BEFORE THE PUBLIC SERVICE COMMISSION OF THE STATE OF MISSOURI

In the Matter of the Application of Grain Belt Express LLC for an Amendment to its Certificate of Convenience and Necessity Authorizing it to Construct, Own, Operate, Control, Manage, and Maintain a High Voltage, Direct Current Transmission Line and Associated Converter Station	))))))	**File No. EA-2023-0017**

NOTICE OF EXTRA-RECORD COMMUNICATION

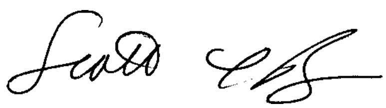
Issue Date: August 23, 2022

On August 23, 2022, the Public Service Commission received letters via personal delivery from Patricia Stemme that were dated August 22, 2022. The letters were received by Chairman Ryan Silvey, Commissioner Scott Rupp, Commissioner Maida Coleman, Commissioner Jason Holsman and Commissioner Glen Kolkmeyer. Since the letters could be considered extra-record communications under Commission Rule 20 CSR 4240-4.030, notice of the contact is hereby given.

In the letters, Ms. Stemme commented, "We are asking commissioners to deny Invenergy's extravagant filing on the grounds that they have not proven demand for their energy; have not told us who their customers are and their energy is not cost effective for this area and definitely not wanted." Ms. Stemme's letters are attached to this notice. This notice is given pursuant to Commission Rule 20 CSR 4240-4.030(2).

Chairman Ryan Silvey,
Missouri Public Service Commission

Dated at Jefferson City, Missouri,
this 23rd day of August, 2022.



Commissioner Scott Rupp,
Missouri Public Service Commission

Dated at Jefferson City, Missouri,
this 23rd day of August, 2022.

Commissioner Maida Coleman,
Missouri Public Service Commission

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this 23rd day of August, 2022.

Commissioner Jason Holsman,
Missouri Public Service Commission

Dated at Jefferson City, Missouri,
this 23rd day of August, 2022.

Commissioner Glen Kolkmeyer,
Missouri Public Service Commission

Dated at Jefferson City, Missouri,
this 23rd day of August, 2022.

Commissioner Ryan Silvey
200 Madison Street
Jefferson City, MO
65102-0360

Commissioner Ryan Silvey

200 Madison Street, P O Box 360

Jefferson City, MO 65102-0360 August 22,2022

My husband and I have been grain farmers in Central Missouri, since 1976. We have worked very hard, struggled through 1980's, managed to pay our loans, taxes and farm payments on time. We have also been good stewards of the land. On July 12, 2022 we received a letter in the mail from a company called Invenergy Transmission, based out of Chicago, IL informing us that they had plans to possibly run a 140 x 140 ft electric transmission towers through our farm. This notice was very upsetting for us. The towers would ruin our farm, the property would be devalued and there is no amount of money to compensate us for the permanent loss. We went to their public meeting, we asked a lot of questions and received very few straightforward answers. We left the meeting feeling frustrated and determined to do our homework; to find out as much as we could. The first thing we learned is there are lots of groups all over Missouri that have organized to fight Invenergy and companies like them. There are also lots of other states that are being impacted and resisting their plans. We attended the Audrain County landowner meeting, where Presiding Commissioner, Wiley Hibbard, said "Invenergy Transmission has no money yet, they are waiting for government subsidy." Lynn Thompson, General Manager at Consolidated Electric Cooperative of Mexico, MO told us they have no interest in purchasing the Invenergy's energy. Consolidated is one of the cooperatives in the Associated Electric Cooperative group, they service over 2 million people in Missouri, Iowa and Oklahoma, they will be forced to let Invenergy hook up to their substation. I believe this is an intrusion on the amazing system that already exists here in our area. We have very reasonable electric rates. Invenergy has filed several condemnations (taking) court cases against landowners who refused to sign an easement. Sure, doesn't sound like the friendly, we'll-work-it-with-you -company they try to portray. They are taking land by force, even though they don't have an approved route and interconnection, or enough customers to make the project economic! What country do we live in? China? I can't imagine how devastating the proud farmers and families I know are feeling about this. Where is their protection? Since they have not gotten enough customers for the Grain Belt Express and Illinois will not let them come through their state, why are you even considering letting them have permission to make the Tiger Connection here in Audrain and Callaway? By the way, it sounds like the Illinois commissioners are protecting their farm landowners.

Keryn Newman, Stoppathwv.com, reports MJMEUC agreed purchase a very small amount of capacity (up to 200 MW) at a loss leader price below GBE's (Grain Belt Express) cost to provide the service. MJMEUC only agreed because it was basically getting something for free, but it was also a very small portion of the available capacity. Since then, GBE has not found any other customers. Nobody wants to buy their service still. In order to be viable GBE needs permission to connect it's 4000 MW transmission project to the existing electric grid. After 10 years, why are we still having this discussion? Looks obvious to me the people of Missouri and the electric cooperatives do not want their kind of power. It is my opinion that intermittent power is not practical because it cannot sustain itself, it relies on the consistent AC energy from coal power and natural gas. The average electric energy produced from solar is 20-30% because of daylight. If we are forced to take payment for the easement on our land, that money is considered capital gains, therefore we would have an added burden at tax time. If Invenergy

does come down to the McCredie substation, they would have to add a second substation to convert their DC electric coming from the solar panels to AC. I repeat; they must have a backup energy source so if their so-called green energy goes dark because of clouds, snow and nighttime. I don't have to tell you that the peak demands for electricity is what causes our electric to rates go up! The government is printing money to pay for these expensive wind turbines and solar farms and high transmission towers. We the taxpayers will get changed for that as well! What I have been told is most of the energy produced isn't even for Missouri. So why are we ruining prime farmland in Missouri for another state to use? Isn't it your job to protect us? And understand, your family will be paying more too. This going to affect every electric consumer and business in the state. Commissioner Silvey please allow the citizens affected a chance to share with you, their concerns, conside r having one or two hearings to give people a chance to share their opinion with you. We heard a healthcare provider worried about the tower lines emitting EMF's (Electric Magnetic Frequencies) and EMR's (Electric Magnetic Radiation) she believes they will be harmful to our health. Another farmer and his wife are worried that the towers will interfere with the radio and cell service. We don't know what side effects of living near these transmission towers will be. We do know it will forever ruin the beauty of the country side that we all love so much. As a farmer works his land, the towers will be a constant pain when he works the ground near them. He will have to be extra careful when using his large equipment, his drones for spraying, the hired helicopters and small planes. He won't be able to irrigate his land near the towers. As I said it will certainly devalue the land, no one wants to build their home near a high tower electric line, there is not enough money to compensate us. According to the Constitution, it protects We the People, from an unregulated merchant like Invenergy from using eminent domain. Granting eminent domain authority to an unregulated merchant for speculative projects that may never be placed in service violates the Fifth Amendment's requirement that property taken for public use. Looks to me like CEO Michael Polsky will be the one that gains the most from this project if it goes through. Protect the landowners and the non-profit utility companies from the unregulated merchant that only care about money. I am trusting you to do the right thing for We the People. I have not heard one person that is in favor of this project. Their proposal cuts right through prime Missouri farmland acres that are presently producing crops for ethanol and biodiesel. Both of them are helping to reduce the fuel emissions in St. Louis, Columbia and Kansas City; truly renewable fuels.

We are asking you Commissioner Silvey and the other commissioners to deny Invenergy's extravagant filing on the grounds that they have not proven demand for their energy; they have not told us who their customers are and their energy is not cost effective for this area and definitely not wanted. Thank you for your time, I have included some supporting information that backs up my request.

Why do we burn coal and trees to make solar panels?

Thomas A. Troszak (2019/11/14 revision)

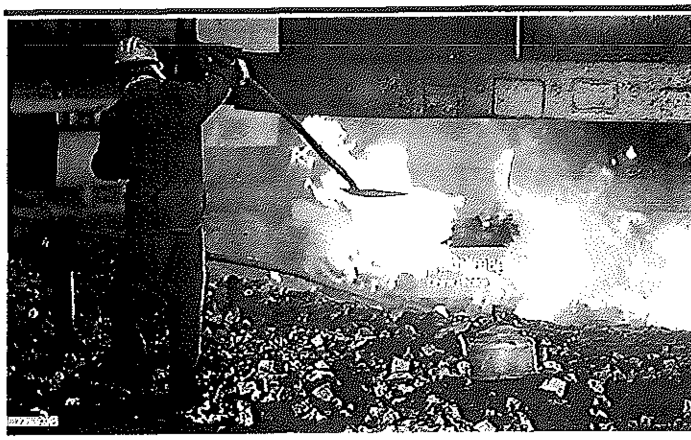


Figure 1. Workman shovels coal and lumpy quartz (silicon ore) into a silicon smelter in China. (photo: Getty)

1. Most commercial solar PV modules use *photovoltaic cells* (solar cells) made from highly purified silicon (Si).

Since the early 1900s, silicon "metal" is reduced from quartz using **carbon** in submerged-arc furnaces, each powered by up to 45 megawatts* of electricity. (Fig 1,2)

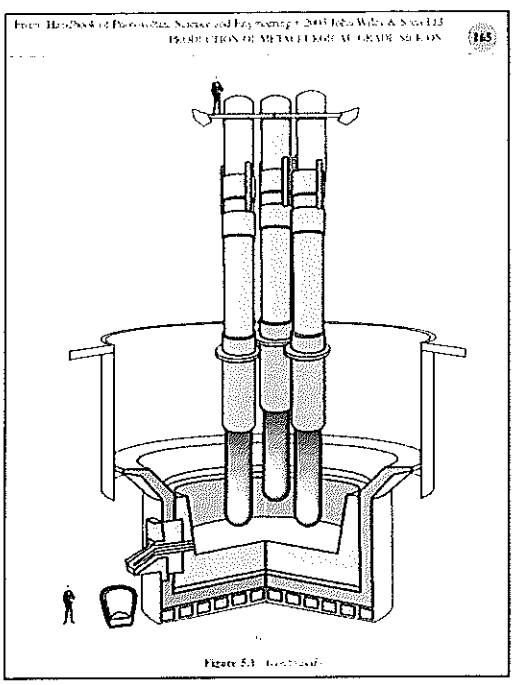


Figure 2. Diagram of a silicon smelter showing the three giant carbon electrodes that provide arc temperatures > 3,000°F for smelting quartz into "metallurgical grade" silicon (mg-Si) using carbon as a reductant (John Wiley and Sons, Ltd.)

