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

Discussion #17: Economics of Renewable Energy

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

ELMS Page: https://myelms.umd.edu/courses/1269254

https://www.usatoday.com/story/money/energy/2018/04/04/energy-costs-renewables-close-fossil-fuels-challenging-price/485210002/

29 October 2019

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AT 15, Q1.

What factor does Yuval Noah Harari claim “enables banks - and the entire economy - to survive and flourish”?

He claims trust in the future is what enables the economy to flourish. This means trusting in the system where profit will made in the future, and therefore people are more likely to invest. In order to grow economies, credit is a source used to build projects today that would profit in the future. Since there is trust in the future, the cycle keeps repeating and more production causes more profits

Here are links to three websites that explain this concept in more detail:

http://www.forbes.com/sites/davidkwilliams/2013/06/20/the-most-valuable-business-commodity-trust

https://dzone.com/articles/importance-trust-business

http://www.capx.co/why-a-strong-society-can-make-us-all-richer

Despite the myriad of ills in modern American society, we are still distinguished throughout the world by the fact that in most business transactions, the “baseline” understanding of both parties is they shall keep their word to earnestly accomplish their side of the transaction.

Unfortunately, “baseline” understanding is not this straightforward in some parts of the world.

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AT 15, Q2

First provide a paragraph describing the central argument put forth by Adam Smith in Wealth of Nations, and then provide another paragraph relating this argument to either a particular success or failure we had discussed from the book Collapse.

Adam Smith in *Wealth of Nations* basically outlines how an increase in private entrepreneurs' profits would *increase the basis of collective wealth and prosperity*. Entrepreneurs can make themselves and everyone else richer by investing their profits into increasing production (to make them more money) and creating employment (to give society jobs so everyone can make money). He explains that this would create a "win-win situation" because if your customers are poor, you are as well since you have no one to sell your products too. However, if you use your profits to create jobs, you are essentially giving people money to spend as they will have a source of income. When people have excess money to spend, they can purchase your products, making you richer and creating a cycle of increasing wealth that involves everyone.

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AT 15, Q2

Examples of success of capitalism include:

- **Tikopia: altruism**
- **New Guinea: innovation**
- **Japan: conservation**
- **Kutubo oil field: far-sighted business leadership**

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AT 15, Q2

Examples of ills of capitalism include:

- **Rapa Nui: resources were finite and not preserved**
- **Maya: rapid growth, hostilities, water resources**
- **Haiti: devastated by the economic interests of slave merchants**
- **Ainu: ended up destroying their own environment in an attempt to gain more wealth from trade with Japan**
- **China: does their economic model have the longevity to provide stable growth**

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AT 15, Q3

With some specificity, describe something new you learned from this reading.

- **Extent to which banking influenced history**
- **Private corporations had such an important role in European Imperialism.**
- **The reading really showed the two faces of capitalism, showing how it has good intentions but also has a high risk for corruption.**
- **Credit helped the Dutch defeat the Spanish**
- **Mississippi Bubble of the 1700**
- **“Greek Rebellion Bonds” issued by the British**
- **British role in the opium addiction in China: x2**
- **Until the late eighteen century, Asia was the world's economic powerhouse**
- **I gained a different perspective by reading about this power dynamic based in money and credit in the context of capitalism.**
- **Impact of village life and the agricultural revolution on the majority of people**
- **A country's credit rating is more important to whether or not it will have economic success than its natural resources**

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AT 15, Q3

With some specificity, describe something new you learned from this reading.

- **Complexity of the Atlantic Slave Trade: x3**

This book, written by Prof Gerald Horne of the Univ of Houston:

https://www.amazon.com/Counter-Revolution-1776-Resistance-Origins-America/dp/1479806897

contends concern over abolishment of slavery in America by the British was driving factor of the Revolutionary War.

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AT 15, Q4

In a recent wall Street Journal opinion piece entitled “Capitalism Will Solve the Climate Problem”:

http://www.atmos.umd.edu/~rjs/class/honr229L/readings/krupp_wsj_181015.pdf

Fred Krupp writes “Climate change is a byproduct of the prosperity created by the market economy” and provides the optimistic outlook that “the market will find winning solutions [to the climate problem]” although he falls short on specifics other than stating public policy that places a price on carbon emissions is a key element of this solution.

Drawing upon elements of the Harari reading as well as other material from this class, write a few paragraphs either ***supporting*** or ***refuting*** the view that “Capitalism Will Solve the Climate Problem”. Great if you can incorporate into your essay an element of our mantra “those who cannot learn from history are doomed to repeat it” (i.e., relate a bit of history from Harari into your reply) and also invoke either an *optimistic* or ***pessimistic*** view regarding the **role of capitalism in solving the climate crisis**.

