires about as much space as a gas-fired plant that produces the same amount of energy, omitting the miles of underground pipeline needed to transport gas (Pros and Cons of Geothermal Energy, 2007).

Specific requirements and regulations must be considered when assessing a possible site for a geothermal energy production plant. A relatively small workforce of 10 to 15 people is required for the exploration phase, while extra workers might be hired to install or operate specific machinery and/or data collections or surveys. Once construction begins, however, several hundred employees are needed to build pipelines and roughly 50 are needed to construct a transmission line, depending on the length of the line.

Drilling activities normally take numerous weeks to complete, resulting in a total of between one and five years to complete all exploration and assessment activities and studies. The materials and resources needed for initial assessment are not particularly demanding. Roughly 80-1000 gallons of water per MWh of plant output is required to control dust, mix concrete, and provide drinkable water for the crew. This water can be brought in from an off-site location or found in an on-site well or local water supply. No utilities are necessary for beginning exploration and assessment, as drill rigs are powered and operated by diesel engines (Department of Energy (a), 2012).

The preliminary investigation does generate some emissions and waste resulting from vehicles used to transport drill rigs, perhaps a diesel generator
trucked onto the site to power equipment, and possibly certain gases from well venting, including hydrogen sulfide, carbon dioxide, mercury, arsenic, and boron. These emissions are most easily controlled after construction of the plant, by installing hydrogen sulfide abatement systems or by re-injecting gas emissions into the geothermal reservoir, which may or may not have adverse effects on the reservoir. The waste produced is mostly sludge, as mentioned above, which is typically removed from plastic and clay lined pits on site. After all the water has evaporated, the sludge is disposed of in a licensed off-site location (Department of Energy, 2012).

Construction

Once the site has been approved and deemed ready, construction begins. Geothermal fields are prepared, power plants are built, and the infrastructure and transmission lines put in place. During construction, typically a few hundred workers work on site; the number, however, may vary over the two to four years it takes to finish construction of a large geothermal development.

Operations and Maintenance

Maintaining geothermal plants requires minimal maintenance and does little to disrupt the land. Approximately 3 workers are required per shift to perform routine operations; as many as 12 workers, based on plant size, might execute additional maintenance and management operations when needed (Department of Energy (d), 2012).

Regarding waste emissions, carbon dioxide is the main emission generated from geothermal power plants; however maintenance vehicle traffic, heating, ventilation, and air conditioning systems also produce a certain amount of
greenhouse gases. If wet cooling is used, cooling tower drift might give off particulate emissions (or emissions that contain small particles of liquids and solids). Additional waste generated consists of sanitary waste resulting from on-site workers, and used cooling water is released to a permitted evaporation pond (Department of Energy (d), 2012).

Any water required is piped in from an off-site municipal water facility or an on-site well. Certain types of geothermal plants, namely water-cooled binary cycle plants, utilize significant amounts of cooling water (S. Williams, K. Porter, 1989). “For example, a 50-megawatt water-cooled binary-cycle plant requires more than 5 million gallons of cooling water per day (100,000 gallons per megawatt per day)” (United States Department of Energy, 1995). Most geothermal plants are located in desert regions, making it difficult to acquire adequate water quantities to continue production.

**Transmission**

The transmission line takes a few more months to build, depending on its length. Portable generators supply any electrical power needs on-site, and water requirements are similar to pre-construction requirements, needing an adequate amount for making concrete, providing drinkable water, and controlling fugitive dust. Construction vehicles emit dust and exhaust, and similar to the assessment process, well venting might release hydrogen sulfide, carbon dioxide, mercury, arsenic, and boron. Sanitary waste from the construction workforce is the only waste generated during the construction period (Department of Energy (c), 2012).
The siting of geothermal energy production plants is limited to areas containing high levels of volcanic activity and functional geothermal hotspots. Thus, the majority of usable sites are often geographically isolated, which limits the ability to efficiently transmit geothermal energy. The major limiting factor to geothermal energy use is the remoteness of sites and areas suitable to geothermal energy development.

Transmission of geothermal electricity and its use are also limited in several minor ways. The first is the fact that “geothermal resources cannot be transported distances over a few miles without heat loss.” (Kagel, 2008, p. 13). Thus, geothermal steam must be used to generate electricity at or relatively near the source of the steam and/or its point of extraction. In addition, the majority of suitable sites are found in predominantly rural, remote locations. Consequently, “[a] large amount of capital is required for transmission expansion, providing a disincentive for utilities to build infrastructure to reach remote geothermal sources” (Geothermal Technologies Program, n.d. p. 31).

For geothermal energy to be effective in supplying energy to a large percentage of the population it would, in theory, necessitate one of three dramatic changes. These solutions include first, an expansion or upgrade of the current infrastructure system, development of technology in participating communities. And finally, a major improvement in the technology used to collect geothermal resources that would lead to the expansion of geothermal energy production in areas that currently are unfeasible for the collection of geothermal energy resources. Each of these three methods has benefits that are promising, but as with all solutions to energy problems they also have downsides.
The US Department of Energy’s (hereafter abbreviated as DOE) lists “Limited access to transmission infrastructure” as the first limiting barrier to expansion (Geothermal Technologies Program, n.d., p. 31). Since geothermal energy sources are often located in remote areas, it is necessary to transport the energy generated large distances into major population centers. Technological improvements that expand the energy grid are therefore required to transport energy farther and more efficiently.

For a new geothermal site to begin transmission, it requires the construction of a new series of “…transmission lines [which] would require from 25-240 acres, ranging in length from five to fifty miles with a corridor width of about forty feet” (Department of Energy (e), n.d.). In some extreme cases the distances that must be spanned are astronomical. For example, the current transmission line system that runs from Dixie Valley, Nevada to Bishop, California, totaling approximately 220 miles (Kagel, 2008, p. 13). The voltage size of transmission systems can vary considerably as well, depending upon the power involved; with a low of 60 kilovolts to a high of 230 kilovolts, and a mean of roughly 100 kilovolts (Kagel, 2008, p. 13).