2. Why do we need to burn carbon to make solar PV? - Elemental silicon (Si) can't be found by itself anywhere in nature. It must be extracted from quartz (SiO_2) using **carbon (C)** and heat (from an electric arc) in the "carbothermic" **(carbon+heat)** reduction process called "smelting." **($SiO_2 + 2C = Si + 2CO$)** Several **carbon sources** are used as **reductants** in the silicon smelting plant, which requires ~20 MWh/t of electricity, and releases CO - resulting in up to 5 - 6 t of CO_2 produced per ton of metallurgical grade (mg-Si) silicon smelted. [1] Thus, the first step of solar PV production is gathering, transporting, and **burning millions of tons of coal, coke and petroleum coke - along with charcoal and wood chips** made from hardwood trees - to smelt >97% pure mg-Si from quartz "ore" (silica rocks). [1][2][3][4][5][6][7][8][9][10]

*45 megawatts (MW) is enough for a small town (about 33,000 homes).

Figure 3. Pouring liquid metallurgical grade (~99% pure) silicon into molds, to cool into silicon "metal". (Getty)

3. Even more fossil fuels are burned later, to generate electricity for the polysilicon, ingot, wafer, cell, and module production steps shown. [21] As a result of all these processes, the solar PV industry generates megatons of CO and CO_2. But as shown below (fig 4), some often-cited descriptions of solar module production **omit the raw materials and smelting process from the PV supply chain** which obscures the use of fossil fuels and the vast amount of deforestation necessary for solar PV production. [1][3][9][27]

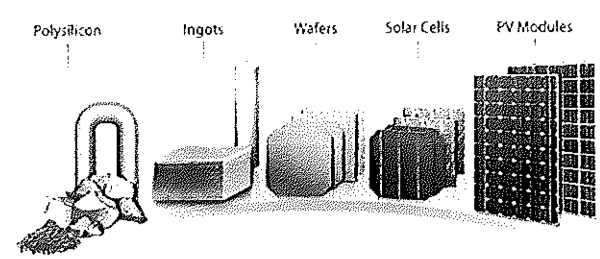


Figure 1. Schematic of c-Si PV module supply chain

Figure 4. (source: National Renewable Energy Laboratory, 2018)

4. Raw materials for metallurgical-grade silicon

Raw materials for one ton (t) MG-Si (Kato, et. al) [37]

- Quartz 2.4 t
- Coal 550 kg
- Oil coke 200 kg
- Charcoal 600 kg
- Woodchip 300 kg

Raw materials for one ton (t) MG-Si (Globe) [3]

- Quartz 2.8 t
- Coal 1.4 t
- Woodchips 2.4 t

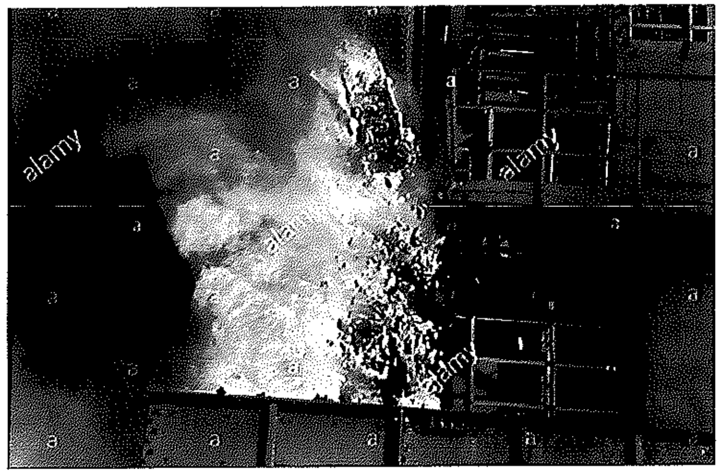
For 110,000 tpy (tons per year) MG-Si (Thorsil) [1]

- Quartz 310,000 tpy
- Coal, coke and anodes 195,000 tpy
- Wood 185,000 tpy
- Total 380,000 tpy

When calculating CO2 emissions from silicon smelting, "by joint agreement" some authors exclude CO2 emissions from non-fossil sources (charcoal, wood chips), power generation, and transportation of raw material. [27]

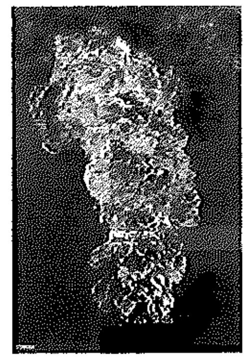
5. Sources of carbon for solar silicon smelting

• **Coal** - Is a dense, rock-like fuel. The (low ash) coal used **directly** for silicon smelting is mostly the **"Blue Gem" from Cerrajón, Columbia**, Kentucky, USA, or Venezuela. [1][2][3][5][6][7][8]

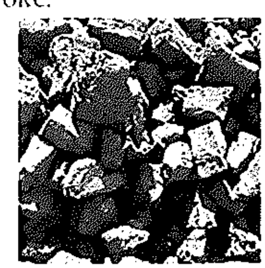


A "Slot Oven" discharging coke into a railroad car. (photo: Alamy)

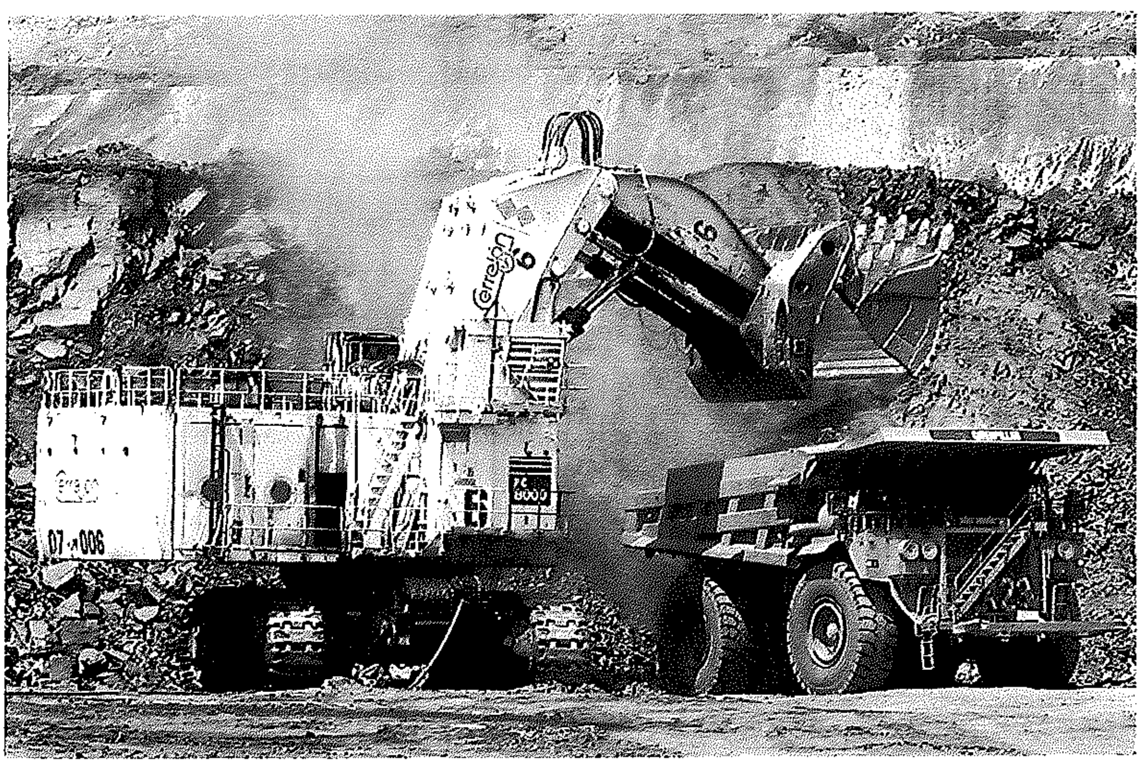
• **Metallurgical Coke** (Metcoke) is a tough, cinder-like solid fuel made by "coking" coal in large "slot ovens" - to drive out most of the volatile tars, etc. to the atmosphere as smoke, flame, carbon monoxide, carbon dioxide, sulfur dioxide, other gasses, and water vapor. (photo: Getty Images)



The **coking process** is nearly identical to the process used for making charcoal from wood (see charcoal production below). Restricting the air supply to a large mass of burning coal allows about 40% of the coal to "burn off" - leaving behind a solid residue (coke) with a **higher carbon content** per ton that the original coal. It takes **about 1.6 t of coal** to make a ton of coke.



Metcoke looks like porous, silvery grey coal.



