HONR 229L: Climate Change: Science, Economics, and Governance

Discussion #15: Hydro, Geo & Wind

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Class Web Site: http://www.atmos.umd.edu/~rjs/class/honr229L

ELMS Page: https://myelms.umd.edu/courses/1229919

https://www.pinterest.com/pin/570549846514943581/

25 October 2017

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In the United States, a major effort had been extended to produce ethanol from corn, to supply a more sustainable source of liquid fossil fuel. This policy was motivated by the “United States’ overwhelming dependence on foreign oil” being “a direct risk to national security”. In Brazil, a similar effort was extended to produce ethanol from sugar.

In terms of sustainability, which effort seems better: ethanol from corn or ethanol from sugar?

The *global warming impact of corn is much higher than sugar*, as corn is much less efficient than sugarcane for extracting ethanol. As well, according to the Economist, Brazil's ethanol is cheaper by 8 cents per liter than the US’, at 22 to 33 cents per liter respectively[1].


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In terms of sustainability, ethanol from sugar is much better at cutting carbon emissions and reducing the global warming impact.

Corn-based ethanol accounts for 90% of the nation's biofuels production yet it carries distinct drawbacks. *Corn-based ethanol places energy and food at competition with one another* and is a relatively poor energy producer. In addition, the carbon reduction due to corn is negligible due to the processes needed to plow, grow, harvest, transport, and convert the corn to biofuel.

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Ethanol from sugar also produces 8 BTUs from every 1 BTU input, compared to ethanol from corn, which produces 1.3 BTUs for every 1 BTU input.


http://large.stanford.edu/courses/2010/ph240/luk1/
Investment in biofuels is quite controversial because some scientists argue apparent positive benefits might disappear when scrutinized under the entire life cycle of a large-scale effort. Summarize, in your own words, the tenant of either the August 2007 Science article or the “unintended consequences of biofuels made from a particular oil”, as stated in Chapter 4.

The August 2007 Science article concludes that, even over a 30 year time span, tearing down forests to create biofuels is worse for the environment that just leaving them there. *If left alone, the forests could sequester 9 times the amount of carbon that could be saved through biofuels*, while also preserving biodiversity and unique ecosystems.
Investment in biofuels is quite controversial because some scientists argue apparent positive benefits might disappear when scrutinized under the entire life cycle of a large-scale effort. Summarize, in your own words, the tenant of either the August 2007 Science article or the “unintended consequences of biofuels made from a particular oil”, as stated in Chapter 4.

Krupp & Horn discuss the unintended consequences of biofuels made from palm oil. Palm oil was being use to help countries meet their greenhouse gas targets; however countries producing palm oil, particularly in southern Asia, were destroying their rain forests in order to build plantations. The rain forests were not able to soak up the carbon in the air and return it to the ground like they use to. This resulted in an increase in carbon emissions. It makes sense that there would be a concern over the use of biofuels because there are a lot of potential costs, such as, ironically enough, more carbon emissions from deforestation, that must be considered.
AT 14, Q2b

Investment in biofuels is quite controversial because some scientists argue apparent positive benefits might disappear when scrutinized under the entire life cycle of a large-scale effort. Summarize, in your own words, the tenant of either the August 2007 Science article or the “unintended consequences of biofuels made from a particular oil”, as stated in Chapter 4.

The unintended consequence of palm oil based diesel came about when European countries were subsidizing heavily in the technology to meet their targets for greenhouse emissions. This ... led to massive deforestation in Malaysia and Indonesia for these palm oil plantations, the second of which destroyed a significant carbon sink system called the peatlands, causing billions of tons of carbon to be released back into the atmosphere.

https://news.mongabay.com/2015/01/indonesia-to-weaken-peatlands-protection-to-support-plantations
While your Professor tries to live a low carbon footprint lifestyle (he lives close to work and enjoys a vegetarian diet), it turns out he does incur a significant carbon footprint due to his frequent air travel. Argh! He would very much like to see a breakthrough in the ability to make jet fuel from biomass, because until this occurs his personal carbon footprint will likely remain above the US norm.

