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

Discussion #13: Biofuels

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16 October 2018
The Krupp and Horn (KH) book (first published in 2008; the paperback editions are dated 2009 and 2010), industry research firm Clean Edge makes a prediction of the total installed capacity for solar photovoltaics (PV) in year 2015.

a) What was the prediction?

b) What was the actual worldwide installed capacity reached at the end of year 2016, according to wiki [https://en.wikipedia.org/wiki/Photovoltaic](https://en.wikipedia.org/wiki/Photovoltaic)?

Also, do you think Fred Krupp and Miriam Horn would be pleased with what has actually happened?

I think that Krupp and Horn would be thrilled with the actual solar base in 2016 being over four times larger than their 2008/9 prediction. However, they acknowledged that their 75 GW figure would only account for around 0.5% of the global 2015 energy demand, and "a more rapid expansion will almost certainly require the next-generation photovoltaic technologies now emerging from labs into the commercial market." Although Krupp and Horn's prediction for gigawatts of solar photovoltaics installed was significantly exceeded, I think that solar still has yet to enter the mainstream market on a large scale (at least in the United States), based on my experience seeing very few private residences making use of photovoltaic technology. If solar energy had truly reached competitive pricing with energy produced by coal, I think I would have seen more solar technology being purchased by price-conscious consumers.
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a) Clean Edge predicts that the solar photovoltaic industry will reach "a total installed base of 75 gigawatts," which would supply just 0.5% of the total amount of energy needed for that year.

b) At the end of 2016, worldwide capacity reached 300 gigawatts, which supplies about 2% [more precisely 1.5% according to table presented last discussion] of the energy needed worldwide.

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Comparisons are based on Levelized Cost of Electricity (LCOE), a quantity that reflects present value of the unit-cost of electricity over the lifetime of a generating asset (generally taken as 20 to 40 years, which we can simplify to 30 years). LCOE considers fuel costs (0 for solar), capital costs, and discount rate (interest earned based on balance at the end of an accounting period), but neglects external costs of environmental impact of a particular method for generating electricity.

Since entire cost of solar has to be borne upfront and the environmental impact of coal is not considered, solar energy is not as widespread as one would think despite the academic argument it has indeed reached a price that is competitive with coal.
The KH book gives a numerical value for how much the price per peak watt for solar energy must be, for solar energy to be able to compete with “coal-fired electricity virtually everywhere”. This number appears twice in the reading; also the wiki page provides the same price per peak watt cost for solar energy to achieve economic parity with the grid.

a) what is the price per peak watt for solar energy needed to achieve cost parity with coal?

b) according to [http://solarcellcentral.com/markets_page.html](http://solarcellcentral.com/markets_page.html), when was this parity achieved?

c) according to KH, what other additional critical hurdle must be overcome to enable solar-generated electricity to compete with coal-fired electricity virtually everywhere?

a) $1 per Watt for price of PV module

b) 2011

c) *energy storage to overcome intermittency*
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b) 2011

c) energy storage to overcome intermittency

Scientists are still working on the storage issue. There are many ideas, but few implementations at needed scale. The best long-term success of which I am aware is described at: http://www.wbur.org/bostonomix/2016/12/02/northfield-mountain-hydroelectric-station


Northfield Mountain is a naturalist's wonderland. But if you look around, you'll see an unnatural site: a 5-billion-gallon battery.
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AT 12a, Q3 & 4

The KH book tells the story of three companies, led by Conrad Burke, Dave Pearce, and Bill Gross. State the name of these companies and for each provide a succinct description of the innovation each was attempting to bring to market. Then pick one of the companies and state what has happened since the time the book was written.

Conrad Burke is the CEO of Innovalight, one of the few solar companies still using silicon in production. However, Burke and his company are attempting to use nanotechnology---engineering at the atomic scale---in order to overcome the traditional problems of using silicon. Normally, purified silicon's market properties have caused companies who utilize it in production to be haunted by the material's unstable prices and quantities. However, Innovalight, by making micrograms of nanosilicon powder from cheap, plentiful sources, has been able to dodge many of these issues. Additionally, nanosilicon is much more effective than its macro counterpart: it is easier to melt and produce in addition to being able to tap into the sun's full spectrum.

Soon after the book was written, Innovalight had pivoted from aspiring to be a module manufacturer to selling their silicon ink as a raw material to build modules [with royalties]. They were able to raise $60 million from investors.

In 2009, the company enhanced the efficiency of a solar cell to 18%. In 2010, the company signed a deal with Yingli Solar, a Chinese solar energy company. The year after, Innovalight was acquired by DuPont in 2011. Today DuPont is one of the top leaders in solar cell efficiency, which can be partly attributed to the acquisition of Innovalight.

https://www.greentechmedia.com/articles/read/innovalight-successful-solar-startup-troubling-exit
http://www.180degreecapital.com/innovalight-inc-acq-dupont/

Text below from first website given above:

He added that Innovalight wants to extract cents per wafer based on its proprietary material, and there is no way the Chinese vendors will do that -- they have too many other options for high efficiency cells that just mean buying capital equipment and having no ongoing costs associated with license fees of proprietary material.
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State the name of these companies and for each provide a succinct description of the innovation each was attempting to bring to market. Then pick one of the companies and state what has happened since the time the book was written.