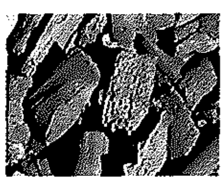
The Cerrajón open-pit mine in Columbia supplies "Blue Gem" coal for silicon smelters around the world

Filling barges with petcoke outside Chicago, Ill. USA (photo)

• **Petroleum Coke** (Petcoke) - is a solid fuel in the form of pellet-like granules, which are a carbon-rich byproduct of crude oil refineries. Millions of tons of petcoke are also made directly from raw bitumen (tar). Due to its low price and high carbon content, petcoke made in American refineries from "Canadian Tar Sands" is a source of carbon exported from the U.S. to silicon manufacturers in China. [9]

"Because it is considered a refinery byproduct, petcoke emissions are not included in most assessments of the climate impact of tar sands" [10]

"Beehive" charcoal ovens in Brazil (Alamy)



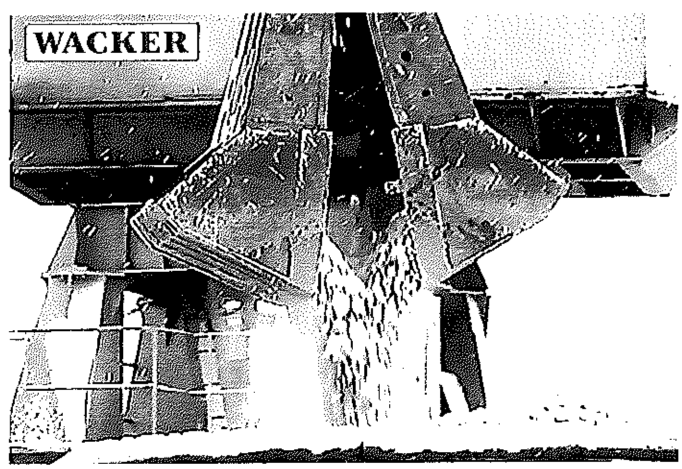
• **Wood Charcoal - Many hardwood trees must be burned to make wood charcoal.** In the traditional process, wood is stacked into "beehive ovens", ignited, then mostly smothered to prevent the wood from burning completely to ash. By weight, **about 75% of the wood is lost to the atmosphere as CO, CO_2, smoke, and heat.**

Some silicon producers use "**charcoal plantations,**" but they **only supply a fraction of the current demand** of carbon for silicon production. The rest of the carbon supply has to come from imported coal or coke, or the cutting and burning of "virgin" rainforest. [13][14][15][16]

In Brazil, it is estimated that more than a third of the country's charcoal is still produced illegally from protected species. [14] Brazil is a charcoal supplier to silicon producers in other countries, including the United States. Silicon smelters around the world use charcoal from many sources, so solar silicon may be smelted with charcoal made directly from rainforest not grown on plantations.

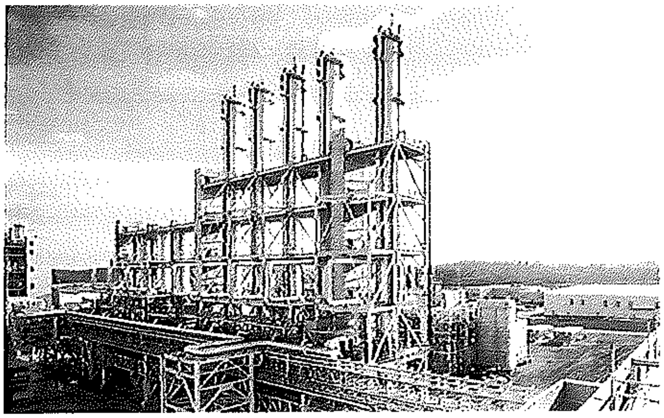
This hardwood forest in the U.S. was clear cut to make wood chips

6. **Hardwood Chips** (also called Metchips) - Matchbox-sized fragments of **shredded hardwood must be mixed into the silicon smelter** "pot" for many reasons - to allow the reactive gasses to circulate, so the liquid silicon that forms can settle to the bottom for tapping, and to allow the resulting CO (and other gasses) to escape the smelter "charge" safely. [4]



Solar silicon quartz rocks (Wacker Chemie)

7. **Silicon ore - Quartz - (silica, silicon dioxide, SiO_2)** Even if sufficiently pure, **silica sand won't work in any silicon smelter**, it is too fine. Selected high-purity quartz is mined and graded into "lumpy" (fist-sized) gravel for smelting. Worldwide, "solar grade" deposits of quartz are somewhat scarce, and highly valued.

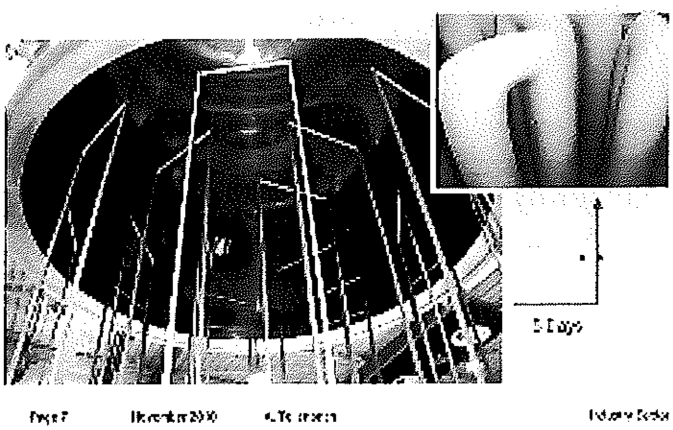


A single polysilicon plant like this one in Tennessee, USA. can draw 400 megawatts of electricity, enough power for about 300,000 homes. (Wacker Polysilicon)

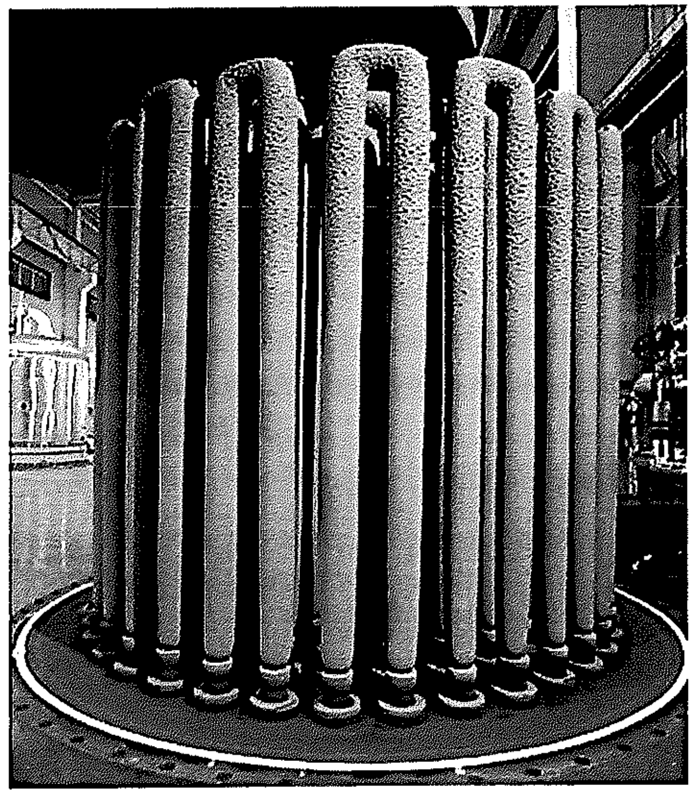
8. Polysilicon production

Metallurgical grade silicon (mg-Si) from the smelter is only about 99% pure, so it must undergo two more energy-intensive processes before it can be made into solar cells. First, **the Siemens Process converts (mg-Si) from the smelter into polycrystalline silicon (called polysilicon)** by a high-temperature vapor deposition process.

This is a bit like "growing rock candy" on hyper-pure silicon "strings" inside a pressurized-gas filled "bell-jar" reactor. As a mixture of silicon gas (made from mg-Si) and hydrogen gas passes through the reactor vessel, some of the silicon gas molecules "cling" to the electrically heated "strings" (called filaments) causing them to grow into "rods" of 99.9999% pure (or better) polysilicon.



Left: When heated to around 1100°C the polysilicon "filaments" standing beneath the reactor cover can "catch" about 20% of the silicon atoms that pass through the reactor in gaseous form. Right: Polysilicon "rods" after 5 days of growth. (Siemens AG)



Each batch of polysilicon "rods" takes several days to grow, and a continuous, 24/7 supply of electricity to each reactor is essential to prevent a costly "run abort." So **polysilicon refineries** depend on highly reliable conventional power grids, and usually have two incoming high-voltage supply feeds.

A polysilicon plant consumes ~1.6 - 6 t of incoming mg-Si, and requires at least **175 MWh** (or more) of **additional electricity** per ton of polysilicon produced - **about 10 times the energy already used for smelting** each ton of mg silicon from ore. **[11]** After the rods are removed from the reactor, they are sawed into sections or broken into "chunks" for loading into crucibles in the next step.

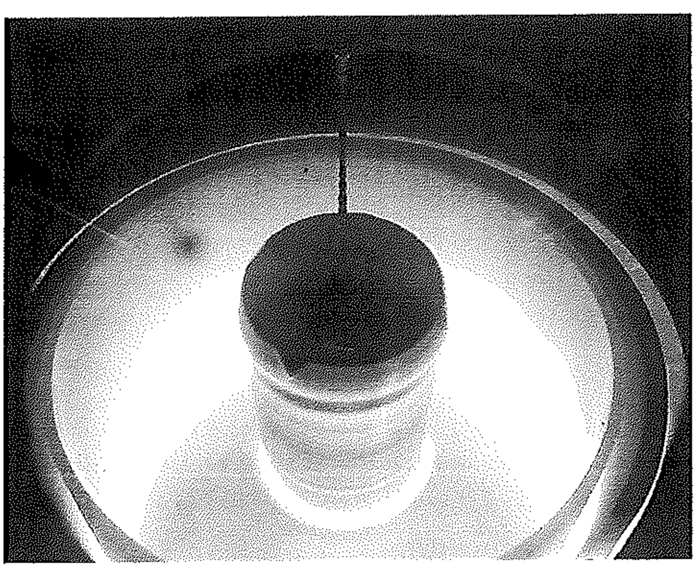
Polysilicon rods and sections being broken into chunks by hand in a clean room. (Hemlock)

Polysilicon chunks being heated in a crucible. When melted, a single crystal will be pulled out of the liquid polysilicon. (Getty)