Why is jet fuel particularly hard to make from biomass?

Jet fuel is difficult to make from biomass because it must have a low freezing point to withstand cold temperatures in the air while having a high energy density to allow planes to fly long routes. It would be tough to meet both of these requirements when producing jet fuel from biomass.

Nonetheless, research is still being directed to produce jet fuel, which you can read about at http://skynrg.com/sustainability/rationale-sustainable-aviation-fuel
AT 14, Q4 Chapter 5 describes two approaches to obtained combustible fossil fuels from cellulose: use of enzymes and use of thermochemical systems.

a) briefly describe what cellulose is and why so much effort is being extended to extract combustible fuels from cellulose

b) what are the potential advantages of the enzyme approach and what hurdles must be overcome to make this approach viable?

c) what are the potential advantages of the thermochemical approach and what hurdles must be overcome to make this approach viable?

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a) Cellulose is the most prevalent form of carbon found in nature. It is a very long chain of six-carbon glucose molecules. So much effort is being extended to extract combustible fuels from it because it has an excellent energy balance—up to 36 BTUs for each BTU input.

Also, cellulose is good because it's not a [human] food

b) The potential advantages of the enzyme approach are that it is considered green compared to current processes that are utilized and a decrease in cost. Hurdles that must be overcome are finding the proper enzymes to make this an efficient process and creating the infrastructure to be able to carry this out on a massive scale. [source](http://pubs.acs.org/doi/abs/10.1021/jf071724y)

c) The advantage of using the thermochemical approach is that it can take a large range of feedstocks without needing to remix the enzymes and organisms. The largest hurdle is cost. Jack Newman of Amyris stated "It takes billions to build a Fischer-Tropsch plant".

Also, many see this method as releasing more carbon into the atmosphere because of the thermochemical process in the 1920s of converting coal to liquid fuels.

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HONR 229L: Climate Change: Science, Economics, and Governance

AT 14, Q5
Please write a short paragraph that addresses one of the following (but not both!), with particular attention to the sustainability benefits for the course of action.

**Why are researchers in the United States focusing on restoration of the native perennial grasses that once extended across the Great Plains?**

**OR**

Why are researchers so interested in potential uses of algae, nature’s building block, for various applications in the area of biofuels?

Some researchers are focused on restoring the native perennial grasses that were once in the Great Plains because of all the benefits they will have for the environment and biofuels. For starters, these grasses store a lot of carbon in their roots, meaning this plant could take a decent amount of carbon out of the atmosphere. More importantly, this grass would be such a good plant to create biofuels. First, they require little energy to grow and keep up, meaning they have a high net energy output and second because they might actually be carbon negative. This is thought to be the case because they would store more carbon in the roots than what would be produced by the process of making the biofuels. As well, these plants are not food sources, eliminating the chance of a competition between energy and food and they would increase the biodiversity. All around, the native perennial grasses have many benefits.
AT 14, Q5

Please write a short paragraph that addresses one of the following (but not both!), with particular attention to the sustainability benefits for the course of action.

Why are researchers in the United States focusing on restoration of the native perennial grasses that once extended across the Great Plains?

OR

Why are researchers so interested in potential uses of algae, nature’s building block, for various applications in the area of biofuels?

When compared to different biofuel crop like soybeans and corn, algae are significantly more efficient to use. For example, an acre of soybeans yields about 60 gallons of biofuels while an acre of algae could yield 5,000 gallons of biodiesel and ethanol in a year. Finally, algae filter nitrogen oxides and carbon dioxides into less harmful substances, which reduces the amount of pollutants and greenhouse gases in the atmosphere.