Dave Pearce is the founder and former CEO of Miasolé, a company that uses a compound semiconductor known CIGS to create panels. This solar company uses a CIGS semiconductor (copper, iridium, gallium, and selenium) in place of silicon. This CIGS film has the same PV effect as a silicon wafer that can be 2-3 hundred times thicker. Miasolé’s innovation is able to gather more sun light at low sun angles and on cloudy days. Their plan is to make these CIGS films simple enough for their average customer to place in their home. Additionally, they want to use this film as the roof.

In October 2009 Miasolé became the first CIGS thin-film model to be simultaneously certified by UL to the three most critical certification standards. In December 2010, Miasolé held the record for efficiency on large area production CIGS module at 15.7% and was in the production with 13% efficiency. By May 2012 Miasolé had established a record for flexible PVC models as commercial size of 15.5%.

A Chinese multinational renewable energy company named Hanergy bought Miasolé for $30 million in 2014. On September 21st, 2018, the company has completed Europe’s biggest thin film solar project in the Netherlands.

Miasolé/Hanergy is holding a philanthropic project that is providing lighting to African children. Using the Humbrella, which is a thin solar panel that can used to generate power during times of high or low sunlight. These off-grid sources of power can help the lack of energy in Africa and allow children to have longer periods to time to read. On a wider scale, Hanergy focuses on producing solar back packs, solar road, and other innovative methods to integrate solar power into our world.

https://en.wikipedia.org/wiki/Miasolé

Text below from second website given above:

“Lighting Africa” is a philanthropic project initiated by Hanergy and joined by China Foundation for Peace and Development this April in Beijing, aiming to provide environmental-friendly lighting devices to African children to improve their reading time and help the electricity deprived populations in Africa.
AT 12a, Q3 & 4

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Bill Gross is the CEO of Energy Innovations, which designs optical devices that focus light onto a solar cell in order to maximize sunlight energy.

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Energy Innovations no longer exists, because technology of concentrated solar PV is not yet ready to compete with old fashioned static solar PV on a cost or performance basis.

http://www.ejewel.com/our_companies/show/all/energy_innovations
https://www.greentechmedia.com/articles/read/CPV-Startup-Energy-Innovations-Seeking-Strategic-Acquirer#gs.KC8yNmw

Solar Efficiencies per unit area

1) The size of a **standard PV** panel used for one of my projects is 62 inches by 37.5 inches and the peak output of the panel is 230 Watts at noon for clear sky conditions.

   Area of a panel: 62 inches \times 37.5 \text{ inches} \times \text{m}^2 / 1550 \text{ inch}^2 = 1.55 \text{ m}^2 

   Therefore, output of a panel is 233 Watts / (1.55 \text{ m}^2) = 150 \text{ W m}^{-2}

2) Nevada Solar One **Concentrated Solar** Energy power plant has a peak output of 64 MW (64\times 10^6 \text{ W}) and the facility covers 400 acres (1.6\times 10^6 \text{ m}^2).

   Therefore, peak output of Nevada Solar One is 64 \times 10^6 \text{ W} / (1.6 \times 10^6 \text{ m}^2) = 40 \text{ W m}^{-2}
PV Efficiency

Panel efficiency is $150 \text{ W m}^{-2} / 1370 \text{ W m}^{-2}$ or 11%. In other words, peak output is only 11% of incident solar radiation. Capacity factor based on real data is 13.1% over 8 years (Univ Park Church of Brethren) and 12.7% over 4.5 years (Univ Park Elementary School).

Therefore, only $0.11 \times 0.13 = \sim 1.4\%$ of incident noontime sunlight on a clear day has been turned into electricity. Our systems are typical of commercial, rooftop solar PVs.
PV Efficiency

Effective Temperature

Nevada Solar One efficiency is $40 \text{ W m}^{-2} / 1370 \text{ W m}^{-2}$ or 3%

Nevada Solar One has achieved a capacity factor of 21%

About $0.03 \times 0.21 = \sim 0.6 \%$ of incident noontime sunlight on a clear day falling over these 400 acres has been turned into electricity.
The KH book provides an estimate of how much land would be needed to produce enough electricity to power the entire US from solar photovoltaic technology. This estimate is based on a certain assumption for the efficiency of the solar PV.

a) what is the “length of the square” (KH use the word “side”) that would be needed for the US to get all of its electricity needs from solar PV?

b) what did KH assume about the efficiency of solar PV to arrive at this estimate?

c) what would the “length of the square” (or “side”) be if the efficiency would rise to the highest achieved using a proprietary triple-junction by the Sharp Corporation, that is described on this wiki page: [https://en.wikipedia.org/wiki/Photovoltaics](https://en.wikipedia.org/wiki/Photovoltaics)

a) 100 miles by 100 miles, or 10,000 square miles

b) 35.8% (note the website stated other high efficiencies; use of any of these received full credit)

c) 52.9 miles because the required area scales inversely with the assumed efficiency of the respective panels. The first area is 10,000 square miles. The area needed for the more efficient panels is \( \frac{10}{35.8} \times 10,000 \) square miles or 2793 square miles. Need to take the square root of 2793 square miles to find this area is 52.9 miles per side.