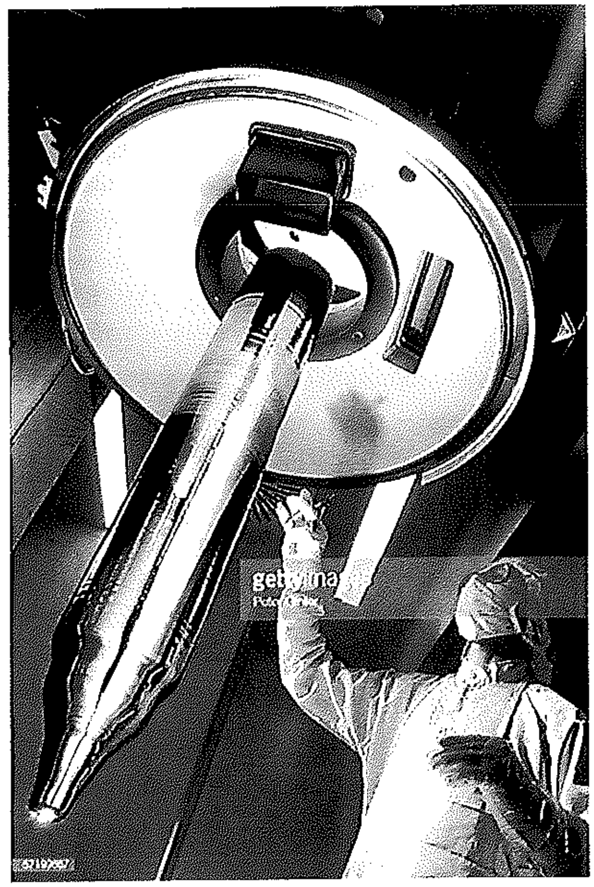
9. Crystal growing (ingot production)

For making single-crystal solar cells (called mono PV) the PV industry uses the **Czochralski process to further purify the polysilicon, and align the silicon molecules into a single-crystal form.**

First, polysilicon chunks are melted in a rotating crucible in an inert atmosphere. Then a small seed crystal of silicon is lowered into the molten polysilicon. As the seed crystal is slowly withdrawn, a single silicon crystal forms from the tip of the seed. As the crucible turns, the polysilicon continues to grow into a cylindrical ingot, leaving most of the non-silicon impurities behind in the 5-10% of "pot scrap" remaining after the crystal is drawn free.

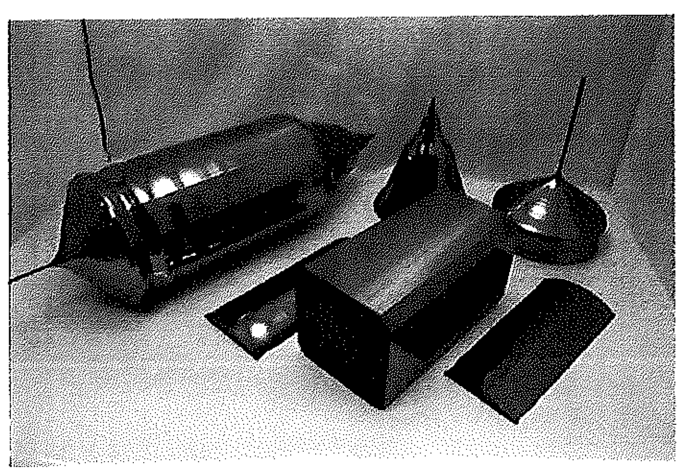


Czochralski ingot being pulled from melted polysilicon. (Image source: Siltronix)



Czochralski ingot after cooling (Image source: Getty)

This process requires several days, and uninterrupted power. An ingot/wafer/cell plant can use more than 100 MWh additional energy per ton of incoming polysilicon, about 6 times as much as the original smelting of the silicon from ore. After slow cooling, the ingot's unusable crown and tail are cut off (about 10%), the center is then ground down, the four "chords" (long sides) are sawn off (about 25%) leaving a rectangular "brick" so the solar wafers will be almost square after slicing.

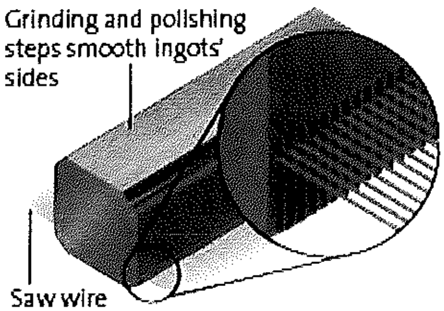


Czochralski process whole ingot (left), and brick and chords after sawing (right), crown and tail (upper right) (SVM)

For multi-crystalline cells (called multi PV) polysilicon is melted in rectangular quartz molds, then allowed to cool slowly into a rectangular ingot of multi-crystalline silicon. which is trimmed to remove unusable portions, then sliced into bricks.

10. Wafer sawing

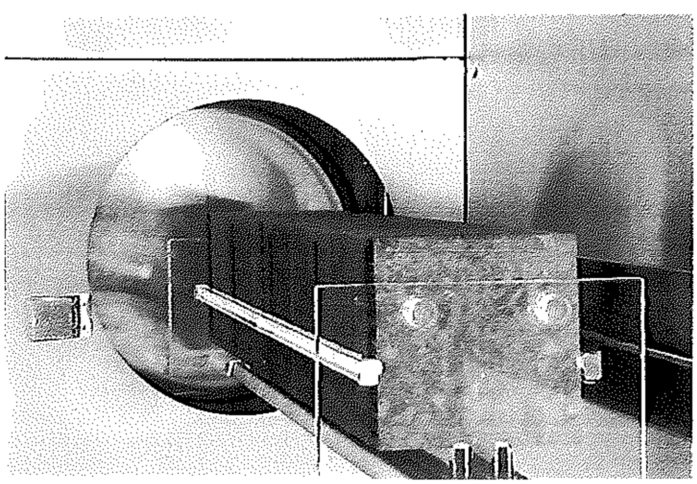
Then, like a loaf of bread, the silicon "bricks" are sliced with wire saws into thin wafers, which will later be processed into cells.



About half of the "brick" is lost as "sawdust" in the wafer slicing process, and this can't be recovered. So, after all of the energy and materials that have gone into making each "brick", much of the incoming polysilicon does not ever become finished wafers. Some of the heads, tails, chords, and trimmings can be etched (to remove contamination) and remelted **using additional energy** if the purity of the scrap is sufficient to justify the expense, otherwise they are discarded as waste.

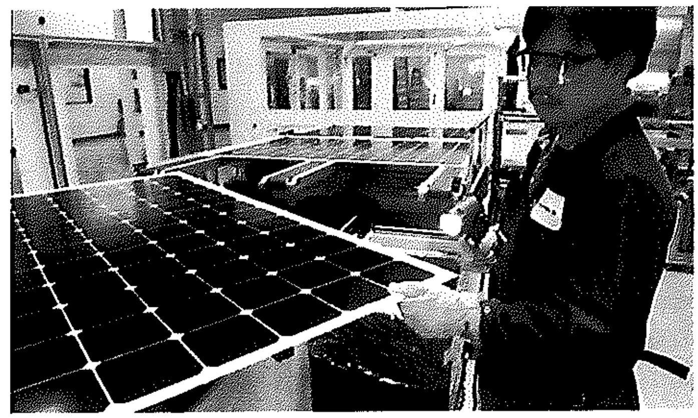
11. Cell and module production.

Once the wafers are sliced, they are made into "cells" by adding layers of other materials and components in a series of additional production steps.



Diffusion Furnace in the PV-TEC at Fraunhofer ISE
Loading of the diffusion tubes with batches of multicrystalline silicon wafers. The wafers, sorted into quartz boats, are brought into the (up to 1050 °C) hot quartz tubes. (Fraunhofer ISE)

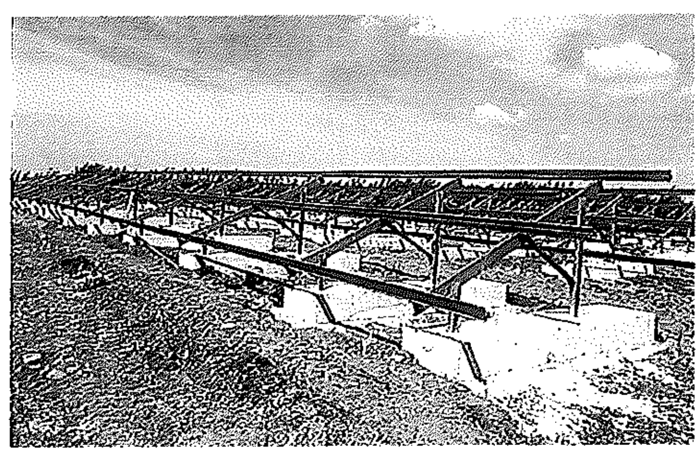
Then the cells are assembled into modules. Beside silicon wafers, most solar PV modules also require many other energy-intensive materials - aluminum (for the frame), silver, copper, glass, plastic, highly toxic rare earth metals, acids, and dozens of other chemicals for processing the polysilicon into cells and modules. A lot of electricity is needed to power the cell production and module assembly, **a supply of natural gas** is used to provide heat in the process.



Solar module inspection on the assembly line. (Solar World)

12. Other materials and steps

Once the modules are made, the whole PV system usually needs steel or aluminum framing, concrete, and some empty land (or a rooftop) to position it securely toward the sun, a lot of wiring to connect (through DC/AC inverters and transformers) to the existing power grid, or directly to battery banks,



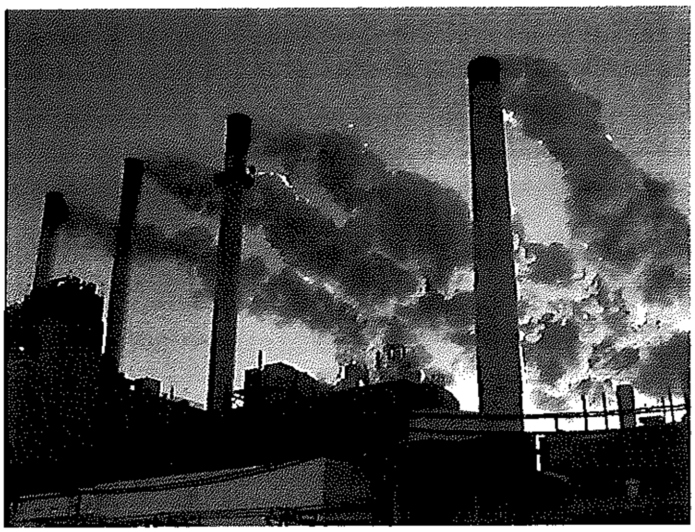
PV support structure and concrete foundation (Hill & Smith)

Of course, it takes **a lot of energy and resources** to make steel, aluminum, concrete, inverters, copper wiring, and all of these other materials. In many cases, the "balance of system" components in a PV installation can require as much (or more) "up-front" resources and energy to make as the modules. **[21]**