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AT 15, Q4. 5 students took the pessimistic stance. Statements include:

The idea that capitalism will solve the climate problem seems to me like a *naive way of thinking* about business and corporation. Specifically, I think that corporations will not switch their production methods because it might help them in the future. Their goal is to maximize profits, and as long as the current systems are working, i.e. burning fossil fuels, they have no incentive to turn to renewable energy sources.

Modern capitalism still has not fixed this issue; in a similar vein, *some in the government have even gone so far to deny climate change altogether in order to curry favor with the fossil fuel lobby* (which provides them with additional wealth in the form of contributions) and maintain their power in the government, hindering any real solutions to climate change in order to do that which Smith championed - accumulate wealth.

The view that capitalism will solve the climate problem is a dangerous view to have. The reliance on an economic theory that has such high risk, and has shown to have downside, to solve such a pressing issue is not a healthy view to have. We must be taking immediate and proactive action to prevent and solve climate change, not relying on capitalism to solve our problems.

To relate back to Harari, climate change shows the fallacy of an ever-expanding pie. In the past, the expansion of the pie was either an expansion only in the eyes of the western world, or a technological expansion of the pie. When the problem becomes global, there is no place to export problems to; capitalism has run into the finite nature of the Earth.

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AT 15, Q4. 7 students took the optimistic stance. Statements include:

I think that capitalism has the potential to solve the climate problem, but *only if governments step in to mandate quotas and enforce laws protecting the environment*. In a free market economy with little to no regulating, powerful companies have historically become greedy and profit-driven, thus ditching their ethics and concern for the general public and environment.

Capitalism will solve the climate problem, *if the government can regulate the market in a manner that will harness its power and direct it at solving the problem*. We've seen effective policy create market incentives favoring renewables, such as how Spain's feed-in tariffs spurred massive investments into solar thermal energy.

I am in accordance with Krupp's standpoint that capitalism and the free market can be solutions to climate change. We have run out of other options, and because capitalism IS the only system that truly works, businesses and our society as a whole MUST utilize it and find ways to solve the climate problem that we have created.

In my opinion, very clearly an unfettered free market will not solve the climate change issue. The challenge for governments is how to impose a "price" on the negative effects of carbon emissions, so that economic actions can help accelerate the changes that are needed.

The Economic of Renewable Energy

Nyah Stewart

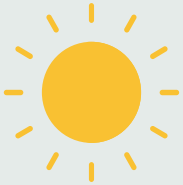
How do renewable energy sources differ from fossil fuels characteristically?

Students, write your response!

MAIN CHALLENGES

Fossil Fuels have very high concentration pools of energy

NET ENERGY



Some days the Sun doesn't shine and the wind doesn't blow

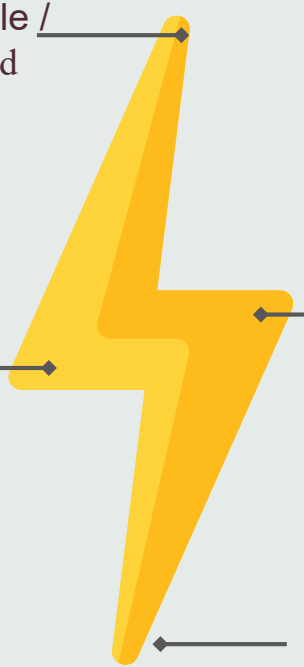
INTERMITTENCY

It costs a lot to invest in solar energy

CAPITAL INTENSI

NET ENERGY

NET ENERGY RATIO
energy available / energy required



LARGE NET ENERGY RATIOS
mean lots of energy is produced for a small energy investment

RENEWABLES
have small ratios : put a lot in to get a little out

AT Question 1

What is is the *least surprising* and what is the *most surprising* aspect of Table 3?

Table 3. Net Energy Ratios for Various Energy Sources

Energy Source	Net Energy Ratio	Reference
Oil (global)	35	(Yandle, Bhattarai and Vijayaraghavan 2004)
Natural gas	10	(Hall 2008)
Coal	80	(Cleveland 2005)
Shale oil	5	(Hall 2008)
Nuclear	5-15	(Lenzen 2008; Murphy and Hall 2010)
Hydropower	>100	(Hall 2008)
Wind	18	(Kubiszewski, Cleveland and Endres 2010)
Photovoltaic cells	6.8	(Battisti and Corrado 2005)
Ethanol (sugarcane)	0.8 – 10	(Hall, Cleveland and Kaufmann 1986),(Goldemberg 2007)
Ethanol (corn-based)	0.8 – 1.6	(Farrell, Pelvin and Turner 2006)
Biodiesel	1.3	(Hall, Cleveland and Kaufmann 1986)
Farmed willow chips	55	(Keoleian and Volk 2005)

Adapted from Murphy and Hall (2010)