Note: U.S. electric usage in 2017 of 3.82 billion MWhr ([https://www.statista.com/statistics/201794/us-electricity-consumption-since-1975](https://www.statista.com/statistics/201794/us-electricity-consumption-since-1975)) combined with actual output of Nevada Solar One (118,000 MWhr) means the entire electricity needs of the U.S. could be met using existing concentrated solar technology, for a collection area of 144 miles by 144 miles.

Of course, would also have to figure out how to transmit and store this energy.
Describe the difference in operating principle between solar photovoltaics and solar thermal

Solar photovoltaics, more commonly known as solar panels, directly convert the sun's rays of light into electricity, where it is then used or stored with great difficulty. Photovoltaics are seen as "riding on the shoulders of advances in quantum physics and solid-state electronics" (Krupp, 46). On the other hand, solar thermals are very similar to other types of power plants, with many moving components and mechanics. However, they are much more efficient than photovoltaics, as energy can be stored much more easily.

The reading seems to not give due justice to the technology of solar thermal; operating equipment continuously at very high temperature is not easy!

KH note “a key advantage of solar thermal over solar PV”. What is this key advantage and how, possibly, might this key advantage play a role in overcoming a major shortcoming of renewable energy.

The "key advantage of solar thermal over photovoltaics" is that solar thermal stores energy as heat, while photovoltaics store energy as electricity. The sun is an inconsistent energy source, interrupted by night, clouds, and winter, so energy storage is essential. Since storing heat energy is less costly than storing electricity, solar thermal can potentially provide a reliable energy source in spite of the sun’s intermittency.

See https://flipboard.com/@raymondbranke/csp-1akv1hhuz for more info.
a) What is a “renewable portfolio standard” (appears in KH, Chapter 3) and what is a “feed-in tariff” (KH, Chapter 2)?

b) According to https://en.wikipedia.org/wiki/Concentrated_solar_power, as of 2017, what country presently is the world leader in electricity generation from solar thermal?

c) Which of the two policy options mentioned in a) did this country employ to facilitate the growth of solar thermal? And is this policy still in place within this country, for new projects?

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a) A renewable portfolio standard is a policy that **requires utilities to buy a certain percentage** of their power from clean sources.

A feed-in tariff is an economic measure that **requires utilities to buy electricity generated by renewable-energy producers**, usually at a **specified above market price**.

b) Spain is the leader of electricity generation from solar thermal as of 2017.

c) Spain implemented a feed-in tariff to promote the growth and usage of solar thermal. However, as of 2012, Spain halted acceptance of new feed-in tariff projects.

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AT 12b, Q3

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Graph from https://www.spanishpropertyinsight.com/2016/06/06/cost-electricity-spain-high-eu-standards
RPS: Renewable Portfolio Standard

RPS Policies Exist in 29 States and DC
Apply to 56% of Total U.S. Retail Electricity Sales

Map from https://emp.lbl.gov/sites/default/files/2017-annual-rps-summary-report.pdf
See also http://www.ncsl.org/research/energy/renewable-portfolio-portfolio-standards.aspx
6. CONCLUDING REMARKS

We have presented a quantitative empirical analysis of the factors leading states to adopt RPS policies. Our results show that the adoption of an RPS is more likely in states with strong renewable potential, a restructured electricity market, a small share of natural gas in the electricity fuel mix, strong Democratic presence in the state legislature, and organized renewable energy interests. Surprisingly, our study suggests that neither local environmental benefits nor economic benefits of job creation seem to be driving forces for RPS adoption, although they are often widely touted in the legislative process.

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Map from https://emp.lbl.gov/sites/default/files/2017-annual-rps-summary-report.pdf
See also http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx
This KH reading again tells the stories of numerous companies: one led by David Mills, one led by Arnold Goldman, and one led by Susan D. Nickey. Give the names and briefly state the mission goal of each company. Then, pick one of the companies and describe what has happened since publication of the book.

a) Mills's company is known as Ausra, and their mission goal is lower the cost of solar thermal energy by using inexpensive technologies to create Fresnel Reflectors to produce solar thermal energy.

In 2010, Ausra was bought by Areva, was renamed Areva Solar and continued its work in solar energy. But in 2014, Areva shut down Areva Solar due to its lack of profitability.

b) Goldman's company is known as BrightSource Energy. Their mission goal is to expand solar thermal through the usage of distributed power towers, which is hoped to achieve higher efficiencies than other systems can achieve, as well as reduce the amount of energy consumed by the plant and mitigate its effect on the environment.