In addition, the amount of fossil fuels and non-renewable resources needed to construct and maintain new PV production infrastructure (smelters, polysilicon refineries, etc.) is considerable, but has been excluded from all "life cycle analysis" (LCA) of solar PV production by definition. [38]

13. Transportation

Throughout the solar PV manufacturing process all of the materials and products must be shipped **to and from more than a dozen countries** around the world in large barges, container ships, trains, or trucks - **all powered by non-renewable oil. [36]**



14. Power

Worldwide, only a few silicon smelters, like those in Norway, are powered primarily by hydro-electricity. Elsewhere, the current majority of smelters, polysilicon refineries, ingot growers, cell and module factories are running on grids **powered mostly by fossil fuels and uranium.** At present, more than 50% of all solar silicon is made in China, where the industrial grid is powered largely by fossil fuels, primarily low-grade coal. Depending on the "energy mix" available, the quantity of coal, coke, or gas that is being burned to deliver power 24/7 to the PV factories may be far greater than the amount needed as the carbon source for smelting silicon. To provide a realistic assessment of the total environmental impact of PV manufacturing, this **must be added to the "fossil fuel bill"** for solar PV production - along with the "embodied energy" of PV factories. [11][12][21]

15. Conclusions

Every step in the production of solar photovoltaic (PV) power systems requires a perpetual input of fossil fuels - as carbon reductants for smelting metals from ore, for process heat and power, international transport, and deployment. Silicon smelters, polysilicon refineries, and crystal growers around the world all depend on uninterrupted, 24/7 power that comes mostly from coal and uranium. **The only "renewable" materials consumed in PV production are obtained by deforestation** - for wood chips, and by burning vast areas of tropical rainforest for charcoal used as a source of carbon for silicon smelters. So far, both **media and journal claims** that solar PV can somehow "replace fossil fuels" **have not addressed the non-renewable reality of global supply chains** necessary for mining, manufacturing, and distribution of PV power systems. Based on current world production levels of solar PV, an attempt to replace conventional electricity production with solar PV would require a **dramatic increase in the amount of coal and petcoke needed for silicon smelting**, along with the **increased cutting of vast areas of forest** for charcoal and wood chips.

Readers are encouraged to **examine all of the references below**, to become aware of other aspects with solar pv manufacturing and deployment that are beyond the scope of this paper.

References

[1] Thorsil (2015) "Metallurgical Grade Silicon Plant - Helguvík, Reykjanes municipality (Reykjanesbær), Reykjanes peninsula, Iceland Environmental Impact Assessment (EIA) Capacity: 110,000 tons" https://www.giek.no/getfile.php/133565/web/Dokumenter/Prosjekter%20under%20vurdering/EIA-Thorsil_Lingua-2-%20konsekvensutredning.pdf (1) "Thorsil's initial assessment report was based on using...**Coal from El Cerrajon in Columbia**...for an annual production...of 110,000 tpy [of mg-Si]...**would correspond to 605,000 tpy of carbon dioxide...The Environment Agency feels that...such exhaust would significantly increase Iceland's overall emissions"**

[2] Efla (2013) "Environmental Impact Assessment of a SILICON METAL PLANT AT BAKKI IN HÚSAVÍK"https://www.agaportal.de/_Resources/Persistent/856d55b1a3c1948e5f856f800195760741faa93b/eia_island_silizium.pdf (2) "The main raw materials used for the production of Silicon Metal are quartzite... **coals (mainly from [Cerrejón] Columbia, Venezuela, and USA)**, charcoal, wood chips"

[3] "New York State Department of Environmental Conservation - Facility DEC ID: 9291100078 PERMIT Under the Environmental Conservation Law (ECL) Permit Issued To: GLOBE METALLURGICAL INC" http://www.dec.ny.gov/dardata/boss/afs/permits/929110007800009_r3.pdf **(3) "Globe Metallurgical produces high purity silicon metal...The facility is a major source of emissions of sulfur dioxide, carbon monoxide, hydrogen chloride and nitrogen oxides...** "The submerged electric arc process is a reduction smelting operation...**Reactants consisting of coal, charcoal, petroleum coke, or other forms of coke, wood chips, and quartz are mixed and added at the top of each furnace... At high temperatures in the reaction zone, the carbon sources react with silicon dioxide and oxygen to form carbon monoxide and reduce the ore to the base metal silicon."**

[4] "The Use and Market for WOOD in the ELECTROMETALLURGICAL Industry" https://www.fs.usda.gov/treesearch/pubs/23800 (4) [woodchips are used in smelters]...**to provide a large surface area for chemical reaction to take place more completely and at improved rates...To maintain a porous charge, thereby promoting gentle and uniform - instead of violent - gas venting**...To help regulate smelting temperatures...To keep the furnace burning smoothly on top...To reduce conductivity...To promote deep electrode penetration...To prevent bridging, crusting, and agglomeration of the mix...To reduce dust, metal vapor, and heat loss; and as a result to improve working conditions near the furnace.

[5] Healy, N., Stephens, J. C., & Malin, S. A. (2019). "Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains." *Energy Research & Social Science*, *48*, 219-234. (link) (5)"**Cerrejón is one of the world's largest open-pit coal mines [supplying silicon manufacturers]**...energy extraction often entails the physical displacement of populations or the "slow violence" of landscape destruction, water contamination and livelihood disruption"

[6] What Terrible Injustices Are Hiding Behind American Energy Habits? By Itai Vardi • Friday, November 16, 2018 (link) (6) **"There is a clear 'consumer blindness' and citizens and residents are often unaware of where the fuel they consume is coming from** and what injustices were inflicted on communities within those sites of fossil fuel extraction," said Healy. "Exposing these **injustices of energy 'sacrifice zones' — like [the Cerrejón open-pit coal mine] in La Guajira, Colombia** ...— could be critical for future energy policy decision-making."

[7] 2017/06/18/why-this-part-of-coal-country-loves-solar-power-215272 (7)**"the seam in Whitley County [Kentucky] is an even more valuable variety of metallurgic coal known as "blue gem."..."You need the blue gem to make the solar panels, and that's what people don't know,"** Moses told me, articulating a simple truth: **"Without Coal Valley, there's no Silicon Valley"**

[8] **https://www.prnewswire.com/news-releases/new-colombia-resources-inc-discovers-huge-new-metallurgical-coal-seam-at-their-property-in-colombia-as-the-company-prepares-to-begin-production-while-coal-prices-continue-to-soar-600823111.html** (8) "Colombian coal accounts for close to 75% of coal imports to the U.S... New Colombia Resources' Blue Gem coal is only found on the KY-TN border and central Colombia and is used to produce specialty metals **such as Silicon to make solar panels**, electric car batteries, and many more next generation products"

[9] https://carnegietsinghua.org/2015/05/31/managing-china-s-petcoke-problem-pub-60023 **(9) "Figure 5. [graph] Chinese Petcoke Consumption by Sector (2013 silicon=6%) (2014 silicon=7%)** A significant share of the petcoke used in China [which was made in U.S. refineries] is imported from the United States, ..."According to the U.S. Energy Information Administration (EIA), **U.S. petcoke exports to China... a staggering 7 million metric tons in 2013...accounting for nearly 75 percent of Chinese petcoke.**

[10] Petroleum Coke: The Coal Hiding in the Tar Sands (10) "Because it is considered a refinery byproduct, **petcoke emissions are not included in most assessments of the climate impact of tar sands**"...

[11] https://www.sightline.org/2018/06/25/small-town-silicon-smelter-plan-tees-up-big-questions/ (11) "**these furnaces would have a voracious appetite for electricity: around 105 megawatts on a continuous basis, roughly the equivalent of 68,000 homes...the facility would demand more power than the dam could provide**....Producing one ton of silicon metal requires about six tons of raw materials...Nearby sawmills would send seven or eight trucks per day to deliver wood chips, which are integral to the smelting process...."**The smelting process requires a rare type of metallurgic coal known as "blue gem," ... Operations at the smelter would demand approximately 48,000 metric tons of coal per year—roughly 40 rail cars each month.**"

[12] **https://siteselection.com/theEnergyReport/2009/apr/Wacker-Chemie/** (12) "A nuclear plant is 1200 megawatts. **Fully built out, [Wacker Polysilicon] could be a third of a nuclear plant [400 MW]**...Not everybody out there can handle that size of a load. We're selling the fact that we [TVA] have the reliability, and we have a very diverse portfolio across **coal, nuclear and hydro.**"

[13] Jungbluth, N., M. Stucki, R. Frischknecht, S. Büsser, and ESU-services Ltd. & Swiss Centre for Life Cycle Inventories. (2009) "Part XII photovoltaics." *Swiss Centre for Life Cycle Inventories* (link) (13) "An issue of concern... **is the use of charcoal in this [photovoltaic silicon] process that originates from Asia or South America and might have been produced from clear cutting rainforest wood**"

[14] Eikeland, Inger Johanne, B. Monsen, and Ingunn S. Modahl.(2001) "Reducing CO2 emissions in Norwegian ferroalloy production." *Greenhouse Gases in the Metallurgical Industries: Policies, Abatement and Treatment, (Met. Soc. CIM), Toronto* 325 . (link) (14) **Most of the charcoal used...[for silicon production]...is imported from Asia and South America.** The crude, traditional methods of charcoal making, which are still widely used in these continents, are inefficient and strongly pollute the environment."

[15] Nisgoski, Silvana & Muniz, Graciela & Morrone, Simone & Schardosin, Felipe & França, Ramiro. (2015). NIR and anatomy of wood and charcoal from Moraceae and Euphorbiaceae species. Revista Ciência da Madeira - RCM. 6. 183-190. 10.12953/2177-6830/rcm.v6n3p183-190. (link) (15) "**charcoal supply is still present in illegal cutting of native forests, which represented 30-35% of total output [in Brazil]**... charcoal consumption represents the deforestation of approximately 1.6 million hectares or 16.000 km² of the Cerrado Biome"

[16] 2017/10/burning-down-the-house-myanmars-destructive-charcoal-trade/ (16) "**Dehong's silicon industry ... "has caused a serious damage to forest resources,**" and estimated that "119,700 tons of charcoal were consumed in the production of industrial silicon in Dehong prefecture **in 2014... 31 square miles—"of forests were cut down. (...) In 2016, the [silicon] industry consumed nearly twice that amount** (216,273 tons of charcoal)

[17] BP Statistical Review of World Energy, 67th Edition, June 2018 (17) "despite the huge policy push encouraging a switch away from coal and the rapid expansion of renewable energy in recent years, **there has been no improvement in the mix of fuels feeding the global power sector over the past 20 years. Astonishingly, the share of coal in 2017 was exactly the same as in 1998. The share of non-fossil fuels was actually lower**, as growth in renewables has failed to compensate for the decline in nuclear energy."