Algae solves many of the problems other biofuels face. It can grow anywhere, even in waste water, eliminating the need to clear land. Secondly, algae grows extremely fast and cleans pollutants like CO₂ and nitrogen oxide at extremely high rates. Finally, algae can be used to create carbon-efficient and energy dense biofuels, even comparable to coal. As stated by Arizona Public Services’ Ray Hobbs, with the right policies and restrictions, algae can be burned, grown, and burned again in a fully sustainable cycle, serving as the answer to climate change and greenhouse emissions.
The Price is Wrong

• Which source of renewable energy sources in today’s reading requires us to pay the least price in terms of GHG emissions?

• Which source of renewable energy requires us to pay the most?
Table 12. Reported GHG estimates for RETs (IPCC, UK and this study).

<table>
<thead>
<tr>
<th>Renewable energy technology (RET)</th>
<th>Life cycle GHG estimates (gCO₂-eq/kWhₑ)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>IPCC</td>
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<tr>
<td>Wind – Onshore</td>
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<td>Wind – Offshore</td>
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<td>Hydro</td>
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<td>Wave</td>
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<td>Tidal</td>
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<tr>
<td>Geothermal</td>
<td>45</td>
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<tr>
<td>Photovoltaic</td>
<td>46</td>
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<tr>
<td>Solar thermal</td>
<td>22</td>
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<tr>
<td>Dedicated biomass</td>
<td>18</td>
</tr>
<tr>
<td>Waste treatment</td>
<td>–</td>
</tr>
</tbody>
</table>

Most “Green” to Least (IPCC Estimates)

1. Hydro Power (1)
2. Wind Power (onshore) (2)
3. Biomass
4. Solar Thermal
5. Geothermal (3)
6. Solar PV

http://www.sciencedirect.com/science/article/pii/S1364032114005395#f0005
https://ars.els-cdn.com/content/image/1-s2.0-S1364032114005395-gr4.jpg
Study from the James Hutton Institute, U.K.

Amposah et al.
http://www.sciencedirect.com/science/article/pii/S1364032114005395#f0005
Figure 8.1 (a) Share of renewables in the world total primary energy supply (TPES) in 2005; (b) share of renewables in world electricity production in 2005. (Source: IEA Renewables Information 2007.)

Source: Olah et al. 2005
World Electricity Production

Figure 4: Fuel shares in world electricity production in 2014

- Coal: 40.7%
- Natural Gas: 21.6%
- Nuclear: 10.6%
- Renewables: 22.3%
- Oil: 4.3%
- Biofuels and waste: 1.8%
- Other Renewables: 4.2%
- Hydro: 16.4%
- Other: 0.4%

US Electricity Production

Sources of Electricity Generation
United States - 2016

Sources of Electricity Generation
Maryland - 2016

http://www.c2es.org/technology/overview/electricity
https://commons.wikimedia.org/wiki/File:Maryland_Electricity_Generation_Sources_Pie_Chart.svg
Hydroelectricity

• How is the energy of moving water converted into electricity?

• What electromagnetic principle allows hydroelectric plants to create electricity?

https://www.pinterest.com/explore/electromagnetic-induction/

Faradays Law of Induction

Kiersn Mckenzia
**Hydroelectricity**

**Q1:** Hydroelectricity is currently the world’s most used renewable energy source for the production of electricity. According to Olah et al.

a) what was the percentage share of hydroelectricity for world electricity production in 2005?

16.0–17.0%

b) what percentage of the overall potential of world hydroelectricity was being tapped in 2005?

Only 18%?!?!

**Q2:** Based on the numbers given in reply to Question 1, if the world's governments decided to fully exploit the available potential to generate electricity via hydroelectric plants, approximately how much of the world electricity demand could be met?

89—94%! 
Cost Benefit Analyses: Hydro

Q3: What would be some of the criticisms, both socially and environmentally, to a decision by the world’s governments to fully exploit the available potential to generate electricity via hydroelectric plants?