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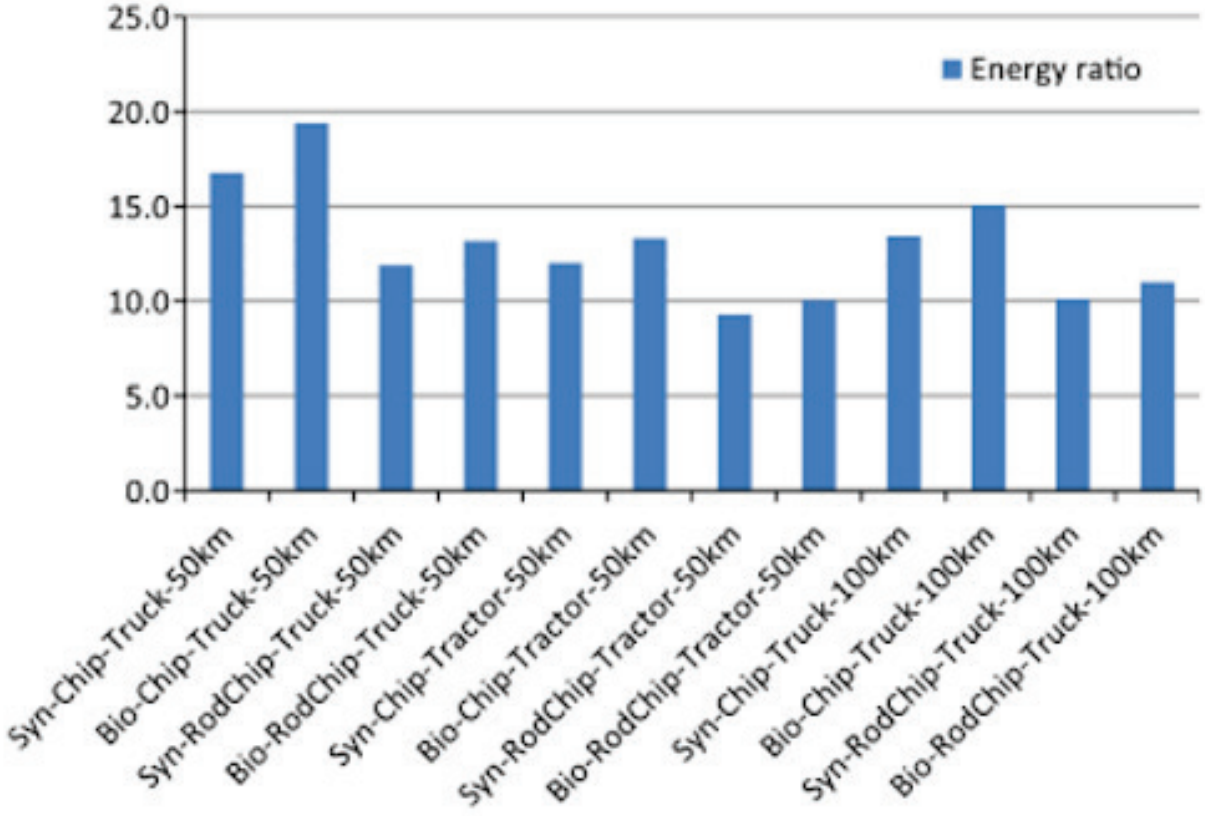


Fig. 5 Effect of management scenarios on energy ratio.

http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12111/full

https://www.wbur.org/bostonomix/2016/12/02/northfield-mountain-hydroelectric-station

Intermittency

supply-demand matching problem

To solve:

- diversity
- storage
- national grid
- variable pricing

Table 4. Capital Cost of Renewable and Non-Renewable Electricity Sources

	Nominal Capacity (MW)	Capital Cost ($/kW)	Assumed Capacity Factor	Capital $/Expected kW
Natural gas: combined cycle	620	$917	90%	$1,019
Coal: advanced pulverized fuel	650	$3,246	90%	$3,607
Hydroelectric: conventional	500	$2,936	75%	$3,915
Nuclear: dual unit	2,234	$5,530	90%	$6,144
Wind: onshore	100	$2,213	25%	$8,852
Biomass combined cycle	20	$8,180	90%	$9,089
Wind: offshore	400	$6,230	35%	$17,800
Solar: photovoltaic	150	$3,873	20%	$19,365
Solar: thermal electric	100	$5,067	20%	$25,335

Adapted from EIA (2013)

Note: For comparing sources with different capacity factors, the authors have defined $ / Expected kW to be ($/kW) / (capacity factor), or "the capital cost to produce the same amount of electricity as one kW of capacity running continuously"

AT Question 2

The authors have decided to use capacity factor in an interesting mathematical manner, for the rank ordering of **"capital cost to produce the same amount of electricity as one kW of capacity running continuously"** given in Table 4.