“In September 2014, BrightSource ended its upcoming California projects, withdrawing its application for a solar thermal power plant at near Riverside, Calif. Biologists, Native American groups, and advocates for Joshua Tree National Park were concerned that the bright light and heat of the project’s heliostats would prove fatal for birds. The company shifted its focus to overseas projects. In November 2014, Bright Source announced a joint venture with Shanghai Electric to build utility scale solar thermal projects" and proposed the construction of two 135 megawatt (MW) CSP plants as part of the Qinghai Delingha Solar Thermal Power Generation Project.”


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c) Nickey's company is known as Acciona Energy North America. They were one of the first companies to utilize solar thermal energy, and their mission goal is to use parabolic troughs to create solar thermal energy.

In recent years, Acciona has expanded globally in both wind and photovoltaics, with examples including construction of photovoltaic plants in Egypt, Mexico, and the Atacama Desert, and new wind farms in Australia and India. In 2017, the company's sales reached a total of 7,257 million euros with a net profit of 220 million euros. The current CFO is José Ángel Tejero Santos.

https://www.acciona.com/shareholders-investors/financial-information/key-figures
The KH reading quotes John O’Donnell as stating financing is “the last big obstacle to large-scale renewable energy deployment”. The book then goes on to name three additional obstacles.

a) What are these three additional obstacles?

b) Based either on the class readings, your intuition, or your own research, which of these three obstacles do you think is truly the hardest to overcome and how do you think it could possibly be overcome?

These three additional obstacles are access to regional transmission grids, costs to create new transmission lines, and reliability of the energy supply.

The biggest obstacle that I think will be the hardest to overcome will be gaining easy access to the concentrated solar power plants. They are situation in a geographic location far from major cities and access points, and with our aging electrical grid, gaining access will be a nightmare. This could be overcome by revamping the American electrical grid so that it is based on 21st century technology, allowing for it to be more efficient and handle the potential amounts of energy generated by the power plants.
Petroleum (including biofuels) used mainly for transportation (72%) and industry (23%), with only minor applications in residences & commerce (5%) and electric power (1%).

U.S. primary energy consumption by source and sector, 2017
Total=97.7 quadrillion British thermal units (Btu)

source

percent of sources

percent of sectors

sector

transportation 28.1 (29%)

industrial 21.9 (22%)

residential and commercial 10.4 (11%)

electric power 37.2 (38%)

Biofuels

Mason Kreps


16 October 2018
AT #1
In the United States a major effort had occurred to produce ethanol from corn, to supply a more sustainable source of liquid hydrocarbon fuel. This policy had been 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?
In the United States a major effort had occurred to produce ethanol from corn, to supply a more sustainable source of liquid hydrocarbon fuel. This policy had been 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?

- Researchers at the University of California evaluate the global warming impact (GWI) of fuels
  - Corn ethanol has 76 GWI
  - Sugar-based ethanol has 36 GWI
  - Both are more sustainable than gasoline at 92 GWI, but corn ethanol is not much better

- Sugarcane is much more efficient at using photosynthesis than corn, i.e., it is better at converting carbon into energy.
  - Sugar ethanol produces 8 BTUs for every BTU put in
  - Corn ethanol produces 1.3 BTUs for every BTU put in

- Sugarcane production requires less fossil fuels
Despite sugarcane ethanol being more efficient and more sustainable than corn ethanol, in 2006 the US used 20% of its corn production for ethanol, which only displaced gasoline demand by 3.5%.

Why do you think the US invests so heavily into corn ethanol? Do you think using 20% of corn production for ethanol is a good percentage, or is it too high/low?


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Why do you think the US invests so heavily into corn ethanol? Do you think using 20% of corn production for ethanol is a good percentage, or is it too high/low?

- Ethanol was the primary substitute for methyl tertiary butyl ether (MTBE)
  - MTBE was an additive to gasoline that was discovered to be polluting groundwater
  - Gasoline suppliers replaced MTBE with ethanol, which they made from corn
- The US is the largest corn producer in the world, so we have a lot of corn to work with
- The US’s sugar production is nowhere near that of Brazil, which is the highest in the world
- Dedicating too much corn for ethanol could be unsustainable

http://us-east.in.thebrazilbusiness.com/www/images/media/700_394/586.jpg
The US is the largest corn producer in the world
Sugar production is much lower
Brazil is the largest sugar producer in the world

Video on Brazil’s use of sugar ethanol

https://www.youtube.com/watch?v=1Jn2AlAWmjg
As described in the book, Amyris is an American renewable product and energy company that aims to create renewable alternatives to a variety of things; particularly fossil fuels.

How did Amyris solve the artemisinin cost dilemma, which became the basis of their work in renewable energy production?
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How did Amyris solve the artemisinin cost dilemma, which became the basis of their work in renewable energy production?