Longer transmission lines result in an increase in funding necessary to build each geothermal plant. In addition to the requirements necessary for construction, a study performed by the Bonneville Power Administration and the Northwest Gas Association, indicated that the average annual cost of maintenance for 100 miles of transmission wire is upwards of $25 million (Comparing Pipes and Wires, n.d.). While this data was found specifically with natural gas in mind, the transmission of electricity produced by geothermal
energy is practically identical to the electricity produced by the burning of fossil fuels. According to the DOE, “[g]eothermal resources are generally remote from load centers, requiring investment in transmission infrastructure, which can lead to high delivery costs that many not be competitive with conventional technologies” (Geothermal Technologies Program, n.d., p. 31).

The expansion of electrical grids has environmental impacts upon the land, but is generally not overly intrusive. These limited impacts are true of both the environment itself as well as some human commercial activities. Evidence from the past shows that “...to some extent, land use can revert to its original uses (e.g., livestock grazing) [after geothermal plant siting, however] many other uses (e.g., mining, farming, or hunting) would be precluded during the life span of the geothermal development” (Department of Energy (d), n.d.). The construction of massive electrical grids also has, as does any construction project upon non-inhabited land, a negative impact upon the surrounding ecosystem.

Expanding communities closer to geothermal resources holds some potential as a solution as the United States’ population rapidly expands past the three hundred million mark. The creation and expansion of cities closer to geothermal resources makes it possible for geothermal energy to reach a greater percentage of the population. An added benefit is that, with shorter transmission distance, this solution effectively cuts into the amount of funds needed to construct new grids for energy transportation. This efficiency is demonstrated by the mere two miles required for transmission from the plant at Steamboat Hills Nevada, to its delivery point on the Sierra Pacific system (Kagel, 2008, p.13).
Conclusion

Geothermal energy siting and transmission requirements are similar to solar energy requirements. The vast amounts of cooling water needed for geothermal energy plants creates difficulties in geothermal energy generation, especially as most geothermal plants are found in deserts. In addition, while a few hundred jobs are generated during the construction of a geothermal energy plant, roughly a dozen long-term workers are needed for maintenance of a geothermal plant once it has been constructed. Land requirements for geothermal energy are somewhat less restricting than those for wind and solar energy, but the specificity of location for geothermal plants i.e. the geothermal plant must be built in a location where geothermal fluid is generated, means that there are very few locations where construction of geothermal plants can occur.
Hydroelectric Energy Resource Requirements

The replenishing nature of water has led to its development as a power source dating back thousands of years (History of Hydro, n.d.). Coincidently, it was this same characteristic which inspired thinkers of the 1800’s to tap into running water as an unlimited source of fuel. Hydropower statistics shine favorably on these technologies through revealing that sixty-five percent of all renewable energy within the United States is generated through hydroelectric power plants (Why Hydro, n.d). It is interesting to note however, that while hydropower plants are almost guaranteed an unrestricted amount of fuel (water) for their efforts, the hydropower industry only represents approximately ten percent of total energy production within the U.S (Water Power Program: History of Hydropower, n.d.).

The potential expansion of the hydro industry is illustrated by the fact that in the United States there is approximately 60,000 MW of potential growth (Faq: National Hydropower Association, n.d). To put this statistic in perspective, one megawatt of power has the capability to power 750-1000 different homes (Faq: National Hydropower Association, n.d.). With such high potential for further growth, the perpetuity of water, and the benefits of reduced greenhouse gasses, it is natural to expect endeavors to increase in the area of hydropower expansion. Such an increase however, requires involved parties to take a closer look into several key areas needed for implementing hydroelectric power plants: land, water, employee requirements, as well as transmission needs.
Siting Requirements

Large Hydro

There are three different types of hydropower plants. This distinction is necessary because each require different amounts/types of land. Definitions vary according to source; however, the U.S. Department of Energy has defined each type of hydropower according to energy output (Water Power Program: types of hydropower plants, n.d.). The first type of plant is large hydropower, which is any plant that generates more than 30 megawatts (water power program: types of hydropower plants, n.d.). If one megawatt is able to power 750-1000 households, 30 megawatts has the potential to power 22,500-30,000 average households. Large hydroelectric plants not only require a decent portion of land, but also require large amounts of water and employees to operate/maintain machinery. Large areas of land are needed for large hydro systems, not only for the plant itself, but also for roadways, transmission lines, and any additional surrounding facilities.

Land

Although large hydro plants have the capability to supply energy to millions of people, there is only minimal potential for furthering large hydro systems in the U.S. because the majority of suitable areas have already been developed. Most large hydropower systems take the form of an impoundment facility, where large amounts of water are stored and then gradually released to cultivate energy. Due to limited land availability, the future of large hydro in the United States is restricted to improving existing facilities. In looking at the
development of these impoundment facilities, there is a clear need for vast amounts of land, although there is no ‘blanket’ statistic that adequately covers the average land needed to site a large hydroelectric facility. Different terrain and river depths, along with varying river widths, create different land requirements for each project.

To gain further insight into the diverse area needs of large hydro projects, it is helpful to compare two of the largest plants within the United States: the Grand Coulee dam and the Hoover dam. The Washington Grand Coulee dam located on the Columbia River, has a generating capacity of almost 6,809MW while the Hoover dam in Nevada follows behind with a generating capacity of 2,078MW (Grand Coulee Dam Statistics and Facts, n.d.). Each dam is monumental, with the Grand Coulee even being labeled as one of the modern wonders of the world (Grand Coulee Dam Statistics and Facts, n.d.). However, to display the vast differences in land requirements, insight is gained from looking into the size of the reservoirs created; keeping in mind that much more land is needed for the structure itself, as well as means for transmitting the energy generated.