Environmental Criticisms

- Flooding out ecosystems
- Habitat loss
- Biodiversity loss
- Soil and Nutrient Sedimentation
- GHG release from water damming and deforestation
  - Which two primarily?
- Effects of stagnant or near stagnant water
  - Water chemistry shifts
  - Change in natural water temperature
  - Significantly altered river flow

Social Criticisms

- Population Displacement
- Proliferation of Water-borne diseases
- Pretty dang expensive

http://masterman7thscience.pbworks.com/w/page/77795072/7-3%20Hydropower%C2%A0versus%C2%A0Coal
https://www.eia.gov/kids/energy.cfm?page=hydropower_home-basics-k.cfm
Hydroelectric Super-projects: Itaipú vs. Three Gorges Dam

- Itaipú, 14 000 MW. Where?
  - Built 1975 to 1991
  - Volume of iron and steel: enough to build 380 Eiffel Towers
  - Volume of concrete: $15 \times$ that of Channel Tunnel between France and England

- Three Gorges Dam, Yangtze River, China: 22,500 MW
  - Fully operational in 2012
  - Cost: $22.5 billion or 1 million $ / MW
  - Largest construction project in China since Great Wall
  - 1 million people displaced
  - Provides $\approx 1.7\%$ of China’s electricity needs?


Typical coal plant: 550 MW
Typical nuclear plant: 1000 MW

Paraná River, South America (Border between Brazil and Paraguay)
Hydroelectric Super-projects:
Three Gorges Dam
Hydro in China and Paraguay: What’s the Difference?

• What percentage of Brazil and Paraguay’s energy supply is obtained from Itaipú, respectively?

  25% and 78%

• Why does Paraguay get so much more energy from one hydroelectric plant than does China? What’s different between the two nations?

China’s Population: ~1.3 Billion
Paraguay’s Population: ~6.7 Million

China’s GNI: $15,500
Paraguay’s GNI: $9,060

https://data.worldbank.org/indicator/NY.GNP.PCAP.CD
Geothermal Energy
Geothermal Energy

Where are the best locations to find geothermal energy in the US?

Should this be an important consideration in possibly building more plants?

Geothermal Energy

Geothermal Power Generation
Current and Planned Nameplate Capacity (MW) by State

Current and planned capacity additions are from the Geothermal Energy Association (GEA, February 2015, Figure 3). Total installed capacity is 3,322 MW and total planned capacity addition is 1,275 MW.

Geothermal Energy Production Outside the US

The US is #1 in the world in geothermal energy production. Which country is #2?

Figure 8.5 Geothermal electricity production, 2005. (Source: Bertani, R. [103].)
Where are the Philippines?

https://www.quora.com/How-was-the-Pacific-ring-of-fire-formed-Why-is-it-so-unstable
Q4. According to Olah et al., the United States was the leader in terms of electricity production from geothermal energy, producing 18,000 GWh of energy.

a) Assuming our geothermal plants operated 24 hours a day, 7 days a week, and 52 weeks a year, what is the power (size) provided by this nation’s geothermal plants?

\[
\frac{18000 \times 10^9 \text{ Wh}}{365 \text{ days} \times 24 \text{ hours per day}} = 2.05 \times 10^9 \text{ W or 2.05 GW}
\]

b) Assuming the average power (size) of a coal power plant in the United States is that given at http://www.ucsusa.org/clean_energy/coalvswind/c01.html#.VjB CyuOWYc and that these coal plants run 24/7/52, how many coal power plants are being displaced by this nation’s reliance on geothermal electricity

\[
\frac{2.05 \text{ GW all geothermal plants}}{547 \text{ MW per coal plant}} = \frac{2.05 \text{ GW all geothermal plants}}{0.547 \text{ GW per coal plant}} = 3.75 \text{ coal plants}
\]
Is geothermal truly a renewable energy source?
Cost Benefit Analysis: Geothermal Energy

Q5:

a) What gas constitutes 90% of the effluent of a geothermal plant?

**Carbon Dioxide!**

b) What is the ratio of the release of this gas from a geothermal plant compared to the amount generated by a typical fossil fuel power station?

Geothermal plants generate about 3 to 10 times less grams of CO$_2$ per kWh (at 122 gkWh$^{-1}$) than an average fossil fuel power station.

c) What can be done about the release of this gas to the atmosphere from geothermal plants?