Briefly, how has capacity factor been used and do you feel the use in this manner is appropriate?

CAPACITY FACTOR

high capital costs

renewables have low operating costs but high start up costs

cost for what you're actually getting

building renewable plant

really sensitive to interest rates

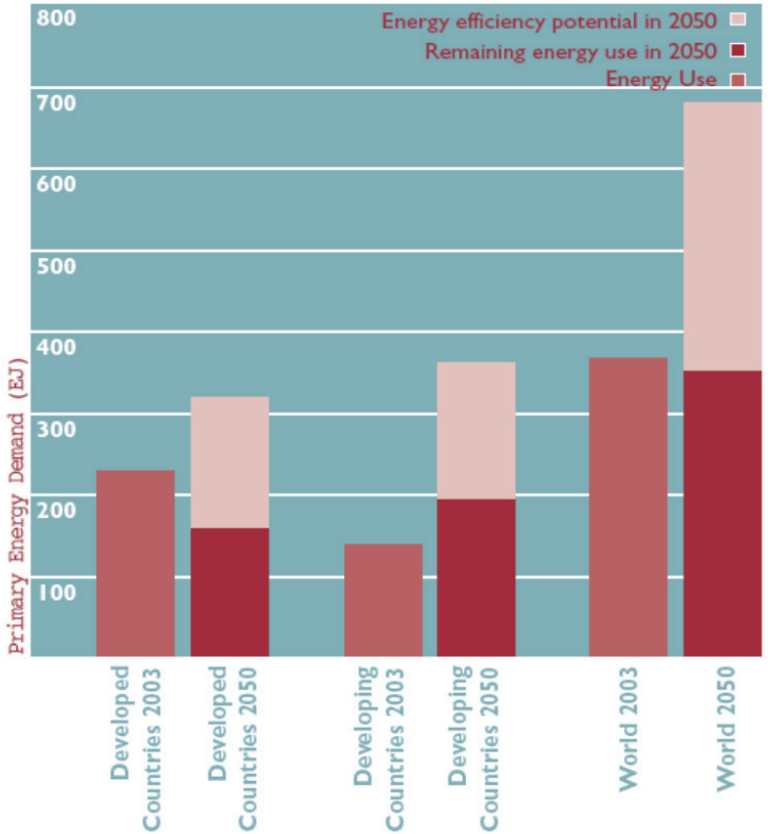
AT Question 3

The reading emphasizes the **potential for energy efficiency to play an increasingly important role** in the transition of society towards reducing the emission of greenhouse gases.

In a few sentences, describe **what is stated about energy efficiency** and also express an opinion as to whether or not you believe the statement

Students choose an option

Figure 5. Global Potential for Energy Efficiency



Source: Blok et al. (2008)

http://www.bu.edu/eci/files/2019/06/RenewableEnergyEcon.pdf

ENERGY SUBSIDIES

PAYMENTS / LOANS

per unit subsidy or favorable loan with low interest

TAX CREDIT & DEDUCTIONS

depletion allowances for oil

PRICE SUPPORTS

feed-in-tariffs

MANDATED PURCHASE QUOTAS

laws that say gas must be % ethanol

AT Question 4 A

reading emphasizes rather strongly that ***directing the bulk of energy subsidies toward fossil fuels tilts the playing field in their favor****" and provides numerical estimates for the subsidies directed towards the fossil fuel industry.*

State the dollar amounts given in the reading for subsidies directed towards fossil fuels

Students, enter a number!

The reading provides no detail as to what these subsidies entail. **Pick a fossil fuel sector (i.e., electricity, transportation, heating fuel, etc) and, based on your own quick internet-based research, succinctly provide this missing detail.**

Explain the conundrum that the **dollar amount of subsidies directed towards the fossil fuel industry is so large compared to the dollar amount directed towards renewables** while at the same time the cent per kilowatt-hour benefit provided to the renewable energy industry via these subsidies is considerably larger than the cent per kilowatt-hour benefit give to the fossil fuel industry

AT Question 4 B

The phrase **internalizing externalities** seems like an oxymoron. Yet this might be the best hope for avoiding catastrophic climate change due to societal dependence on fossil fuels.

Provide a brief essay explaining this phrase and either support or refute the view that internalizing externalities is our best hope for avoiding catastrophic climate change. Try to work the phrase **Pigovian taxes** into your essay.

FINAL QUESTION

Why does public policy have such a big role in promoting renewable energy? What public policy approaches do you think will be most effective?