The Grand Coulee reservoir (Lake Roosevelt) covers approximately 82,300 acres of land in comparison to the Hoover dam, which holds back waters spanning across 157,900 acres (Grand Coulee Dam Statistics and Facts, n.d.; Hoover dam, n.d.). One would think that as the amount of water increases, the more energy output would increase; however, this is not the case with these two as the Grand Coulee generates a much higher amount of electricity. Most examples of large hydro plants follow the patterns of these two dams, in the fact
that many different qualities (terrain and river characteristics) affect land use and ultimately, energy output. As the Colorado River travels through the canyon leading up to the Hoover dam, canyon walls act as additional barriers and streamline the body of water (minimizing the flooding of nearby lands). Conversely, the Columbia River does not have these natural barriers, therefore the water spreads and greater land purchases are needed to contain the impounded waters.

Land requirements for large hydro projects vary in size dependent on the type of land as well as the size of the river. Those developing such large facilities require Congressional approval, for the placement of a dam, followed by an assessment from an engineering team to determine the dam’s actual size (FERC: Off-Limits Sites, n.d.; River Operations Office: Tennessee Valley Authority, Phone Interview, 2012). However, most of the potential for large hydro projects within the United States has already been exhausted, making the future of hydropower in the U.S. likely to be in the form of smaller hydro projects (Hydroelectric power and water use, n.d.). The availability of lands with adequate characteristics for large hydro systems is scarce, limiting further developments to simply improving existing facilities.

Water and Employees

The number of employees needed to implement a hydro facility varies according to project size. After construction is complete, the minimum amount of workers required also varies according to size dimensions and energy output. One example of worker requirements is found in looking at the Hoover dam: where “A total of 21,000 men worked on the dam with an average of 3,500 and a
maximum of 5,218 daily” during construction in the 1930’s (Bureau of Reclamation: Lower Colorado Region - Hoover Dam FAQs, n.d.) As expected, the number of workers required for construction would be much greater than those needed for daily operations; however, due to security concerns the number of daily required operators is unavailable (Hoover Dam, Visitors Center, Phone Interview, 2012).

Finding an adequate amount of water needed to generate 30 MW or more is made complicated by fluctuating river capacities, as well as the speed of their currents. Enormous amounts of water are necessary for large hydro projects; however, these amounts vary according to each facility. In the case of the Hoover Dam, there are four penstocks capable of holding 96,000 gallons of water per second (Hoover Dam, Visitors Center, Phone Interview, 2012). Oftentimes, as shown by the Hoover Dam, a general capacity can be given but the amount of actual water running through on a daily basis is less clear as amounts fluctuate depending on downstream community water needs (Hoover Dam, Visitors Center, Phone Interview, 2012).

Small Hydro

Small hydro refers to hydroelectric systems that produce less than 30 MW. Some agencies classify mini and micro hydro systems in the larger category of small hydro, but for the sake of consistency emphasis will be placed on the Department of Energy’s plant-type classifications to limit confusion (Hydropower Program: Types of Hydropower Plants, n.d.). Small hydropower holds many advantages over large-scale hydropower. It combines “the advantages of hydropower with those of decentralized power generation without the
disadvantages of large-scale installations” (Hydropower Basic: Introduction, n.d.). According to Jon Wellinghoff, the chairman of the Federal Energy Regulatory Commission, "Efforts to reduce carbon emissions and meet the growing number of state renewable energy standards are drawing increased attention to small hydropower project development” (FERC: News Release: FERC looks to ease development of small hydropower projects, 2010).

**Siting Requirements**

*Land*

Similarly to large hydro, the land requirements for citing small hydro projects are very diverse, but for separate reasons. It is true that smaller facilities are also reliant on terrain and river characteristics to determine the land required; but small hydro carries even greater variety in the implementation of such systems. There are many ways to go about creating smaller systems, which can take place as small dams, irrigation pipes connected to turbines, or a series of iconic waterwheels (Riverbank Power: Utah Office, Phone Interview, 2012). These many different systems, classified as small hydro, cause the land requirement to vary for each. One example of a small hydro project is the system implemented in Afton Wyoming which generates $95,435 worth of electricity (DWSRF ARRA Success Story, n.d.). The initial land asked for to run the profitable operation was 10.5 acres, a significant difference compared with the thousands used by large hydro systems (Federal Register/Vol. 73, No. 248, 2008).
**Water and Employees**

Areas where small hydro is applicable include: small industries, farms or households, and rural communities. These are all decentralized locations with small demand for power (Hydropower Basic: Introduction, n.d.). Generally, small hydro utilizes low head sites. In this context, head refers to the distance the water falls before impacting the turbine. For small hydro, the elevation difference is less than five meters (fifteen feet). These types of systems often rely on run-of-river hydropower facilities that utilize the natural flow of stream and rivers. These facilities do not require large dams or reservoirs but some do have a small dam that simply keeps the impounded waters within the river’s banks. Therefore, a natural flow of water continues over the dam.

Small hydro does not have near the costs for energy distribution or to the environment in comparison with large hydro projects. Generally, daily operations are automatic and small hydro facilities require once-weekly maintenance visits to secure that everything is working correctly (Low-Head Hydropower Operation: Resource Requirements and Impact Sources, n.d.). The low operating need cuts employee costs dramatically and makes small hydro even more economically feasible.

Increased use of small hydro projects is expected due to their minimal environmental impact on both land and in the waters they use. Many different options are available to developers looking to implement small hydro systems, with some being as simple as an irrigation pipe leading to a turbine (Riverbank Power: Utah Office, Phone Interview, 2012). The number of hydroelectric systems is expected to rise, thus providing greater energy independence while generating
profits. In 2006 the Idaho National Laboratory assessed 100,000 sites throughout the United States for small hydro capability and determined that approximately 5,400 had potential. The U.S. Department of Energy approximated that if these projects were developed, they would result in more than a 50% increase in total hydroelectricity generation (Campbell, 2010; Feasibility Assessment of Water Energy Resources, n.d.). With this supposed increase of hydroelectric power plants, the dependence the country has on conventional energy such as coal and oil would be decreased dramatically.

**Micro Hydro**

Micro systems are the smallest classification of hydroelectric power according to the Department of Energy (Water Power Program: types of hydropower plants, n.d.). With an energy supply of 100KW or less these systems are not expected to be a major priority for developers. Similarly to small hydro, micro hydropower on this small of a scale is used to power homes, villages, or other small properties, but on a lesser scale (Water Power Program: types of hydropower plants, n.d.). To exemplify the land used by micro systems, it is helpful to look to the lands used by small hydro facilities and realize that micro systems use even less.