- Amyris built artemisinin in yeast, described as “reprogramming” the yeast, which then produced the plant and thus the cure for malaria much more efficiently and cost-effectively than growing and harvesting artemisinin
As stated in Chapter 4, in 2007 Amyris was using their yeast technique to produce “crystal clear, mild-smelling” fuels with sugar. The only inhibition was the cost of the fuel, which they planned to get below $2 a gallon by 2010. Where is Amyris today?
As stated in Chapter 4, in 2007 Amyris was using their yeast technique to produce “crystal clear, mild-smelling” fuels with sugar. The only inhibition was the cost of the fuel, which they planned to get below $2 a gallon by 2010. Where is Amyris today?

Amyris is no longer working on producing renewable transportation fuel. We have to assume that their methods were not cost-efficient.
Chapter 5 begins by stating the benefits of cellulose for fuel and describes two approaches for obtaining combustible fossil fuels from cellulose: the use of enzymes as well as the use of thermochemical systems.

What is cellulose and why is so much effort being exerted to extract combustible fuels from it?
AT #4
Chapter 5 begins by stating the benefits of cellulose for fuel and describes two approaches for obtaining combustible fossil fuels from cellulose: the use of enzymes as well as the use of thermochemical systems.

What is cellulose and why is so much effort being exerted to extract combustible fuels from it?

- Cellulose is the fibrous material that makes up grasses, stalks, husks, cobs, tree trunks, branches, and leaves. It can be considered the structure of plants, and it is inedible and very hard to break down.

- Cellulose is a much more efficient energy producer than corn or sugar
  - Cellulose produces up to 36 BTUs for each BTU put in
  - Sugar produces 8 BTUs and corn only produces 1.3 BTUs

https://d2gg9evh47fn9z.cloudfront.net/800px_COLOURBOX4498666.jpg
AT #4
What are the potential advantages of the enzyme approach and what hurdles must be overcome to make this approach viable? (pg. 97)

What are the potential advantages of the thermochemical approach and what hurdles must be overcome to make this approach viable? (pg. 98)
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Enzyme Approach
• genetically modify plants so that they produce an enzyme to break down their own cellulose
• saves us the trouble of breaking it down
• can make the plants more susceptible to disease, and could have unintended effects when cross-fertilizing with other plants
AT #4
What are the potential advantages of the enzyme approach and what hurdles must be overcome to make this approach viable? (pg. 97)

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Enzyme Approach
• genetically modify plants so that they produce an enzyme to break down their own cellulose
• saves us the trouble of breaking it down
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Thermochemical Approach
• uses extreme heat and pressure to break down cellulose
• can be used regardless of plant species, i.e., don’t have to worry about choosing enzymes
• Fischer-Tropsch plants cost billions, and aren’t profitable in the long run
• the book mentions a plant being built by the German company CHOREN
Distilling Fuel from Agricultural Waste

1. Sources of cellulose include all the plant materials we can't eat: corn stalks, grasses, husks, wood, shrubs, squeezed-out sugar cane, etc.

2. Delivered to the biorefinery, these plant materials are pumped full of liquid and "exploded" with pressure and heat to burst apart the fibers.

3. Enzymes or microorganisms are added to break the long chains of cellulose into their component sugars.

4. Yeast or bacteria ferment the sugars into a brew.

5. The brew is distilled into ethanol. At some refineries, the required heat comes from burning the remaining plant residues.

6. The ethanol is mixed in small percentages with gasoline or trucked to special ethanol pumps at gas stations.

Cellulose is the most difficult kind of biomass to turn into liquid fuel (one method is shown here). But it may also be the best kind, dramatically reducing carbon dioxide emissions, ecosystem damage, and competition with the food supply.
What is this?
From what I can gather, this is the plant that is mentioned in the book. After many unsuccessful runs with technical issues, most private investors, including Shell, pulled out of CHOREN, and the plant was decommissioned in 2011.

Researchers in the US are interested in restoring the native perennial grasses that once covered the Great Plains. What are the environmental benefits of these grasses?
Researchers in the US are interested in restoring the native perennial grasses that once covered the Great Plains. What are the environmental benefits of these grasses?

**Benefits**
- Their long roots allow them to store carbon in the ground, reducing atmospheric carbon
  - 1000 pounds of carbon per year in each acre
- Improve soil structure, water infiltration, and fertility
- Can be used to produce biofuels
  - The grasses would store more carbon than is released during biofuel production
- Provide habitat for grassland species

![Big Bluestem](https://www.americanmeadows.com/media/catalog/product/cache/1/image/2664a1c26d20ff89f08769f165108d16/a/n/andropogon-geradii-big-bluestem.jpg)

![Sundial Lupine](https://sggphoto.files.wordpress.com/2015/05/sundial-lupine-2-052515-700web.jpg)
Should research be done and resources be committed to restoring these
grasses to the Great Plains?