[18] De Castro, Carlos, Margarita Mediavilla, Luis Javier Miguel, and Fernando Frechoso. "Global solar electric potential: A review of their technical and sustainable limits." *Renewable and Sustainable Energy Reviews* 28 (2013): 824-835. (link) (18) "**based on real examples...our results show that present and foreseeable future density power of solar infrastructures are much less (4–10 times) than most published studies**... an overview of the land and materials needed for large scale implementation show that many of the estimations found in the literature are hardly compatible with the rest of human activities."

[19] Koomey, J. G., Calwell, C., Laitner, S., Thornton, J., Brown, R. E., Eto, J. H., ... & Cullicott, C. (2002). Sorry, wrong number: The use and misuse of numerical facts in analysis and media reporting of energy issues. *Annual review of energy and the environment*, *27*(1), 119-158. (link) (19) "Unfortunately, numbers that prove decisive in policy debates are not always carefully developed, credibly documented, or correct...**A common mistake in the media has been to apply this statistic (1000 homes per MW) to intermittent renewable power sources**...Intermittent renewables generally produce far fewer kilowatt-hours per MW than conventional power

plants...this widely used equivalence between homes and MW should generally not be applied to intermittent renewables such as...PVs."

[20] Shaner, Matthew R., Steven J. Davis, Nathan S. Lewis, and Ken Caldeira. (2018) "Geophysical constraints on the reliability of solar and wind power in the United States." *Energy & Environmental Science* 11, no. 4 (2018): 914-925 (link) **(20) "Achieving 99.97% reliability with a system consisting solely of solar and wind generation... would require** a storage capacity equivalent to several weeks of average demand...**Three weeks of storage (227 TW h) [which] results in ~6500 years of the annual Tesla Gigafactory production capacity** or a **~900x increase** in the pumped hydro capacity of the U.S."

[21] Carbajales-Dale, Michael, Charles J. Barnhart, and Sally M. Benson.(2014) "Can we afford storage? A dynamic net energy analysis of renewable electricity generation supported by energy storage." *Energy & Environmental Science* 7, no. 5 (2014): 1538-1544. (link) (21) **"PV technologies (CIGS and sc-Si)**...cannot 'afford' any storage while still supplying an energy surplus to society... **since they are already operating at a deficit**...These technologies require large, 'up-front' energetic investments...A fractional [energy] re-investment of greater than 100% ... means that **the industry consumes more electricity than it produces** on an annual basis, i.e. running an energy deficit"

[22] Milligan, M., Ela, E., Hein, J., Schneider, T., Brinkman, G., & Denholm, P. (2012). *Renewable Electricity Futures Study. Volume 4: Bulk Electric Power Systems: Operations and Transmission Planning* (No. NREL/TP-6A20-52409-4). National Renewable Energy Lab.(NREL), Golden, CO (United States). (link) (22) "although **RE Futures** describes the system characteristics needed to accommodate high levels of renewable generation, it **does not address the institutional, market, and regulatory changes that may be needed to facilitate such a transformation**...[and] **a full cost-benefit analysis was not conducted** to comprehensively evaluate the relative impacts of renewable and non-renewable electricity generation options.

[23] Lithium Ion batteries for Stationary Energy Storage - The Office of Electricity Delivery and Energy Reliability, Pacific Northwest National Laboratory **(23)** "Despite their success in mobile applications, **Li-ion technologies have not demonstrated sufficient grid-scale energy storage feasibility "**

[24] Lessons Learned Report - Electrical Energy Storage DOCUMENT NUMBER CLNR-L163 AUTHORS John Baker, James Cross, EA Technology Ltd, Ian Lloyd, Northern Powergrid PUBLISHED 08 December 2014 **(24) "The round trip efficiencies for the [Li-ion] EES systems have been calculated [in actual use]... between 41% and 69% where parasitic loads are included"**

[25] https://energy.stanford.edu/news/calculating-energetic-cost-grid-scale-storage **(25) "using the kind of lead-acid batteries available today to provide storage for the worldwide power grid is impractical."**

[26] Luque, A., & Hegedus, S. (Eds.). (2011). *Handbook of photovoltaic science and engineering*. John Wiley & Sons. (link) **(26) "Photovoltaics is polluting just like all high-technology or high-energy industries only with different toxic emissions** ... Manufacturing of PV modules on a large scale requires the handling of large quantities of hazardous or potentially hazardous materials (e.g. heavy metals, reactive chemical solutions, toxic gases"

[27] https://www.researchgate.net/publication/311440469_CO2_Emissions_from_the_Production_of_Ferrosilicon_and_Silicon_metal_in_Norway (27) "These emission factors only include CO2 emitted from fossil raw materials in the reduction process. **CO2 from biological, renewable sources is not included (according to joint agreement). Neither is CO2 emitted from electric power production or during transportation of raw materials."**

[28] Cleaning Up Clean Energy - https://web.stanford.edu/group/sjir/pdf/Solar_11.2.pdf **(28) "the (PV) industry has largely overlooked investigative reports revealing current problems with production waste,** particularly pertaining to Chinese manufacturing. Until these concerns receive more attention, **promises of panel recycling will quell any public anxiety, preventing the creation of necessary safeguards** to stop rogue firms from unsafe manufacturing practices"

[29] https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/#256668c121cc **(29) "We estimate there are 100,000 pounds of cadmium contained in the 1.8 million panels,"** Sean Fogarty of the group told me.

"Leaching from broken panels damaged during natural events – hail storms, tornadoes, hurricanes, earthquakes, etc. – and at decommissioning is a big concern."

[30] https://www.scmp.com/news/china/society/article/2104162/chinas-ageing-solar-panels-are-going-be-big-environmental-problem (30) Lu Fang, secretary general of the photovoltaics decision in the China Renewable Energy Society, wrote...**By 2050 these waste panels would add up to 20 million tonnes, or 2,000 times the weight of the Eiffel Tower**...Tian Min, general manager of Nanjing Fangrun Materials, a recycling company in Jiangsu province that collects retired solar panels, said **the solar power industry was a ticking time bomb."It will explode with full force in two or three decades and wreck the environment, if the estimate is correct,"**

[31] https://www.solarpowerworldonline.com/2018/04/its-time-to-plan-for-solar-panel-recycling-in-the-united-states/ (31) "We've conducted some toxicity testing on modules, and we have seen results showing that **the presence of lead is higher than the threshold allowed by the TCLP (toxicity characteristic leaching procedure)**...There is a potential for leaching of toxic materials such as lead in landfill environments. **If modules are intact, it's a low risk, but as soon as they're broken or crushed, then the potential for leaching is increased."**

[32] https://www.welt.de/wirtschaft/article176294243/Studie-Umweltrisiken-durch-Schadstoffe-in-Solarmodulen.html (32) "Based on installed power and performance weight, we can estimate that **by the year 2016, photovoltaics has spread about 11,000 tonnes of lead and about 800 tonnes of Cd (cadmium),**" the study said"

[33] https://www.solarpowerinternational.com/wp-content/uploads/2016/09/N253_9-14-1530.pdf (33) "disposal in "regular landfills [is] not recommended **in case modules break and toxic materials leach into the soil"** and so "disposal is potentially a major issue."

[34] Tao, Coby S., Jiechao Jiang, and Meng Tao. "Natural resource limitations to terawatt-scale solar cells." *Solar Energy Materials and Solar Cells* 95, no. 12 (2011): 3176-3180. https://doi.org/10.1016/j.solmat.2011.06.013 **"Material scarcity prevents most current solar cell technologies from reaching terawatt scales.** (...) Scarce materials in solar cells include indium, gallium, tellurium, ruthenium, and silver. - Natural resource limitations to terawatt-scale solar cells."

[35] Metal-demand-for-renewable-electricity-generation-in-the-netherlands **"The current global supply of several critical metals is insufficient to transition to a renewable energy system.** ...production of wind turbines and photovoltaic (PV) solar panels already requires a significant share of the annual global production of some critical metals... Furthermore, mining is often associated with significant environmental and social costs"

[36] INCREASES IN EFFICIENCY HAVE NOT REDUCED ABSOLUTE CO2 EMISSIONS FROM SHIPS **"Although the CO2 intensity of many major ship classes decreased (i.e., they became more efficient) from 2013 to 2015, total CO2 emissions from ships increased**. For example, although the CO2 intensity of general cargo ships (measured as emissions per unit of transport supply) decreased by 5%, CO2 emissions increased by 9% **Thus, increases in distance traveled due to a greater demand for shipping more than offset gains in operational efficiency during the period studied"**

[37] Kato, K., Murata, A., & Sakuta, K. (1998). Energy pay-back time and life-cycle CO2 emission of residential PV power system with silicon PV module. *Progress in Photovoltaics: Research and Applications*, *6*(2), 105-115.

[38] Fthenakis, V., Kim, H., Frischknecht, R., Raugei, M., Sinha, P., & Stucki, M. (2011). Life cycle inventories and life cycle assessment of photovoltaic systems. *International Energy Agency (IEA) PVPS Task, 12.* http://www.clca.columbia.edu/Task12_LCI_LCA_10_21_Final_Report.pdf

Energy + Environment
Legislature

Grain Belt Express takes first resistant Missouri landowner to court

Progress on the $2 billion transmission line is accelerating as 65% of the route in Missouri and Kansas has been acquired voluntarily

By: Lukas Vanacker - December 21, 2021 12:00 pm

Evergy's Flat Ridge Wind Farm in Kansas (photo submitted).