The small hydropower system in Afton, Wyoming started out as a community project to tap into the forces behind the town’s culinary water supply (Riverbank Power: Utah Office, Phone Interview, 2012). The original land requested for the project was 10.5 acres of land (DWSRF ARRA Success Story, n.d.). Because Micro hydroelectric systems generate even less energy, it is easily anticipated that micro systems require even smaller portions of land. Some
systems are so simple and small they can even be purchased online and transported to homes across the country and fit within 15 square feet (Energy Systems and Design, n.d.).

Micro hydro is generally used to provide power in remote areas by utilizing water resources available at a specific site. These systems generally use run-of-river systems and therefore do not require a dam. Consequently, they are dependent on the flow available which often varies with the seasons. Run-of-river systems consist of an intake structure which channels water through a pipe or conduit down to the turbines before the water is set free downstream. A generator or alternator controls the speed of the turbine. Generally, at least three feet of head is required with a water flow of approximately twenty gallons per minute to run the turbine efficiently (Campbell, 2010). In addition, no full-time employees are needed but a once a week maintenance visit is suggested (Low-Head Hydropower Operation: Resource Requirements and Impact Sources, n.d.).

**Transmission Requirements**

The current state of large hydro, along with the growing interest in small hydro systems generates an increased need to focus on the transmission requirements to maintain and create these facilities. With advancing technologies, and growing contributions to the electrical grid from multiple renewable sources, hydroelectric developers need to keep transmission in mind when considering implementing new facilities.

In all hydro facilities, volumes of water flow and elevation differences, known as “head,” determine the amount of electricity produced. The produced power can be utilized locally or carried through transmission lines to industrial or
metropolitan areas (Campbell, 2010). As has been previously expressed, there is
great diversity in the implementation of hydroelectric projects, which means that
there is also some diversity in the ways energy is transmitted from those projects
(dependent on the project size). Some projects may require very basic
transmission systems, while others may require more complex systems
dependent on the accessibility or location of the hydroelectric plant.

Hydro-Quebec TransEnergie “...operates the most extensive transmission
system in North America,” and is located in Quebec (TransÉnergie Hydro-Québec,
n.d.). Their systems include 33,630 km of transmission lines, which have
10,850MW of import capacity and 7,994MW of export capacity. The complex
manages this large amount of power through its 514 substations (TransÉnergie
Hydro-Québec, n.d.). This impressive and complex system generates power for
both Quebec and parts of the Northeastern United States (TransÉnergie- Hydro-
Québec. Transmission System Overview, n.d). Although this particular example is
rather large, it is similar to smaller transmissions, which follow the same pattern.

The energy process begins at the project site where the flowing water is
converted into energy, usually through the use of turbines. For large systems, like
the one operated by Hydro-Quebec TransEnergie, such large amounts of energy
are generated that this power must first be converted into smaller amounts
before being transmitted to the electrical grid. This conversion to manageable
amounts takes place within substations, whose purpose is to “reduce its voltage,
and route it [to] the area surrounding it.” (Willis, 1997). Transmission lines are
then connected to these substations and are directly connected to the electrical
Transmission requires many different kinds of employees for large systems, where engineers, system control managers, and linesman all play an active role. Another Canadian hydropower company, Manitoba Hydro, employs an approximate total of 6,500 workers. Of these 6,500, approximately 1,250 deal directly with operating and maintaining the many transmission lines which spread throughout Canada and the Northern United States (Manitoba Hydro, H.R. Department, Phone Interview, 2012).

Hydropower is desirable “due primarily to the fact that once a facility has been built it is one of the least expensive sources of electricity to operate” (Campbell, 2010). Unlike other mainstream electricity sources, hydroelectricity requires no fuel costs; however, dam maintenance is a significant ongoing cost (Campbell, 2010). This cost includes the transmission of electricity as well as water storage for flood control, irrigation, and recreational activities (Campbell, 2010). Hydroelectric facilities have a significant initial cost; however, this cost is arguably worth it when considering the cost of maintenance compared with the profit generated. Transmission lines are required for hydroelectric projects due to the fact that many hydro facilities are in rural areas and need a means of transmitting energy generated. Land and material needs for the implementation of transmission systems vary based on the size of each plant and the amount of energy generated.
Conclusion

While large hydroelectric plants require the largest amount of land, water, and employees for siting and transmission of all renewable energy examined in this study, the potential of large hydro plants in the United States has largely been exhausted. Because of this, any expansion of hydroelectric energy will likely come in the form of small and micro hydro projects. For both of these, a weekly check-up is all that is required for maintenance of the plant. In addition, a water elevation “head” is required for both to ensure proper energy generation.
Oil Shale Energy Resources

Oil shale, sometimes called kerogen shale, is a sedimentary rock that contains organic matter. Oil is extracted from liquid hydrocarbons within the kerogen, which is part of the organic matter within the rock. The oil is extracted through a process called ‘retorting’, where the rock is heated to approximately 700 degrees Fahrenheit in an oxygen-free environment. This heat encourages the kerogen to expel the oil, releasing approximately three quarters of the rock’s total oil content. There are two different methods of retorting—surface retorting and situ retorting. Yield percentages vary slightly, depending upon the specific physical characteristics of the rock.

Oil shale popularity began in the 1970’s during the oil crisis. The new means of power and technology were considered the savior of the industry, however after oil prices fell back down to a more standard normality, oil shale was forgotten and was not developed further. Recently markets have pushed for more oil drilling in the U.S., and the probability of gas and oil prices decreasing are not as likely to happen within the near future, or at least not as dramatic to have a major impact. Oil shale is becoming more widely recognized as an alternative, especially with the quantity that the United States has available. The following represents the process and requirements necessary for the production of oil shale.