Last Word: Economics of Renewable Energy

Ross Salawitch

29 October 2019

Think Globally, Act Locally

"Think globally, act locally" urges people to consider the health of the entire planet and to take action in their own communities and cities. Long before governments began enforcing environmental laws, individuals were coming together to protect habitats and the organisms that live within them. These efforts are referred to as grassroots efforts. They occur on a local level and are primarily run by volunteers and helpers.

https://en.wikipedia.org/wiki/Think_globally,_act_locally

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Home » UNIVERSITY PARK SCHOOLS SMALL TOWNS ON UPGRADES

UNIVERSITY PARK SCHOOLS SMALL TOWNS ON UPGRADES

- Better Buildings Neighborhood Program Home
- Accomplishments
- History
- Better Buildings Partners
- Stories
- Interviews
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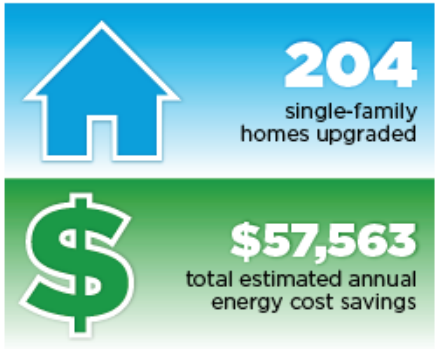
University Park, Maryland, a town of only 2,500 residents, sought to address the energy efficiency needs of its homeowners. To create a model for other resource-constrained small communities throughout the United States, and to improve the efficiency of 20% of its residents' homes, University Park piloted the Small Town Energy Program (STEP) with $1.4 million in seed funding from the U.S. Department of Energy's Better Buildings Neighborhood Program, then expanded STEP to an additional three small towns in Maryland.

ACCOMPLISHMENTS

(July 2010 to September 2013)



University Park data dashboard and summary of reported data

University Park final report

http://energy.gov/sites/prod/files/2014/10/f18/bbnp_university_park%20Summary_reported_data.pd
https://www.osti.gov/scitech/servlets/purl/1113542f

Home Energy Efficiency

University Park (UP), Maryland:

- 2,540 residents
- 919 homes
- 2 churches
- 1 school
- 1 town hall

STEP-UP (Small Town Energy Program for UP) achieved

- 30% of community households participated
- 25% of homes received a Home Performance with ENERGY STAR assessment
- 16% of households made energy efficiency improvements to their home (i.e., lighting, refrigerator, furnace etc)
- 64% of households proceeded with an upgrade after their assessment (i.e., insulation, air sealing, duct sealing, windows)

http://energy.gov/sites/prod/files/2014/10/f18/bbnp_university_park%20Summary_reported_data.pd
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Home Energy Efficiency

1.9 Estimated Energy Savings Synopsis

Recipients reported estimated energy savings in two ways. First, recipients were asked to report estimated savings data quarterly: total kilowatt-hours (kWh) of electricity, therms of natural gas, gallons of fuel oil, and gallons of propane saved, along with dollars in energy costs saved. Table 2 shows the total estimated annual energy savings of the recipient's activities reported through September 30, 2013.

Table 2. Estimated Annual Energy Savings (Through September 30, 2013), as Reported in Program Summaries

Estimated Annual Energy Savings (Through 9/30/13)	
kWh Electricity	204,407
Therms Natural Gas	24,800
Gallons of Oil	2,581
Gallons of Propane	0
Total Estimated MMBTU Savings (Source Energy)[9]	5,474
Total Estimated Energy Cost Savings	$57,563

204,407 × 0.12 kHW = $ 24,528

24,800 × $1/therm = $ 24,800

2,581 × $3 / gallon = $ 7,743

Total: $57,071

Note: about 43% of the savings are in the form of electricity and 57% in the form of fuel for heat

http://energy.gov/sites/prod/files/2014/10/f18/bbnp_university_park%20Summary_reported_data.pdf
https://www.osti.gov/scitech/servlets/purl/1113542f

Home Energy Efficiency

Expenditure to home energy retrofits

204 homes $\times$ \$4500 / home = \$918,000

Critical detail: rebates and incentives covered ~45% of the cost
So, actual out of pocket cost was 0.55 $\times$ \$918,000 = \$504,900

If the cost of energy stays constant over time, it will take

\$ 504,900 / \$57,563 per year = 8.77 yrs to “break even”