Carbon dioxide can be captured in high percentages since it comes from a "high concentration source" or it can be sequestered and even used to manufacture chemicals like methanol.

d) Are you surprised to learn about this nuance of geothermal plants?
What happened at this drill site in December 2006? Why?

http://energie.deangeli.ch/Logo/Kleinhueningen.jpg

http://archiv.ethlife.ethz.ch/e/articles/sciencelife/Interview_Deichmann_SED.html
Is geothermal energy production even **worth it**?
Wind Energy

How would you summarize electricity production by wind power?

What is the most important factor is planning a wind farm?

How are these two velocities different?
Wind Power: Betz’s Law

Figure 1: Power Available from the Wind

Velocity is cubed

http://people.bu.edu/dew11/windasenergy.html
Wind Power: Worldwide Proliferation

Q6: According to Olah et al., electricity from wind is the fastest-growing energy source in the world.

a) What is the ratio of installed wind capacity at the end of 2007 compared to 1992, and where has most of this growth occurred?

The installed wind capacity in 2007 was 90,000MW compared to 2500 MW in 1992, a 36:1 ratio. Most of the growth has occurred in Europe.

b) According to the reading, what are some of the challenges that must be overcome, if the world is to more fully realize the promising future for electricity generation via wind?

Wind energy is highly variable/seasonal, which makes wind electric production in some places exceedingly difficult. Some members of the public find wind turbines aesthetically unappealing and noisy. Furthermore, building wind turbines offshore where they are most productive is considerably more expensive than offshore projects. Finally, the electricity from wind turbines cannot be stored with current technology and therefore must be fed directly into the power grid which raises issues of logistics for supplying power to more remote regions in nations.
Wind Potential in the US

This map shows the annual average wind power estimates at a height of 50 meters. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.

[Map image]

What do you notice that is different for the wind potential chart vs. the geothermal potential?
Why aren’t there wind farms everywhere?

- Would you want to live near a wind farm?
- Would you want to vacation near one?

https://mdcoastdispatch.com/2014/08/21/offshore-wind-farm-lease-areas-auction-for-8-7m/
HONR 229L: Climate Change: Science, Economics, and Governance

Hydro, Geo & Wind: Last Word

Ross Salawitch
Hydro

### Annual Production of Electricity, Three Gorges Dam

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of installed units</th>
<th>TWh</th>
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<tbody>
<tr>
<td>2003</td>
<td>6</td>
<td>8.607</td>
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<tr>
<td>2004</td>
<td>11</td>
<td>39.155</td>
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<td>2005</td>
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<td>49.090</td>
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<td>2007</td>
<td>21</td>
<td>61.600</td>
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<td>2008</td>
<td>26</td>
<td>80.812</td>
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<td>2009</td>
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<td>79.470</td>
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<td>2010</td>
<td>26</td>
<td>84.370</td>
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<td>2011</td>
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<td>2012</td>
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<td>2013</td>
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<td>83.270</td>
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• Three Gorges Dam, Yangtze River, China: 22,500 MW
  – Fully operational in 2012
  – Cost: $22.5 billion or 1 million $ / MW
  – Largest construction project in China since Great Wall
  – 1 million people displaced
  – Now provides ~1.7% of China’s electricity needs

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If Three Gorges had run 24/7/52 for a year at full capacity, then: 

\[
22,500 \text{ MW} \times 8760 \text{ hr} = 1.97 \times 10^8 \text{ MWh of energy would have been produced}
\]
Hydro

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22,500 \text{ MW} \times 8760 \text{ hr} = 1.97 \times 10^8 \text{ MWh} = 1.97 \times 10^8 \text{ MWh} \times (\text{TW} / 10^6 \text{ MW}) = 197.1 \text{ TW hr}
\]
### Hydro

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</tr>
<tr>
<td>2015</td>
<td>32</td>
<td>87.000</td>
</tr>
<tr>
<td>2016</td>
<td>32</td>
<td>93.500</td>
</tr>
</tbody>
</table>