Where Oil Shale is Found

Over half of the world’s known deposits of oil shale are located within the United States. These deposits are centralized in the West, appearing in Colorado, Utah and Wyoming. A majority of this shale, 72 percent, is located on federally-
owned lands within a 16,000 square mile area that the three states share. The Bureau of Land Management (BLM) estimates that these deposits contain 2.6 trillion barrels of in-place oil and 1.5 trillion barrels of oil that is recoverable. The grade quality of oil derived from shale varies, depending upon the location and nature of the shale. On average, a ton of shale will yield 15 gallons of oil (BLM, 2012). In order for oil shale to be a reliable resource on a large scale, a great deal of land must be used.

**Siting Requirements**

The siting of oil shale projects is primarily dependent upon regulations imposed by the Environmental Protection Agency. Fortunately for the industry, the process of extracting oil shale produces a relatively small amount of pollution. As a result, the practice receives a certain level of protection under the Clean Air Act’s Prevention of Significant Deterioration provisions (Center of the American West, 2008). These provisions outline the requirements that classify oil shale sites, based on the air quality of the region and the designation of lands in close proximity to the site.

There are two levels of classification in the Clean Air Act for oil shale sites—Class I and Class II. The bulk of existing sites are categorized as Class II, the more lenient of the designations, which permits moderate levels of ambient air pollution in the area. Class I areas are held to a greater standard of air quality because of their close proximity to sensitive, protected lands such as national parks and monuments and areas designated as wilderness (Center of the American West, 2008). To date, there are ten Class I sites in the U.S., primarily in Utah but also in Colorado and Wyoming.
Land Requirements

Since the specific characteristics of the shale dictate how much oil it will produce and also determine what grade it will be it is difficult to pin down precisely how much land is needed to produce a certain amount of shale oil. Estimates of the presence of oil shale in the Washakie Basin in southwest Wyoming reveal as much as 8.7 million tons of in-situ oil shale per square kilometer. In terms of what the shale may actually yield researchers studying Utah’s Unita Basin have calculated that the land contains 214 billion barrels of oil shale in an area sized 5,200 kilometers (Trudell et. al., 1983).

Because the bulk of oil shale is located on federally owned land, the land must be leased in order for extraction operations to take place. The Bureau of Land Management follows a semi-formal process in granting competitive oil shale leases, beginning by notifying state and local governments and interested Indian tribes and inviting comment. The lease applicant must pay a fee before the application will be considered.

Upon payment, the BLM will publish a notice of competitive lease sale dated no later than thirty days prior to the proposed sale. In the application, the applicant must estimate the total surface area of land that will be affected and the source and quantity of water that will be used in the extraction process. The maximum size of an oil shale lease is 5,760 acres. While bidding prices vary, the minimum amount per acre is $1,000. Leases are issued for a period of twenty years but may continue as long as the annual minimum production is met. Leases may also endure for as long as payments in lieu of production are received (43 CFR 3920).


**Water Requirements**

Water is a necessary resource used in the process of oil shale recovery. The Government Accountability Office (GAO) estimates that between four and five barrels of water are needed to produce one barrel of oil shale (Western Resource Advocates, 2010). Water is used in several different ways throughout the process. It is used during drilling and processing procedures and for filling and cooling the heated interval during reclamation. Water is also used on the construction site at large, controlling dust and rinsing the zone inside the freeze wall that keeps the extraction site isolated from seeping groundwater. Potable water is also used to sustain the construction site.

Recent estimates by the GAO indicate that oil shale developed on a large scale would require 378,000 acres of feet of water per year. Recognizing that deposits of oil shale are located in arid, desert areas of the West, the need for water poses a great challenge to such endeavors. To demonstrate this challenge, in a water diversion program called the Colorado Big-Thompson project, average prices per share (0.7 acre feet (860 m³)/share) increased from some $2,000 in 1990 to more than $12,000 in mid-2003 (constant 2001 dollars). The Colorado Big-Thompson project prices from 2001 to 2006 had a range of $10,000 to $14,000 per share, or $14,000 to $20,000 per acre foot. At $10,000 per acre foot, capital costs for water rights to produce 2.5 million barrels per day (400×10³ m³/d) would range between 1.8 to 4.2 billion dollars (Adams, 2004, p.10-12).
Energy Requirements

To measure the energy that oil shale produces we use the energy return on investment (EROI). EROI is the ratio of energy delivered to energy costs. The most reliable studies suggest that the EROI for oil shale falls between 1:1 and 2:1 (Cleveland, 2010, p.2). In comparison, shown is also the EROI of conventional crude oil which is at about 20:1. This places the EROI for oil shale considerably below the conventional crude oil at the wellhead. This conclusion holds for both the crude product and refined fuel stages of processing. Even in its depleted state—smaller and deeper fields, depleted natural drive mechanisms, etc.—conventional crude oil generates a significantly larger energy surplus than oil shale (Cleveland, 2010, p.2).

To see how this measurement occurs, the more technical side must be discussed. The refined fuel delivered is 2333-2475 MJ, or megajoule, per ton of shale. The energy inputs prior to crude transport are 1309-1638 MJ per ton of shale. Thus, resource recovery consumes an amount of energy equal to 53-70% of the energy in the final product. Crude transport, refining, and fuel distribution consume an additional 231-342 MJ per ton, or 9-15% of the energy in the final product. Overall, processing requires 62-85% of the energy in the final product; so production of 100 MJ of oil shale requires inputs of 62-85 MJ along the way. This gives the overall EROI of 1.2-1.6 (Cleveland, 2010, p.16). What this technical jargon means is that due to resource recovery, crude transportation, refining, and fuel distribution of the oil shale, over half of the energy produced is burned in the process of its creation. That is why the EROI is so low, representing a weak and costly fuel to produce.
Manpower Requirements

According to JBR Environmental Consultants, currently there are twenty-five full time employees in state of Utah employed directly with the oil shale industry, which estimates an annual payroll of $1,750,000 (Bayer, 2010, p.2). Those numbers are expected to increase dramatically due to future projects. Both Brazil and Estonia have oil shale investments in the state of Utah, both with planned projects, pending on regulatory procedures.