Renewable Energy

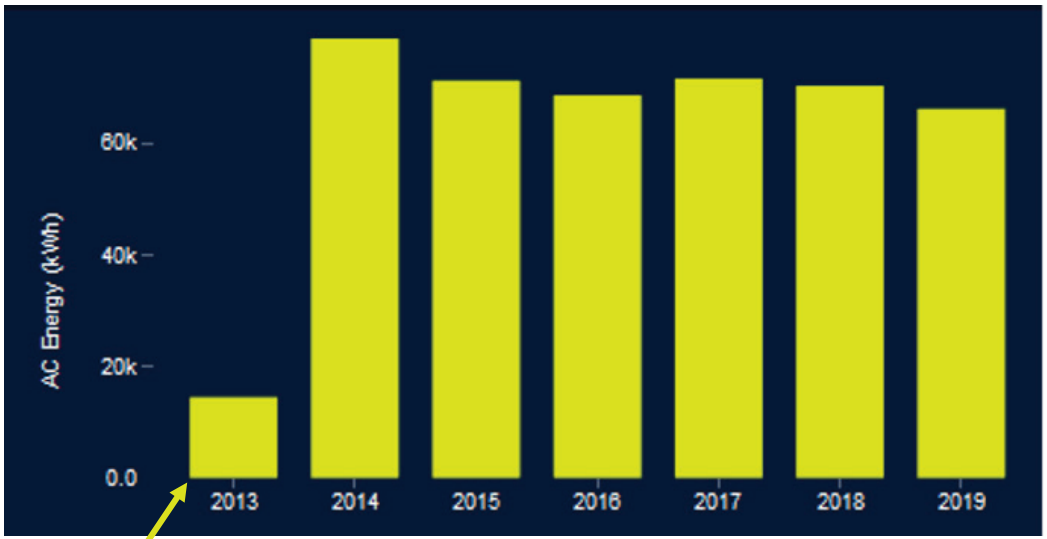
STEP-UP also obtained $250,000 from the US DOE to spend on renewable energy

A 64.8 kW photovoltaic solar array was installed on the roof of the local school, the first such installation on a public school in Prince George's County

https://www.upmd.org/226/Sustainability-Solar-Array
https://www.hyattsvillewire.com/2017/06/29/hyattsville-solar/

Univ Park Elementary Solar Array

Univ Park Elementary Solar Array



System has generated 441 MWh = 441,000 kWh since turn on

Number of days since turn on: 73 + 365 + 365+ 366 + 365 + 365 + 299 = 2198 days
Number of hours since turn on: 2198 days × 24 hr/day = 52,752 hr

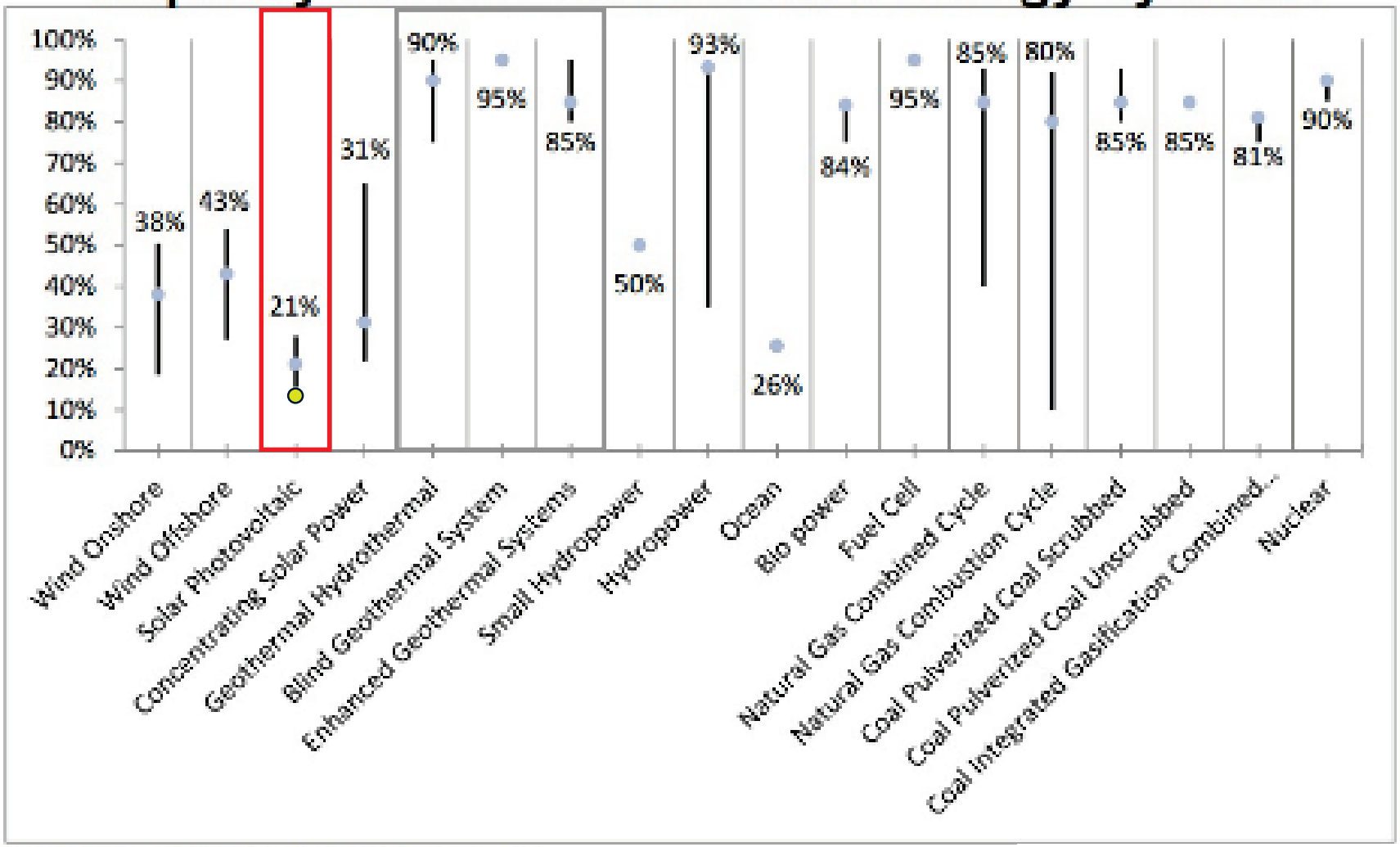
Energy at full capacity given 64.8 kW rating: 64.8 kW × 52,752 hr = 3,148,000 kW hr