If Three Gorges had run 24/7/52 for a year at full capacity, then:

\[
22,500 \text{ MW} \times 8760 \text{ hr} = 1.97 \times 10^8 \text{ MWh} = 1.97 \times 10^8 \text{ MWh} \times \left(\frac{\text{TWh}}{10^6 \text{ MW}}\right) = 197.1 \text{ TW hr}
\]

During best year, Three Gorges produced 98.8 TW hr

#### Three Gorges Dam, Yangtze River, China: 22,500 MW
- Fully operational in 2012
- Cost: $22.5 billion or 1 million $ / MW
- Largest construction project in China since Great Wall
- 1 million people displaced
- Now provides ~1.7% of China’s electricity needs

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During best year, Three Gorges produced 98.8 TW hr

Capacity Factor = \frac{98.8 \text{ TW hr}}{(197.1 \text{ TW hr})} = 0.50

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of installed units</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>6</td>
<td>8.607</td>
</tr>
<tr>
<td>2004</td>
<td>11</td>
<td>39.155</td>
</tr>
<tr>
<td>2005</td>
<td>14</td>
<td>49.090</td>
</tr>
<tr>
<td>2006</td>
<td>14</td>
<td>49.250</td>
</tr>
<tr>
<td>2007</td>
<td>21</td>
<td>61.600</td>
</tr>
<tr>
<td>2008</td>
<td>26</td>
<td>80.812 [54]</td>
</tr>
<tr>
<td>2009</td>
<td>26</td>
<td>79.470 [55]</td>
</tr>
<tr>
<td>2010</td>
<td>26</td>
<td>84.370 [56]</td>
</tr>
<tr>
<td>2011</td>
<td>29</td>
<td>78.290 [57]</td>
</tr>
<tr>
<td>2012</td>
<td>32</td>
<td>98.100 [58]</td>
</tr>
<tr>
<td>2013</td>
<td>32</td>
<td>83.270 [59]</td>
</tr>
<tr>
<td>2014</td>
<td>32</td>
<td>98.800 [60]</td>
</tr>
<tr>
<td>2015</td>
<td>32</td>
<td>87.000 [61]</td>
</tr>
<tr>
<td>2016</td>
<td>32</td>
<td>93.500 [62]</td>
</tr>
</tbody>
</table>
• Three Gorges Dam, Yangtze River, China: 22,500 MW

• Itaipú, Paraná River, South America: 14,000 MW

Capacity Factor of Itaipú = 103.1 TW hr / (157.7 TW hr) = 0.65

### Annual Production of Electricity, Itaipú Dam

<table>
<thead>
<tr>
<th>Year</th>
<th>Installed units</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>18</td>
<td>90.001</td>
</tr>
<tr>
<td>2000</td>
<td>18</td>
<td>93.428</td>
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<tr>
<td>2001</td>
<td>18</td>
<td>79.300</td>
</tr>
<tr>
<td>2004</td>
<td>18</td>
<td>89.911</td>
</tr>
<tr>
<td>2005</td>
<td>18</td>
<td>87.971</td>
</tr>
<tr>
<td>2006</td>
<td>19</td>
<td>92.690</td>
</tr>
<tr>
<td>2007</td>
<td>20</td>
<td>90.620</td>
</tr>
<tr>
<td>2008</td>
<td>20</td>
<td>94.684</td>
</tr>
<tr>
<td>2009</td>
<td>20</td>
<td>91.652</td>
</tr>
<tr>
<td>2010</td>
<td>20</td>
<td>85.970</td>
</tr>
<tr>
<td>2011</td>
<td>20</td>
<td>92.246[^23]</td>
</tr>
<tr>
<td>2012</td>
<td>20</td>
<td>98.287[^24]</td>
</tr>
<tr>
<td>2013</td>
<td>20</td>
<td>98.639[^2][^25]</td>
</tr>
<tr>
<td>2014</td>
<td>20</td>
<td>87.8[^2]</td>
</tr>
<tr>
<td>2015</td>
<td>20</td>
<td>89.2[^26]</td>
</tr>
<tr>
<td>2016</td>
<td>20</td>
<td>103.1[^27]</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>2,415.781</td>
</tr>
</tbody>
</table>