A 2006 endeavor by Shell Company illustrates the manpower necessary to operate an oil shale project. Shell produced a plan of operation for the Bureau of Land Management to consider the approval an oil shale test project. They estimated that to construct a 160-acre in-situ project would require 720 full time employees. The construction would take up to eighteen to twenty-four months. After the construction phase is through, only 155 full time employees would be required (Oil Shale Test Project, 2006, p.4-22).

Transmission Requirements

Once oil shale is in its final form, it is loaded onto trucks and transported on the highway, limiting transmission costs to the diesel fuel required to power those trucks and the wages for the employees who drive them.

Conclusion

The amount of water needed for oil shale, while quite a bit larger than the requirements for wind energy, is less than the amount necessary for geothermal, solar, and hydroelectric energy. And while oil shale siting land requirements may exceed solar, geothermal, wind, and small and micro hydro energy land requirements, the number of employees required is much higher for oil shale site
construction and maintenance than for the other types of renewable energy discussed in this report. Transmission requirements for oil shale are unique in that they consist solely of costs associated with the transport of oil shale from the supplier to the seller of the oil shale.
Ethanol Resource Requirements

Producing ethanol for fuel is an extremely resource intensive process. The main reason for this is efficiency; it takes 50% more ethanol than gas for the same energy results. Because this energy source is less efficient than petroleum fuel sources it also causes more air pollution. Ethanol actually puts more carbon dioxide into the atmosphere than petroleum when combusted to reach the same energy output. Other problems result from ethanol’s water and land usage. These are very limited non-producible resources that ethanol production requires in huge amounts. We will look at these factors to discuss how ethanol compares as a fuel source to gasoline.

Fuel Efficiency

A major problem with ethanol as a fuel source is that it takes 1.5 gallons of ethanol to produce the same amount of energy as one gallon of gasoline (U.S. Department of Energy n.d.). This inefficiency causes serious problems in all aspects of its use and production because we must burn 50% more of it in our engines than gasoline to get the same return. The answer then is to make higher compression engines that can produce better efficiency. But even if you have a high efficiency high compression engine, it is still 50% better to use that new engine with gasoline than with ethanol. This problem becomes the greatest factor in all the other problems that need to be looked at when using ethanol as a fuel source instead of gasoline.

Air pollution

The second greatest concern for most people in fuel combustion is air pollution. Because ethanol is less efficient than gasoline it releases 19% more CO2
into the atmosphere to achieve equivalent energy in our engines. Proponents of ethanol often ignore this difference in efficiency. Instead they cite the fact that gasoline produces 2.44 kg/l of CO2 when it is combusted while ethanol releases 1.94 kg/l of CO2 when it is combusted. Taken at face value, it appears as though ethanol is a cleaner fuel source, when in fact it is not due to decreased fuel efficiency (Bogdan 2009).

An even greater concern for many people like Stanford Professor Dr. Mark Z. Jacobson, is the release of toxins into the atmosphere, particularly the increase of ozone from burning ethanol. Ozone is a good thing in the upper atmosphere, where a layer of it protects us from harmful radiation, but at ground level it is a serious health concern when we are exposed to it for long periods of time or in high quantities. This increase, especially in cities with many cars, can increase ozone related deaths, hospitalization, and asthma (Jacobsen 2007).

Another surprising effect of growing our fuel is the release of Green House Gases (GHG). GHG are stored in soil when organic material is trapped under the earth (Soil Science Society of America n.d.). As new land is cleared for ethanol production, GHG, mainly carbon, is emitted into the atmosphere. As we increase demand for ethanol, farmers clear new land to grow more crops. Researchers like Timothy Searchinger at Princeton University and scientist Joseph Fargione at the Nature Conservancy explain how these Green House Gasses are released (2008). Fargione warns that the gases released from clearing new land are ninety three times greater than the gases saved by the fuel made annually on the same new land (Rosenthal 2008).
The amount of GHG trapped under the soil depends greatly on the type of land. Arid desolate land such as the Sahara desert has very little organic material trapped in it because very little organic material can grow there. The majority of land that can effectively be converted to farmland is grassland, forest, and wetland. While grassland traps the least organic material in the soil of the three, it is still a significant bank for carbon storage. Forestland is next just a little less effective than wetlands for trapping organic material under the ground because wetlands trap more organic material under water keeping the plants from normal decay. Any of these three have the possibility to collect enough organic material to form peat. Peat is one of the most effective ways to store carbon in the earth. Given enough pressure heat and time it will become coal. When we clear new land that has trapped organic matter in it to grow crops, the GHG that was trapped is now brought to the surface with soil preparation techniques such as tilling and plowing and released into the atmosphere.

**Water and Land Usage**

Increasing the demand for growing crops such as corn and sugar cane increases the need for fresh water to grow them. This is a major concern in many places where we already have water shortages, and can create water shortages in places where new crops are grown. There are two major crops currently being used to produce the vast majority of the ethanol being used, corn and sugar cane. Corn produces 321 gallons per acre, while sugar cane produces 727 gallons per acre (Brazil Institute 2007). Using the data from 2011 regarding yearly motor fuel consumption energy we find that the US would need as much as 207,736,830,000 gallons of ethanol to completely replace petroleum as a fuel
source (assuming we could do a full conversion from gasoline), (U.S Energy Information Administration 2011). In the last census, 922,095,840 acres or 40.8% of the country was farmland (United States Department of Agriculture 2007). Taking the best case scenario, if the United States were to produce 727 gallons per acre, we would need to convert 31% of our farmland to ethanol production to fuel our cars.

The loss of this land from its current use to produce food would increase the price of foodstuffs drastically (ICTSD 2011). It would also force the expansion of our farmland to try to cover the new demand. This transition could result in a greater dependency on imported food. Not only would the costs go up, but we would have even less control over food prices. A much worse problem though is the quality of food we would be consuming. Deadly dog food from China, (Lisa Paddock n.d.) mutant E. coli found in Germany, (B.B.C 2011) and salmonella poisoned Papayas from Mexico (Fair Warning 2011) are just a few examples of problems resulting from imported food. The simple fact is that the less control and fewer inspectors we have during the cultivation, processing, and transportation process, the greater the risk is of contaminated food making it into the market.