A $2 billion wind energy project spanning the length of northern Missouri is for the first time asking a judge to force a resistant landowner to sell the company an easement on their land.

Grain Belt Express, a proposed high-voltage transmission line that would carry 4,000 megawatts of renewable energy from Western Kansas to Indiana, has faced fierce criticism from some Missouri landowners and elected officials.

In September, it filed a petition for condemnation against a farmer from Gower named Bradley Horn. A hearing in the case was originally scheduled last week in the Circuit Court of Buchanan County but was delayed until Feb. 2.

The company is arguing that Horn "did not accept the written offer for the property interests," and later "negotiations were unsuccessful." It marks the first time Grain Belt Express has taken a resistant landowner to court.

The judge can appoint three disinterested residents of the county, who have to assess the just compensation for Horn.

Horn's attorneys declined to comment.

Payments

When the Grain Belt Express got its approval from the Missouri Public Service Commission in 2019, the decision was criticized by some because it granted the private company the right to obtain easements through eminent domain.

Yet the company has always insisted it would only use that procedure as a last resort to acquire 1,700 parcels of land in Kansas and Missouri.

According to Patrick Whitty, vice president of the project's parent company, Invenergy Transmission, Grain Belt Express has "now completed right-of-way acquisition through voluntary easement agreements for approximately 65% of the route in Missouri and Kansas, compared to only one third completed at the start of

the year."

At the beginning of this year, the company had made payments of $4.9 million to landowners in Missouri combined. As it stands today, that figure is $8.5 million.

Grain Belt Express offers landowners compensation of 110% of the market value of land, plus $18,000 per tower structure. That offer was recently increased, Whitty said, to reflect "rising farmland values." For example, one farmer from Madison in northeast Missouri was offered $98,000 to allow two tower structures on nine acres of cropland.

Donna and Kenneth Inglis, a retired couple from Huntsville, were happy to close a deal with Grain Belt Express a year ago.

"I strongly support the project because I strongly believe in green energy," Donna Inglis said. "If our ancestors wouldn't have accepted rural electricity, we would still be working with kerosine lamps."

Inglis didn't want to disclose the details of the financial offer, but she said "it's a lot of money."

However, while some landowners are more than willing to grant the company access to their land, others continue to resist the transmission structures, which are 40 feet by 40 feet wide and between 130 to 160 feet tall.

"Some people have been farming here for more than 100 years," says Marilyn O'Bannon, western district commissioner in Monroe County. "Their land is their heritage. And now, they want to build something through the middle of our land, next to an existing electricity line. We can't farm efficiently around obstacles. And show me where the value for our state is."

O'Bannon's family owns land on the future transmission line. Whereas Inglis praises the professionalism of Grain Belt Express agents, O'Bannon says there has been a lack of transparency.

"The potential dangers and unknowns as well as lack of project details are overwhelming," O'Bannon said. "Landowners are left in the dark as long as possible. I can't describe the emotional impact."

Risks

The road ahead to complete the Grain Belt Express project remains long and bumpy.

In the summer of 2020, Invenergy announced the transmission line would deliver more energy to Missouri than originally anticipated, doubling its investment in the state to $1 billion.

The Public Service Commission still has to approve the extended plan. And after years of litigation and regulatory proceedings involving the project, that could once again stir up opposition to the transmission line.

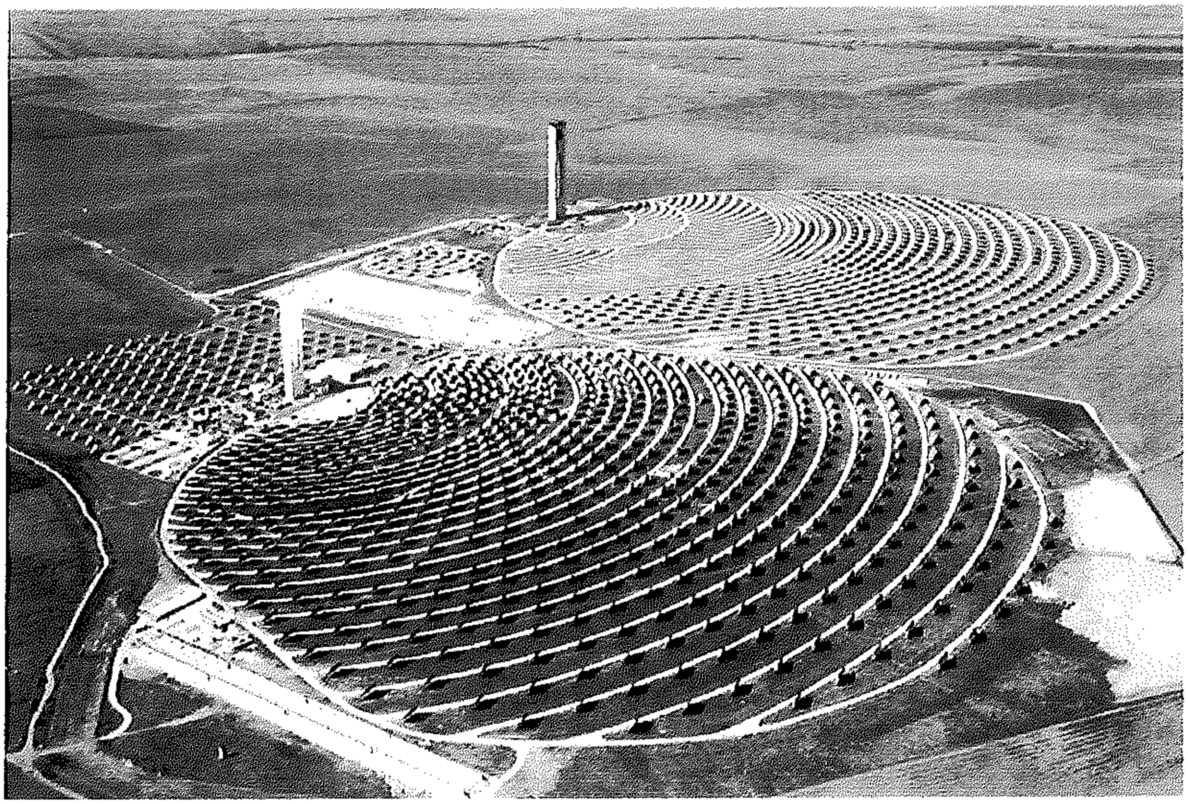
It could also fuel continued efforts by Grain Belt Express critics to push Missouri lawmakers to pass legislation undermining the project.

Earlier this year, a bill requiring that Grain Belt Express gets resolutions of support from county commissions in each of the counties in the project's path cleared the Missouri House but died in the Senate.

This story has been updated since it originally published.

Analysis: 41 Inconvenient Truths on the "New Energy Economy"

Heartland Author August 19, 2022



By Mark P. Mills

A week doesn't pass without a mayor, governor, policymaker or pundit joining the rush to demand, or predict, an energy future that is entirely based on wind/solar and batteries, freed from the "burden" of the hydrocarbons that have fueled societies for centuries. Regardless of one's opinion about whether, or why, an energy "transformation" is called for, the physics and economics of energy combined with scale realities make it clear that there is no possibility of anything resembling a radically "new energy economy" in the foreseeable future. Bill Gates has said that when it comes to understanding energy realities "we need to bring math to the problem."

He's right. So, in my recent Manhattan Institute report, "The New Energy Economy: An Exercise in Magical Thinking," I did just that.

Herein, then, is a summary of some of the bottom-line realities from the underlying math. (See the full report for explanations, documentation, and citations.)

Realities About the Scale of Energy Demand

1. Hydrocarbons supply over 80 percent of world energy: If all that were in the form of oil, the barrels would line up from Washington, D.C., to Los Angeles, and that entire line would grow by the height of the Washington Monument every week.

2. The small two-percentage-point decline in the hydrocarbon share of world energy use entailed over $2 trillion in cumulative global spending on alternatives over that period; solar and wind today supply less than two percent of the global energy.

3. When the world's four billion poor people increase energy use to just one-third of Europe's per capita level, global demand rises by an amount equal to twice America's total consumption.

4. A 100x growth in the number of electric vehicles to 400 million on the roads by 2040 would displace five percent of global oil demand.

5. Renewable energy would have to expand 90-fold to replace global hydrocarbons in two decades. It took a half-century for global petroleum production to expand "only" ten-fold.

6. Replacing U.S. hydrocarbon-based electric generation over the next 30 years would require a construction program building out the grid at a rate 14-fold greater than any time in history.

7. Eliminating hydrocarbons to make U.S. electricity (impossible soon, infeasible for decades) would leave untouched 70 percent of U.S. hydrocarbons use—America uses 16 percent of world energy.

8. Efficiency increases energy demand by making products & services cheaper: since 1990, global energy efficiency improved 33 percent, the economy grew 80 percent and global energy use is up 40 percent.

9. Efficiency increases energy demand: Since 1995, aviation fuel use/passenger-mile is down 70 percent, air traffic rose more than 10-fold, and global aviation fuel use rose over 50 percent.

10. Efficiency increases energy demand: since 1995, energy used per byte is down about 10,000-fold, but global data traffic rose about a million-fold; global electricity used for computing soared.

11. Since 1995, total world energy use rose by 50 percent, an amount equal to adding two entire United States' worth of demand.

12. For security and reliability, an average of two months of national demand for hydrocarbons are in storage at any time. Today, barely two *hours* of national electricity demand can be stored in all utility-scale batteries plus all batteries in one million electric cars in America.

13. Batteries produced annually by the Tesla Gigafactory (world's biggest battery factory) can store three *minutes* worth of annual U.S. electric demand.

14. To make enough batteries to store two day's worth of U.S. electricity demand would require 1,000 years of production by the Gigafactory (world's biggest battery factory).

15. Every $1 billion in aircraft produced leads to some $5 billion in aviation fuel consumed over two decades to operate them. Global spending on new jets is more than $50 billion a year—and rising.

16. Every $1 billion spent on data centers leads to $7 billion in electricity consumed over two decades. Global spending on data centers is more than $100 billion a year—and rising.