Capacity Factor = 441,000 kW hr / 3,148,000 kW hr = 0.129

Lose ½ due to night, ½ due to seasons, and ½ due to weather: ½ × ½ × ½ = 1⁄8 or 0.125

http://kiosk.datareadings.com/elkWdi6e/overview?granularity=total

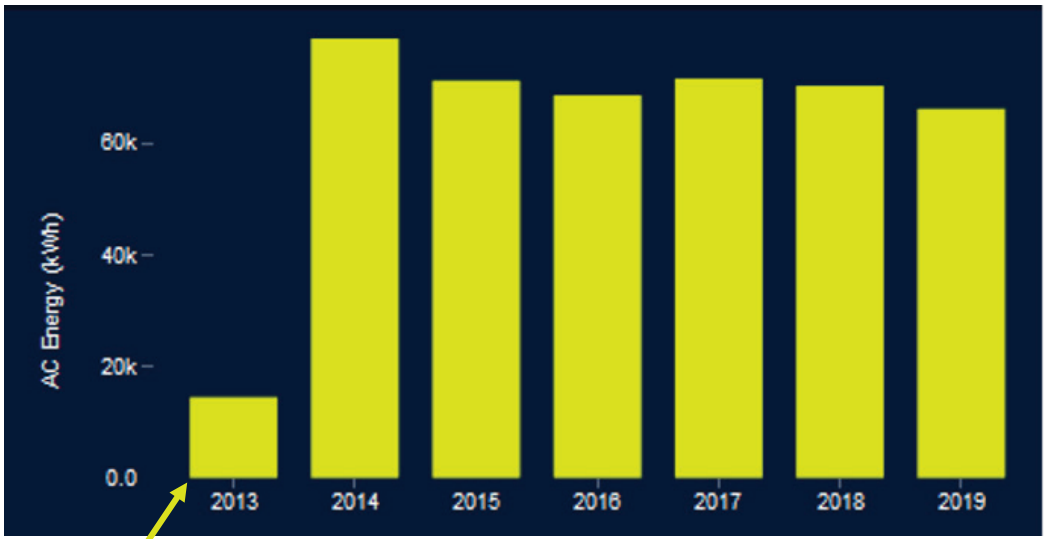
Capacity Factors for Assorted Energy Systems



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/

Univ Park Elementary Solar Array



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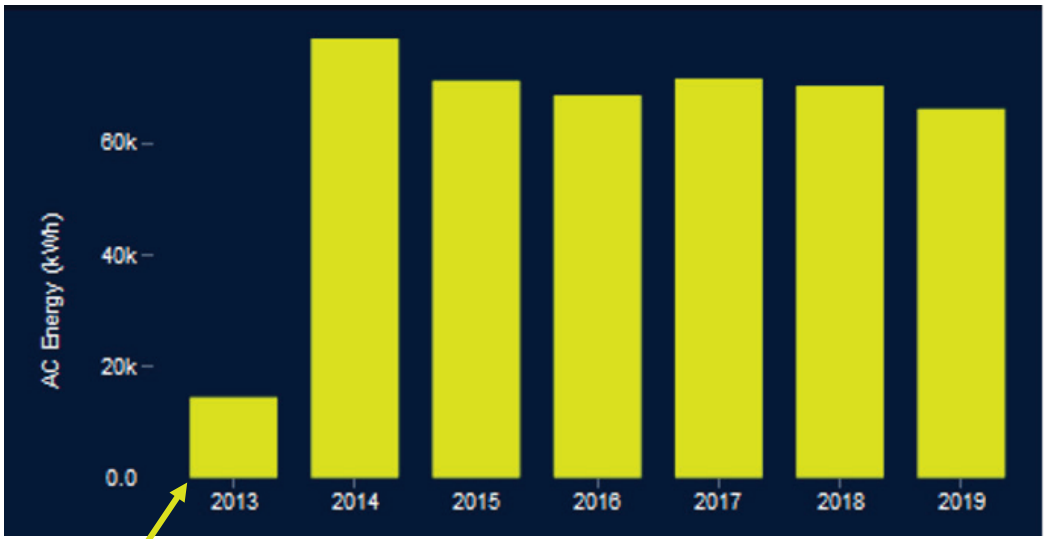
Carbon Offset = 617,367 lbs = 280 metric tons