The problem is compounded, however, because these numbers are much better than logic dictates. Much of the United States is unsuitable for sugar cane production, leaving us with corn as the other currently used alternative, which is less than half as efficient in the production of ethanol. In addition, the oil we use for our motor gas consumption is less than half of the total oil we use in our day to day lives (U.S Energy Information Administration 2011).
Energy Returned on Energy Invested

There are several factors that must be addressed when looking at ethanol as a fuel source. Regardless of the type of biofuel being produced there are basic costs associated with their production. Seeds must be bought or saved from previous growing seasons. Irrigation canals, pipes, pumps, gates, regulators, and sprinklers are used in many fields. Tractors of various sizes and capabilities must have fuel and maintenance to pull plows, discs, harrows, tillers, levelers, cultivators, planters, fertilizer spreaders, insecticide sprayers, reapers, combines and finally trailers full of the final products. The many trips to, through, and from the fields also must be noted in the accounting. When the product is finally harvested it then must be sent to the distillery to be converted to ethanol.

After the product is distilled into fuel grade ethanol there is the final cost of transporting it to distributor. Through all of these steps there is also the cost of labor. National Geographic has concluded that for every acre of corn converted to ethanol there is a ratio of 1 unit energy put into that acre to receive 1.3 units in return. The return on sugar cane, however, is much higher. In Brazil the ratio is increased to 8 units of return for every single unit of energy used to create the fuel (Joel K. Bourne, Jr. 2007). Unfortunately the climate and water enjoyed in Brazil is found in very few regions of the United States; leaving corn as the option for mass ethanol production in the U.S.

Conclusion

When compared to traditional fossil fuels, ethanol is less efficient and causes more air pollution. In addition, the amount of land and water needed for the production of ethanol is much higher in the United States than in Brazil, a
major producer of ethanol. A comparison of costs associated with the development and production of ethanol indicates that the amount of energy returned on energy invested is roughly six times higher in Brazil than in the United States. A key reason for this is that sugar cane, the main source of ethanol in Brazil, produces more ethanol than corn does, the main source of ethanol in the United States. Because of climatic differences, however, the United States cannot switch from mass corn production to mass sugar cane production. Because of this, Brazil has a distinct comparative advantage over the United States in the production of ethanol.
Biodiesel Resource Requirements

Biodiesel is an organic source replacement fuel for petroleum diesel. Use can be problematic in low temperatures common in the US in winter, as at low temperatures it forms wax crystals which can clog fuel lines and filters. “The ‘cloud point’ is the temperature at which a sample of the fuel starts to appear cloudy, indicating that wax crystals have begun to form” (Radich, n.d.). At even lower temperatures, it becomes a gel which cannot be pumped. “The “pour point” is the temperature below which the fuel will not flow” (Radich, n.d.). Energy efficiency is another problem; the volumetric efficiency (expressed as miles per gallon) is approximately 11 percent lower than that of petroleum diesel. A vehicle running on B20 (the most common blend) are expected to see a 2.2 percent (20 percent blended x 11 percent fuel economy reduction) reduction in miles per gallon of fuel (Radich, n.d.).

Many processes can produce Biodiesel, but there are two most commonly used. The first involves converting vegetable oils or fats to fatty acids, which are then converted to esters. Alternatively, oils or fats can be converted directly to methyl or ethyl esters, using a catalyst to accelerate the reaction (this is referred to as transesterification. Most commonly, the catalyst used is sodium hydroxide (lye), and the reaction is done with methanol. The process produces methyl esters and glycerin (Radich, n.d.). Ethanol can be substituted for methanol, but is generally not because the cost is higher.

Siting Requirements

Barriers to siting a biodiesel refinery are similar to those faced by any fuel refinery. Given the emissions and volatile nature of any combustible fuel, citizens
are generally resistant to any site in close proximity to residences. Furthermore, the Clean Air Act governs operations and registration with the Environmental Protection Agency (EPA) (under 40 CFR parts 79 and 80) to ensure compliance with fuel and emissions standards (Guidance for Biodiesel Producers and Biodiesel Blenders/Users (Guidance), 2007). Properties of the fuel produced are also subject to registration with the EPA and must comply with the standards of ASTM D 6751, or the fuel is considered an unregistered fuel and the company is subject to daily civil penalties (Guidance, 2007).

Numerous other factors influence the siting of a biodiesel refinery including distance from feedstocks, proximity to transportation routes, and accessibility to a power source. These last three are more factors of profitability that influence preferable locations for siting, rather than requirements for doing so. Often both Federal and State required permits must be obtained for compliance with air, water, emissions, fire safety, and (for operations) workforce safety and other regulations. These applications for permits generally take time, and often must be completed and approved before any construction can commence.

Feedstock costs make up 50-60 percent of the operational cost of a typical biofuel facility (Sabrsula, 2007). Utility costs are the next largest factor (20-30 percent), including natural gas and water (Sabrsula, 2007). These factors influence profitability of a production facility, and availability can determine choice of siting. In general, sites are chosen to minimize the distance from feedstock supplies, and distance from major markets (Sabrsula, 2007). Requirements for land vary with the size of the facility being considered. A typical
ethanol plant (comparable to a biodiesel facility) will require 40-80 acres, but some smaller companies have reported sites as small as 10 acres (Sabrsula, 2007). Extremely large production facilities, capable of producing 100 million gallons per year of ethanol (comparable to biodiesel production) require up to 160 acres (trade). Price per acre of land varies across the US. Proximity to rail lines and major road routes also strongly influence selection and profitability of sites (Sabrsula, 2007).

Federal and state incentives and regulations can also have a strong influence on site selection, affecting tax incentives, start-up costs (in the form of grants), and legalities involved in citing (Sabrsula, 2007). Local communities concerns also affect choice of siting, through effects of noise, light, sound, dust, air, and odors on local communities (Sabrsula, 2007).