So far, not much advancement in this area has occurred. Why do you think
this is, given the apparent benefits of the grass?
Should research be done and resources be committed to restoring these grasses to the Great Plains?

So far, not much advancement in this area has occurred. Why do you think this is, given the apparent benefits of the grass?

• I don’t see any downside to restoring the grass, since it could be grown on land that is otherwise useless for agriculture. There are also many positive environmental effects, at least according to the reading.

• I assume politics are the major barrier in funding the research and restoration of the grass. It would probably be best to solve the problem with a bottom-up approach.
Renewable Jet Fuel

What percentage of total emissions does air travel account for?

a) <1%   b) 2%   c) 5%   d) 10%   e) 15%
Renewable Jet Fuel

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Despite such a small contribution, airline emissions are heavily regulated and so airlines are investing in renewable energy companies in an effort to reduce their emissions and maybe switch entirely over to biofuel.

AT #3
Why is jet fuel particularly hard to make from biomass?
Renewable Jet Fuel

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AT #3
Why is jet fuel particularly hard to make from biomass?

• Jet fuel must have a low enough freezing point to withstand low temperatures at high altitude
• It also must have a high energy density so that it doesn’t add too much weight to the aircraft
Renewable Jet Fuel

United Airlines is investing $30 million in Fulcrum BioEnergy, a company that produces fuel from city waste.

Renewable Jet Fuel

In 2011, a United Airlines aircraft, the Solajet, flew from Houston to Chicago on a fuel blend of 40% algae-based fuel and 60% traditional jet fuel.

Solajet, a passenger aircraft

Solajet taking off, 2011
Renewable Jet Fuel

Alaska Airlines is working with Northwest Advanced Renewables Alliance (NARA) to produce fuel from leftover tree limbs and branches after harvesting a forest.

https://blog.forest2market.com/hubfs/Blog/NARA_Supply_Chain_Infographic.jpg?t=1534965798166
AT #5
Why are researchers so interested in potential uses of algae, nature’s building block, for various applications in the area of biofuels?

https://www.nature.scot/sites/default/files/styles/hero_banner_half_width/public/2017-07/Algae-01.jpg?itok=yy1HnwZf
AT #5
Why are researchers so interested in potential uses of algae, nature’s building block, for various applications in the area of biofuels?

- Algae grow extremely fast and can survive in nearly any environment
- They are the richest in high-energy oils (vegetable oil)
- They are rich in carbohydrates which is good for ethanol production
- They are the world’s most efficient converters of CO₂ to oxygen and biomass
- All they do is consume CO₂ and divide

https://www.nature.scot/sites/default/files/styles/hero_banner_half_width/public/2017-07/Algae-01.jpg?itok=yy1HnwZf
Figure 1: 2014 fuel shares in world total primary energy supply

- Oil: 31.3%
- Natural Gas: 21.2%
- Coal: 28.5%
- Renewables: 13.8%
- Nuclear: 4.8%
- Other\(^1\): 0.3%
- Hydro: 2.4%
- Biofuels and waste: 10.1%
- Other renewables\(^2\): 1.3%

solar, wind, etc.
Do you think it’s worth it to continue investing in biofuel companies, considering the failures of Amyris, CHOREN, GreenFuel, and the palm oil situation?

Do you think countries should increase biofuel production? Which biofuel do you believe is the most effective?

If you think countries should decrease or not change biofuel production, which other renewables do you believe should be expanded?
Biofuels: Last Word

Ross Salawitch

16 October 2018
Interesting Cameo

cameo: 3) a usually brief literary or filmic piece that brings into delicate or sharp relief the character of a person, place, or event  
https://www.merriam-webster.com/dictionary/cameo
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Frances Arnold, a chemical engineering and biochemistry professor at Caltech and a member of the Amyris scientific advisory board, sees a challenging path ahead, for Amyris and for her own biofuels company, Gevo, which makes biobutanol, another energy-dense fuel. “None of us really knows yet how to lower costs. We engineer organisms to do our bidding, but they don’t have high enough productivity. And switching out genes is like writing Moby-Dick by pulling discrete paragraphs off the Web; you end up with a kludgy design.” Arnold’s researchers have developed strategies for using evolution as an “editor” to smooth out any inelegant passages in the genomes they write. They design a genome for their desired organism, but then introduce thousands of random changes in the DNA. From those mutations, they select the best, then do it again. The approach is called “directed evolution” or “semi-rational design,” because it mixes the high-speed, directionless shuffling of mutations with the conscious writing of genetic code.

page 87 of my paperback copy of Earth: The Sequel
Interesting Cameo

Frances Arnold Wins 2018 Nobel Prize in Chemistry

Frances H. Arnold, the Linus Pauling Professor of Chemical Engineering, Bioengineering and Biochemistry, has won the 2018 Nobel Prize in Chemistry for "the directed evolution of enzymes," according to the award citation. Directed evolution, pioneered by Arnold in the early 1990s, is a bioengineering method for creating new and better enzymes in the laboratory using the principles of evolution. Today, the method is used in hundreds of laboratories and companies that make everything from laundry detergents to biofuels to medicines. Enzymes created with the technique have replaced toxic chemicals in many industrial processes.

https://www.youtube.com/watch?time_continue=85&v=h_OTCQ_fxuc
Updates to Reading

Much of Chapter 5 is devoted to **use of algae to scrub \( \text{CO}_2 \) from power plant stacks**

Stack gas is an ideal feedstock for photosynthetic algae producing any one of a number of products.