System Cost: \$250,000 ⇒ : \$250,000 / 280 metric tons = \$892 / metric ton

http://kiosk.datareadings.com/elkWdi6e/overview?granularity=total

Univ Park Elementary Solar Array



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System warranted for 25 yrs; over this lifetime, CO_2 mitigation would be \$214 / metric ton

Crucial starting point for understanding how to think about price of a metric tonne (1000 kg = 2,204 pounds = 1.102 short tons) of CO_2

Fuel	Price (Oct 2019)	Door 1	Door 2	Door 3
Coal	$57 per short ton	$17	$34	$68

Crucial starting point for understanding how to think about price of a metric tonne (1000 kg = 2,204 pounds = 1.102 short tons) of CO_2

Fuel	Price (Oct 2019)	Door 1	Door 2	Door 3
Coal	$57 per short ton	**$17**	$34	$68

Note: The combustion of coal is approximately $C_{137}H_{97}O_9NS$, give or take a few toxic metals, as detailed at http://chemed.chem.purdue.edu/genchem/topicreview/bp/1organic/coal.html
The fraction of C in coal is $(137 \times 12) / (137 \times 12 + 97 + 9 \times 16 + 14 + 32) = 0.85$

Combustion of a short ton (2000 lbs) of coal will release $(44/12) \times 0.851 \times 2000$ lbs = 6243.3 lbs (or 2832 kg) of CO_2 to the atmosphere
For atmospheric CO_2 to rise by 1000 kg, must burn 1000/2832 = 0.35 short tons of coal, which costs the utility a grand total of $0.35 \times \$49 = \$20$

Combustion of $20 of coal leads to emission of a metric tonne of atmospheric CO_2

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Fuel	Price (Oct 2019)	Door 1	Door 2	Door 3
Coal	$57 per short ton	**$17**	$34	$68
Natural Gas (utility price)	$3.42 / 1000 cubic foot	$25	$50	$100

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Crucial starting point for understanding how to think about price of a metric tonne (1000 kg = 2,204 pounds = 1.102 short tons) of CO_2

Fuel	Price (Oct 2019)	Door 1	Door 2	Door 3
Coal	\$57 per short ton	**\$17**	\$34	\$68
Natural Gas (utility price)	\$3.42 / 1000 cubic foot	\$25	**\$50**	\$100
Automobile Gasoline	\$2.96 / galloon			

Note: Natural gas in the U.S. is sold as 1000 cubic feet at 60°F and 14.73 pounds per square inch
Ideal gas law can be used to show that 1000 ft^3 of pure CH_4 = 19.17 kg of CH_4
Combustion of 1000 ft^3 of CH_4 releases (44/16) × 19.17 kg = 52.72 kg of CO_2 to the atmosphere

The release of 1000 kg of CO_2 requires combustion of 1000 / 52.72 or 19 cubic feet of natural gas
At \$2.62 per cubic foot, this comes to 19 × \$2.62 = \$50

Combustion of \$50 of natural gas leads to release of a metric tonne of atmospheric CO_2

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Natural Gas (utility price)	$3.42 / 1000 cubic foot	$25	**$50**	$100
Automobile Gasoline	$2.72 / galloon	$75	$150	$300

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Natural Gas (utility price)	\$3.42 / 1000 cubic foot	\$25	**\$50**	\$100
Automobile Gasoline	\$2.72 / galloon	\$75	\$150	**\$300**

Note: A gallon of gasoline (C_8H_{18}) weighs 6.3 lbs and is 0.84 [= $(8\times12)/(8\times12+18)$] carbon

Each gallon of gasoline releases 0.84×6.3 lbs$\times(44/12)$ = 19.45 lbs of CO_2 to the atmosphere

One metric tonne of CO_2 = 2204 lbs or 113 gallons

113 gallons $\times$ \$2.72 = \$307

Combustion of \$307 of gasoline releases a metric tonne of CO_2
or 10 fill-ups at ~\$30 per fill-up to release