Soybeans require specific soil type, temperature, and sunlight to grow efficiently. In general, loose soil, a minimum of 55 degrees, and 3-5 months growing season are recommended (National Soybean Research Laboratory (NSRL), n.d.). These requirements are not particularly prohibitive for most potential farming areas, and are not significantly different than that of most other plant types. US average yield in 2010 was estimated at 43.5 bushels per acre, with 77.4 million acres planted, yielding 3.33 billion bushels (U.S. Growers Produce Abundant Crops in 2010 (U.S. Growers), 2011). As with any commodity good, the price of soybeans varies; the price for one bushel (at 10 am on April 30, 2012) was 1363.75 cents per bushel (Soybeans Prices, Grain Prices, n.d.).

In addition to the feedstock costs, the National Renewable Energy Laboratories estimated a cost of 31 cents per gallon (in 2002 cents) (Radich,
Some costs (15 cents per gallon) are recuperated by sale of glycerol (a byproduct of the production process). The production process also uses .083 kilowatt-hours of electricity, and 38,300 Btus of natural gas per gallon (Radich, n.d.). Costs of these inputs were estimated (in 2002 cents) at 18 cents per gallon in 2004, and 16 cents in 2005 and 2006 (Radich, n.d.). Capital costs for a new biodiesel plant are estimated at 13.6 cents per gallon at full output (2002 cents) (Radich, n.d.).

This yields a set of estimated production costs (in 2002 dollars) for 2012 of $2.80 per gallon of soybean oil, $1.55 per gallon for yellow grease diesel, compared to $0.75 per gallon of petroleum (Radich, n.d.). Subsidies (in the form of tax credits, blending credits, and grants), reduce the effective producer cost per gallon. These tax and transfers are, however, borne by the public and create an effective transfer from non-biodiesel using citizens to those who produce and use biodiesel. According to the AFDC, the average nationwide price of B20 in January of 2012 was $3.95 per gallon, while B100 was $4.20 per gallon (in 2012 dollars) (EERE, n.d.). This reflects the “at-the pump” price, with the effects of subsidies already incorporated. If the subsidies are removed, this implies the true price per gallon is approximately $1 per gallon higher ($4.95 for B20, $5.20 for B100), as compared to the price of petro diesel of $3.86 per gallon.

With efficiency accounted for (percent biodiesel x 11% reduction in fuel economy) comparisons for true cost to the consumer can be more accurately reported.
Biodiesel

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<th>B20</th>
<th>B100</th>
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<tr>
<td>Price per Gallon (subsidy) Petro equivalent</td>
<td>3.95</td>
<td>4.20</td>
</tr>
<tr>
<td>Price per Gallon (no subsidy) Petro equivalent</td>
<td>4.95</td>
<td>5.20</td>
</tr>
<tr>
<td>Petro Diesel</td>
<td>3.86</td>
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</table>

Equivalent: Biodiesel achieves 11% fewer miles per gallon in proportion to blend. Prices are therefore adjusted for comparison to petro diesel by (biodiesel %*11%+1)*petro diesel price.

Biodiesel cannot replace much petroleum-based biodiesel without significant impacts on food prices for soybean-based foods. Were the full US production of soybeans dedicated to biodiesel production, only 6% of total national diesel demand could be met (Hill et al., 2006).

Alternative feedstocks are in development that could expand the available supplies and satisfy a greater portion of diesel demand. Nearly any source high in lipids can be converted to biodiesel, with varying degrees of efficiency. Yellow grease (waste grease) can be easily converted, and is the least expensive source however supplies are limited, and this grease is commonly used for a variety of other products (including animal feed, and production of soaps and detergents). Alternatives include rapeseed (canola), mustard, jatropha, palm oil, and algae (Biodiesel, n.d.). Palm oil for biodiesel production is commonly used in Indonesia and Malaysia, but is not well suited climatologically for the United States. Rapeseed oil (or canola oil) has higher value uses than biofuel production, as does mustard seed. While experiments are ongoing with algae based fuels, it has not yet reach commercial scale production (Wisner, 2009).
**Subsidies**

Before December 31, 2009, blender tax credits allowed biodiesel blenders to claim a tax credit against the Federal motor fuels excise tax if a batch of diesel fuel contains biodiesel (Radich, n.d.) For biodiesel sourced from virgin oil (such as soybean oil) the credit allowed was $1 per gallon of biodiesel (Radich, n.d.). Use of yellow grease sourced biodiesel allowed a tax credit of 50 cents per gallon (Radich, n.d.). This tax credit was effectively a tax and transfer system, allowing credits for producers (and users, in effect) which came at a cost to the remainder of the US taxpayers. The “no subsidy” cost reflected in the following chart reflects the price of biodiesel with the $1 tax credit removed. Even with the subsidy in effect, the price per gallon of biodiesel is 9 cents higher than the price of petroleum based diesel. When the reduced efficiency of biodiesel (as compared to petro diesel) is accounted for, the cost is even higher; to adjust for the 11 percent reduction in efficiency, the percentage mix of biodiesel is multiplied by the 11 percent reduction in efficiency (Radich, n.d.). This yields the effective cost in biodiesel to achieve the same effect as a gallon of petro diesel.

The lapse of the biodiesel tax incentive (December 31, 2009) revealed the fundamentally higher production cost of biodiesel, when a 42% drop in production was observed for the 2010 year (Wisner, 2009). Upon reimplementation of the credit in December 2010, production expanded again.

**Conclusion**

Barriers to siting a biodiesel refinery include regulatory demands, citizen resistance, and various other factors including distance from feedstocks, proximity to transportation routes, and accessibility to a power source. These
factors influence profitability of a production facility, and availability can
determine siting choice. The major source of biodiesel in the United States is
soybeans; however, the plant requires specific soil type, temperature, and
sunlight to grow efficiently. In addition, biodiesel cannot replace a large portion
of petroleum-based biodiesel without significant impacts on food prices for
soybean-based foods Alternative feedstocks, including rapeseed (canola),
mustard, jatropha, palm oil, and algae, can be used, but with lesser degrees of
efficiency. Federal and state incentives, regulations, and subsidies can also have a
strong influence on biodiesel site selection and production.
References


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