The problem with using **stack gas** effectively is that it basically **requires the use of enclosed photobioreactors** to fully utilize the potential of the high concentration of carbon dioxide.

Photobioreactors are **expensive** to buy, **difficult** to maintain, and have never commercially succeeded for anything but nutraceuticals [nutritional food supplements]. Over the last ten years I've seen commercial algae photobioreactor designs move first from expensive, sophisticated hard plastic bubble columns all the way to what we're seeing now, which are essentially glorified clear ziploc bags, in the quest for cost reduction. Even so we are still at the stage where **no photosynthetic algae play has achieved commercial success for anything but, as I said before, nutraceuticals or food supplements**.*

The **economics of algae** fundamentally depend on being able to **monetize the algae** in some way - be that through tipping fees for water treatment, selling the algae, processing for oil, biofuels, biochemicals, etc. **Even if the objective is to break even, there are significant costs associated with algae growth at a large scale.**

Josh Velson, 22 June 2014, expressed as:


**Campus Climate Action Plan states:**

By 2020, all electricity coming from sources other than CHP [combined heat and power plant, on Route 1] must be produced renewably and any carbon emissions associated with powering new facilities must be offset. **New technologies including algae-based carbon capture** may drive carbon emissions even lower.

[https://sustainability.umd.edu/progress/climate-action-plan](https://sustainability.umd.edu/progress/climate-action-plan)
Updates to Reading

Page 76 states “U.S. vehicle fleet pumps 1.3 billion tons of CO\(_2\) into the atmosphere every year, and $820 million in capital is exported every day for the oil needed to do so:

\[
6,511 \times 0.28 \times 1 \text{ billion} / 1000 \text{ million} = 1.8 \text{ billion tons of CO}_2
\]

https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

* Land Use, Land-Use Change, and Forestry in the United States is a net sink and offsets approximately 11 percent of these greenhouse gas emissions, not included in total above. All emission estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2016.

https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
Updates to Reading

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https://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm

Price of oil $70 / barrel in Sept 2018
Page 76 states “U.S. vehicle fleet pumps 1.3 billion tons of CO₂ into the atmosphere every year, and $820 million in capital is exported every day for the oil needed to do so:

https://www.eia.gov/dnav/pet/pet_move_neti_a_EP00_IMN_mbblpd_m.htm

U.S. imported $2.35 \times 10^6$ barrels of crude oil in July 2018, costing $165 million per day in capital.

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Updates to Reading

U.S. has greatly expanded production of so-called tight oil [https://en.wikipedia.org/wiki/Tight_oil](https://en.wikipedia.org/wiki/Tight_oil) from the Permain, Bakken, and Eagle Ford deposits since the book was written.

Further reading:


**FEBRUARY 22, 2018**

**Tight oil remains the leading source of future U.S. crude oil production**

- [https://www.eia.gov/todayinenergy/detail.php?id=35052](https://www.eia.gov/todayinenergy/detail.php?id=35052)
Updates to Reading

Page 88 mentions the US renewable fuel standard:

Updates to Reading

Trump to lift restrictions on ethanol

WASHINGTON — The Trump administration is moving to allow year-round sales of gasoline with higher blends of ethanol, a boon for Iowa and other farm states that have pushed for greater sales of the corn-based fuel.

President Donald Trump was expected to announce he is lifting a federal ban on summer sales of high-ethanol blends during a trip to Iowa on Tuesday.

The long-expected announcement is something of a reward to Iowa Sen. Chuck Grassley, who as Senate Judiciary Committee chairman led a contentious but successful fight to confirm Brett Kavanaugh to the Supreme Court. The veteran Republican lawmaker is the Senate’s leading ethanol proponent and sharply criticized the Trump administration’s proposed rollback in ethanol volumes earlier this year.

At that time Grassley threatened to call for the resignation of the Environmental Protection Agency’s chief, Scott Pruitt, if Pruitt did not work to fulfill the federal ethanol mandate. Pruitt later stepped down amid a host of ethics investigations.

A senior administration official said Monday that the EPA will publish a rule in coming days to allow high-ethanol blends as part of a package of proposed changes to the ethanol mandate. The official spoke on condition of anonymity ahead of Trump’s announcement.

The change would allow year-round sales of gasoline blends with up to 15 percent ethanol. Gasoline typically contains 10 percent ethanol.