Capacity Factors for Assorted Energy Systems

Source: DOE and NREL “Transparent Costs Database”
Note: Blue dots represent estimate for the average capacity factor of each technology.

http://www.lightevolution.co.uk/blog/geothermal-visual-capacity-factors-for-assorted-energy-systems/
Hydro

Three Gorges Dam has a maximum generating capacity of 22,500 megawatts (MW) and Itaipú Dam has a maximum generating capacity of 14,000 MW.

Over a year long periods of time, both dams generate about the same amount of electricity because seasonal variations in water availability on the Yangtze River in China limit power generation at Three Gorges Dam for a number of months during the year.

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<thead>
<tr>
<th>Year</th>
<th>Installed units</th>
<th>TWh</th>
</tr>
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<tbody>
<tr>
<td>1984</td>
<td>0–2</td>
<td>2.770</td>
</tr>
<tr>
<td>1985</td>
<td>2–3</td>
<td>6.327</td>
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<td>1986</td>
<td>3–6</td>
<td>21.853</td>
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<tr>
<td>1987</td>
<td>6–9</td>
<td>35.807</td>
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<td>1988</td>
<td>11–12</td>
<td>49.295</td>
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<tr>
<td>1999</td>
<td>18</td>
<td>90.001</td>
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<td>18</td>
<td>87.971</td>
</tr>
<tr>
<td>2006</td>
<td>18</td>
<td>88.928</td>
</tr>
</tbody>
</table>

[https://en.wikipedia.org/wiki/Itaipu_Dam](https://en.wikipedia.org/wiki/Itaipu_Dam)

• Three Gorges Dam, Yangtze River, China: 22,500 MW
• Itaipú, Paraná River, South America: 14,000 MW
Hydro

DOE estimates over 65 gigawatts (GW) of potential new hydropower in the US, across more than three million rivers and streams.

http://energy.gov/articles/energy-dept-report-finds-major-potential-grow-clean-sustainable-us-hydropower
http://nhaap.ornl.gov/sites/default
Wind

Timmons, Harris, and Roach state, when writing about wind:

Noise and bird mortality may be mitigated by appropriate siting of wind facilities, though wind power is not completely flexible in siting, given the need to be in the windiest locations. Aesthetic impact is not easily mitigated, as wind power requires large structures that are not easily hidden. But perhaps all beauty is subjective, and some of us find wind turbines attractive, in part because of the renewable energy transition they represent. Offshore wind energy is a renewable energy resource with the potential for fewer negative externalities than onshore (see Box 3).

They also devote a page, their “Box 3”, to offshore wind power in Cape Cod, Massachusetts (many of their examples are from Mass; Tufts Univ is in Medford, Mass)
Offshore Wind, Massachusetts

Project in financing & final commercial contracting stage after having won 17 legal challenges.

15 year Power Purchase Agreement in place between Cape Wind Assoc. & National Grid and NSTAR, both approved by the Massachusetts Department of Public Utilities

130 wind turbines would be located in shallow water of the Nantucket Sound, with a capacity of 468 MW and an expected annual output of 174 MW, which is about 75% of the electricity demand for Cape Cod, Martha’s Vineyard and Nantucket.

http://www.capewind.org
Offshore Wind, Massachusetts

Graphic Map & Visual Simulations

Cape Wind will be located on Horseshoe Shoal off the coast of Cape Cod. Hyannis will be over five miles away—and most of the Cape beaches will be further away. The wind turbines will be visible one half-inch above the horizon on clear days.

http://www.capewind.org
Offshore Wind, Maryland

Two projects under development for offshore wind in Maryland:

U.S. Wind, a subsidiary of Italian Toto Holdings plans to place 62 turbines at least 14 miles off the coast of Ocean City, with operations expected to start in 2020 that would yield 750 MW (project cost $1.3 billion)

Skipjack Offshore Wind LLC plans to place 15 turbines 19.5 miles from shore and 26 miles from the Ocean City Pier, with operations expected to start in 2022 that would yield 120 MW (project cost $720 million)

http://www.4coffshore.com/windfarms/skipjack-united-states-us4z.html
Offshore Wind, Maryland

NIMBY alive and well:

Maryland Politics

Rep. Andy Harris erects new obstacle in path of Md. wind-farm projects

By Rachel Siegel  July 22  

At least one of two offshore wind projects approved by Maryland utility regulators in May could be in jeopardy after an amendment sponsored by Rep. Andy Harris (R-Md.) that seeks to push the turbines farther from the coast was approved by the U.S. House Appropriations Committee in the past week.

The amendment would block the use of federal funds to conduct reviews of site assessments or construction plans for any turbines closer than 24 nautical miles from the shoreline — funding that officials from one of the projects said is crucial to executing the program.

In May, the Maryland Public Service Commission approved subsidies for two projects off the coast of Ocean City — managed by U.S. Wind and Skipjack Offshore Energy — that would be the largest of their kind in the country.

Offshore Wind, Maryland

NIMBY alive and well:

Wind

Timmons, Harris, and Roach state, when writing about Wind:

perhaps all beauty is subjective; some of us find wind turbines attractive
Wind

Samsø, Denmark

- 40 square miles
- 4000 inhabitants
- wind power, on-shore and off-shore, key components of world’s first carbon neutral community


Photo: Page 74, June 2008 National Geographic
Geothermal Electricity

2017 starts with new record for geothermal energy production in

![Sasso 2 geothermal plant by Enel Green Power, (source: Volcanex)](image)

The year of 2016 has been yet another record year for geothermal energy production in Italy. The 34 geothermal power plants have produced 51 GWh more in 2016 than they did in 2015 for a grand total of 5,871 GWh.

Alexander Richter
Geothermal Electricity

2017 starts with new record for geothermal energy production in Tuscany, Italy

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Sasso 2 geothermal plant by Enel Green Power, Tuscany, Italy (source: Volcanex)

Geothermal Electricity

2017 starts with new record for geothermal energy production in Tuscany, Italy

Reverse engineering:

\[ 5871 \times 10^9 \, \text{W hr} / 8760 \, \text{hr} = 6.7 \times 10^8 \, \text{W} \text{ if these plants ran at full capacity} \]

\[ 6.7 \times 10^8 \, \text{W} \times \text{MW} / (10^6 \, \text{W}) = 670 \, \text{W} \]

670 W is nearly the size of a single coal power plants

Number of coal power plants in the world =

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Number of coal power plants in the world = 1,443

http://globalenergyobservatory.org/list.php?db=PowerPlants&type=Coal

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Number of coal power plants in the world = 1,443

US: 647 (total size of 382 GW)  China: 80 (total size of 156 GW)

http://globalenergyobservatory.org/list.php?db=PowerPlants&type=Coal

Sasso 2 geothermal plant by Enel Green Power, Tuscany, Italy (source: Volcanex)

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Low Earth Geothermal *Heating*

Winter: pump drives fluid to transfer energy from ground to building

http://geothermal.marin.org/geopresentation/sld102.htm
Low Earth Geothermal *Cooling*

Summer: pump reverses direction, drives fluid to transfer energy from building to ground

http://geothermal.marin.org/geopresentation/sld103.htm
Geo-thermal heating/cooling at local church:

Paint Branch Unitarian / Universalist, Adelphi, Md
Geo-thermal heating/cooling at local church:
Structure heated and cooled by geothermal
6 units, installed 2005 at cost of ________?
Geo-thermal heating/cooling at local church:
Structure heated and cooled by geothermal 6 units, installed 2005 at cost of $200,000!