The EPA currently bans the high-ethanol blend, called E15, during the summer because of concerns that it contributes to smog on hot days, a claim ethanol industry advocates say is unfounded.
Ethanol is one area in which Senator **Person A** strongly disagrees with his (or her) **Dem or Reb** opponent, Senator **Person B** of **State**. While both presidential candidates emphasize the need for the United States to achieve “energy security” while also slowing down the carbon emissions that are believed to contribute to global warming, they offer sharply different visions of the role that ethanol, which can be made from a variety of organic materials, should play in those efforts.

**Person B** advocates eliminating the multibillion-dollar annual government subsidies that domestic ethanol has long enjoyed. As a free trade advocate, he (or she) also opposes the 54-cent-a-gallon tariff that the United States slaps on imports of ethanol made from sugar cane, which packs more of an energy punch than corn-based ethanol and is cheaper to produce.

... The candidates’ views were tested recently in the **Farm Bill** approved by Congress that extended the subsidies for corn ethanol, though reducing them slightly, and the tariffs on imported sugar cane ethanol. Because **Persons A and B** were campaigning, neither voted. But **Person B** said that as president he (or she) would veto the bill, while **Person A** praised it.

Ethanol is one area in which Senator Barack Obama strongly disagrees with his (or her) Republican opponent, Senator John McCain of Arizona. While both presidential candidates emphasize the need for the United States to achieve “energy security” while also slowing down the carbon emissions that are believed to contribute to global warming, they offer sharply different visions of the role that ethanol, which can be made from a variety of organic materials, should play in those efforts.

McCain advocates eliminating the multibillion-dollar annual government subsidies that domestic ethanol has long enjoyed. As a free trade advocate, he (or she) also opposes the 54-cent-a-gallon tariff that the United States slaps on imports of ethanol made from sugar cane, which packs more of an energy punch than corn-based ethanol and is cheaper to produce.

... The candidates’ views were tested recently in the Farm Bill approved by Congress that extended the subsidies for corn ethanol, though reducing them slightly, and the tariffs on imported sugar cane ethanol. Because McCain and Obama were campaigning, neither voted. But McCain said that as president he would veto the bill, while Obama praised it.
In 2014, world obtained ~80% of its energy from combustion of fossil fuels

NEW DELHI, Jan 3 (IPS) - Women and young girls coughing and choking as they cook food over traditional stoves that burn wood, leaves or dung is a common a sight in poor homes across Asia, Africa and Latin America. But no one notices the deleterious effects.

Over 1.5 million females die prematurely every year by inhaling poisonous fumes as they cook or heat their homes with these organic fuels but catch little attention from governments, policy experts, scientists and medical experts.

Almost three billion people burn traditional fuels indoors for cooking and heating and their numbers are expected to "rise substantially by 2020," John Mitchell, coordinator of the partnership for clean indoor air at the United States Environmental Protection Agency told IPS at an international meeting on better air quality held in Yogyakarta, in December.

Most people in the region rely on firewood for cooking and heating, but this not only destroys the local forest but also causes serious health problems due to indoor air pollution. TNC initiated an alternative energy programme in 2001 to protect the rich biodiversity in northwest Yunan and use energy strategies.

http://ipsnews.net/news.asp?idnews=36052
Residential Biofuels in South Asia: Carbonaceous Aerosol Emissions and Climate Impacts


High concentrations of pollution particles, including “soot” or black carbon, exist over the Indian Ocean, but their sources and geographical origins are not well understood. We measured emissions from the combustion of biofuels, used widely in south Asia for cooking, and found that large amounts of carbonaceous aerosols are emitted per kilogram of fuel burnt. We calculate that biofuel combustion is the largest source of black carbon emissions in India, and we suggest that its control is central to climate change mitigation in the south Asian region.

An analysis of the climate response of soot emissions from fossil fuel and biofuel combustion has suggested that control of soot, in addition to greenhouse gases, is an important measure to slow global warming, especially on short time scales (6, 7). Our results suggest that biofuel combustion could significantly affect atmospheric BC concentrations in the south Asian region. The climate effects of biofuel combustion aerosols have been combined with the effects of open biomass burning in the scientific consensus reports of the Intergovernmental Panel on Climate Change (29). We suggest that biofuel combustion needs to be addressed as a distinct source, and that cleaner cooking technologies not only could yield significant local health and air quality benefits but also could have an important role in climate change mitigation in the south Asian region.
Electricity from Waste

• Opened in 1984
• Site of old pyrolysis plant
• Burns 2,250 tons of trash per day
• Metals recovered; volume of trash reduced by factor of 10
• Capacity to generate 60 MW of electricity ⇒ ~6% typical nuclear plant
• Heat used for direct steam heating / cooling downtown Baltimore
• One of 16 such plants in the US

Baltimore RESCO (Refuse Energy Systems Company) Plant
Russell Street & U.S Interstate 95 (shadow of Ravens Stadium)

https://www.nmwda.org/baltimore-resco/
http://www.eia.doe.gov/kids/energy.cfm?page=RESCOE_Plant