Realities about Energy Economics

17. Over a 30-year period, $1 million worth of utility-scale solar or wind produces 40 million and 55 million kWh respectively: $1 million worth of shale well produces enough natural gas to generate 300 million kWh over 30 years.

18. It costs about the same to build one shale well or two wind turbines: the latter, combined, produces 0.7 barrels of oil (equivalent energy) per hour, the shale rig averages 10 barrels of oil per hour.

19. It costs less than $0.50 to store a barrel of oil, or its equivalent in natural gas, but it costs $200 to store the equivalent energy of a barrel of oil in batteries.

20. Cost models for wind and solar assume, respectively, 41 percent and 29 percent capacity factors (i.e., how often they produce electricity). Real-world data reveal as much as ten percentage points less for both. That translates into $3 million less energy produced than assumed over a 20-year life of a 2-MW $3 million wind turbine.

21. In order to compensate for episodic wind/solar output, U.S. utilities are using oil- and gas-burning reciprocating engines (big cruise-ship-like diesels); three times as many have been added to the grid since 2000 as in the 50 years prior to that.

22. Wind-farm capacity factors have improved at about 0.7 percent per year; this small gain comes mainly from reducing the number of turbines per acre leading to a 50 percent increase in average land used to produce a wind-kilowatt-hour.

23. Over 90 percent of America's electricity, and 99 percent of the power used in transportation, comes from sources that can easily supply energy to the economy any time the market demands it.

24. Wind and solar machines produce energy an average of 25 percent–30 percent of the time, and only when nature permits. Conventional power plants can operate nearly continuously and are available when needed.

25. The shale revolution collapsed the prices of natural gas & coal, the two fuels that produce 70 percent of U.S. electricity. But electric rates haven't gone down, rising instead 20 percent since 2008. Direct and indirect subsidies for solar and wind consumed those savings.

Energy Physics... Inconvenient Realities

26. Politicians and pundits like to invoke "moonshot" language. But transforming the energy economy is not like putting a few people on the moon a few times. It is like putting all of humanity on the moon—permanently.

27. The common cliché: an energy tech disruption will echo the digital tech disruption. But *information*-producing machines and *energy*-producing machines involve profoundly different physics; the cliché is sillier than comparing apples to bowling balls.

28. If solar power scaled like computer-tech, a single postage-stamp-size solar array would power the Empire State Building. That only happens in comic books.

29. If batteries scaled like digital tech, a battery the size of a book, costing three cents, could power a jetliner to Asia. That only happens in comic books.

30. If combustion engines scaled like computers, a car engine would shrink to the size of an ant and produce a thousand-fold more horsepower; actual ant-sized engines produce 100,000 times less power.

31. No digital-like 10x gains exist for solar tech. Physics limit for solar cells (the Shockley-Queisser limit) is a max conversion of about 33 percent of photons into electrons; commercial cells today are at 26 percent.

32. No digital-like 10x gains exist for wind tech. Physics limit for wind turbines (the Betz limit) is a max capture of 60 percent of energy in moving air; commercial turbines achieve 45 percent.

33. No digital-like 10x gains exist for batteries: maximum theoretical energy in a pound of oil is 1,500 percent greater than max theoretical energy in the best pound of battery chemicals.

34. About 60 pounds of batteries are needed to store the energy equivalent of one pound of hydrocarbons.

35. At least 100 pounds of materials are mined, moved and processed for every pound of battery fabricated.

36. Storing the energy equivalent of one barrel of oil, which weighs 300 pounds, requires 20,000 pounds of Tesla batteries ($200,000 worth).

37. Carrying the energy equivalent of the aviation fuel used by an aircraft flying to Asia would require $60 million worth of Tesla-type batteries weighing five times more than that aircraft.

38. It takes the energy equivalent of 100 barrels of oil to fabricate a quantity of batteries that can store the energy equivalent of a single barrel of oil.

39. A battery-centric grid and car world means mining gigatons more of the earth to access lithium, copper, nickel, graphite, rare earths, cobalt, etc.—and using millions of tons of oil and coal both in mining and to fabricate metals and concrete.

40. China dominates global battery production with its grid 70 percent coal-fueled: EVs using Chinese batteries will create *more* carbon-dioxide than saved by replacing oil-burning engines.

41. One would no more use helicopters for regular trans-Atlantic travel—doable with elaborately expensive logistics—than employ a nuclear reactor to power a train or photovoltaic systems to power a nation.

Mark P. Mills is a senior fellow at the Manhattan Institute, a McCormick School of Engineering Faculty Fellow at Northwestern University, and author of Work in the Age of Robots, published by Encounter Books.

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For more the Green New Deal, click here and here.

Comissioner Scott Rupp
200 Madison Street
Jefferson City, MO
65102-0360

Commissioner Scott Rupp

200 Madison Street, P O Box 360

Jefferson City, MO 65102-0360 August 22,2022

My husband and I have been grain farmers in Central Missouri, since 1976. We have worked very hard, struggled through 1980's, managed to pay our loans, taxes and farm payments on time. We have also been good stewards of the land. On July 12, 2022 we received a letter in the mail from a company called Invenergy Transmission, based out of Chicago, IL informing us that they had plans to possibly run a 140 x 140 ft electric transmission towers through our farm. This notice was very upsetting for us. The towers would ruin our farm, the property would be devalued and there is no amount of money to compensate us for the permanent loss. We went to their public meeting, we asked a lot of questions and received very few straightforward answers. We left the meeting feeling frustrated and determined to do our homework; to find out as much as we could. The first thing we learned is there are lots of groups all over Missouri that have organized to fight Invenergy and companies like them. There are also lots of other states that are being impacted and resisting their plans. We attended the Audrain County landowner meeting, where Presiding Commissioner, Wiley Hibbard, said "Invenergy Transmission has no money yet, they are waiting for government subsidy." Lynn Thompson, General Manager at Consolidated Electric Cooperative of Mexico, MO told us they have no interest in purchasing the Invenergy's energy. Consolidated is one of the cooperatives in the Associated Electric Cooperative group, they service over 2 million people in Missouri, Iowa and Oklahoma, they will be forced to let Invenergy hook up to their substation. I believe this is an intrusion on the amazing system that already exists here in our area. We have very reasonable electric rates. Invenergy has filed several condemnations (taking) court cases against landowners who refused to sign an easement. Sure, doesn't sound like the friendly, we'll-work-it-with-you -company they try to portray. They are taking land by force, even though they don't have an approved route and interconnection, or enough customers to make the project economic! What country do we live in? China? I can't imagine how devastating the proud farmers and families I know are feeling about this. Where is their protection? Since they have not gotten enough customers for the Grain Belt Express and Illinois will not let them come through their state, why are you even considering letting them have permission to make the Tiger Connection here in Audrain and Callaway? By the way, it sounds like the Illinois commissioners are protecting their farm landowners.

Keryn Newman, Stoppathwv.com, reports MJMEUC agreed purchase a very small amount of capacity (up to 200 MW) at a loss leader price below GBE's (Grain Belt Express) cost to provide the service. MJMEUC only agreed because it was basically getting something for free, but it was also a very small portion of the available capacity. Since then, GBE has not found any other customers. Nobody wants to buy their service still. In order to be viable GBE needs permission to connect it's 4000 MW transmission project to the existing electric grid. After 10 years, why are we still having this discussion? Looks obvious to me the people of Missouri and the electric cooperatives do not want their kind of power. It is my opinion that intermittent power is not practical because it cannot sustain itself, it relies on the consistent AC energy from coal power and natural gas. The average electric energy produced from solar is 20-30% because of daylight. If we are forced to take payment for the easement on our land, that money is considered capital gains, therefore we would have an added burden at tax time. If Invenergy

does come down to the McCredie substation, they would have to add a second substation to convert their DC electric coming from the solar panels to AC. I repeat; they must have a backup energy source so if their so-called green energy goes dark because of clouds, snow and nighttime. I don't have to tell you that the peak demands for electricity is what causes our electric to rates go up! The government is printing money to pay for these expensive wind turbines and solar farms and high transmission towers. We the taxpayers will get changed for that as well! What I have been told is most of the energy produced isn't even for Missouri. So why are we ruining prime farmland in Missouri for another state to use? Isn't it your job to protect us? And understand, your family will be paying more too. This going to affect every electric consumer and business in the state. Commissioner Rupp please allow the citizens affected a chance to share with you, their concerns, consider having one or two hearings to give people a chance to share their opinion with you. We heard a healthcare provider worried about the tower lines emitting EMF's (Electric Magnetic Frequencies) and EMR's (Electric Magnetic Radiation) she believes they will be harmful to our health. Another farmer and his wife are worried that the towers will interfere with the radio and cell service. We don't know what side effects of living near these transmission towers will be. We do know it will forever ruin the beauty of the country side that we all love so much. As a farmer works his land, the towers will be a constant pain when he works the ground near them. He will have to be extra careful when using his large equipment, his drones for spraying, the hired helicopters and small planes. He won't be able to irrigate his land near the towers. As I said it will certainly devalue the land, no one wants to build their home near a high tower electric line, there is not enough money to compensate us. According to the Constitution, it protects We the People, from an unregulated merchant like Invenergy from using eminent domain. Granting eminent domain authority to an unregulated merchant for speculative projects that may never be placed in service violates the Fifth Amendment's requirement that property taken for public use. Looks to me like CEO Michael Polsky will be the one that gains the most from this project if it goes through. Protect the landowners and the non-profit utility companies from the unregulated merchant that only care about money. I am trusting you to do the right thing for We the People. I have not heard one person that is in favor of this project. Their proposal cuts right through prime Missouri farmland acres that are presently producing crops for ethanol and biodiesel. Both of them are helping to reduce the fuel emissions in St. Louis, Columbia and Kansas City; truly renewable fuels.

We are asking you Commissioner Rupp and the other commissioners to deny Invenergy's extravagant filing on the grounds that they have not proven demand for their energy; they have not told us who their customers are and their energy is not cost effective for this area and definitely not wanted. Thank you for your time, I have included some supporting information that backs up my request.

Why do we burn coal and trees to make solar panels?

Thomas A. Troszak (2019/11/14 revision)

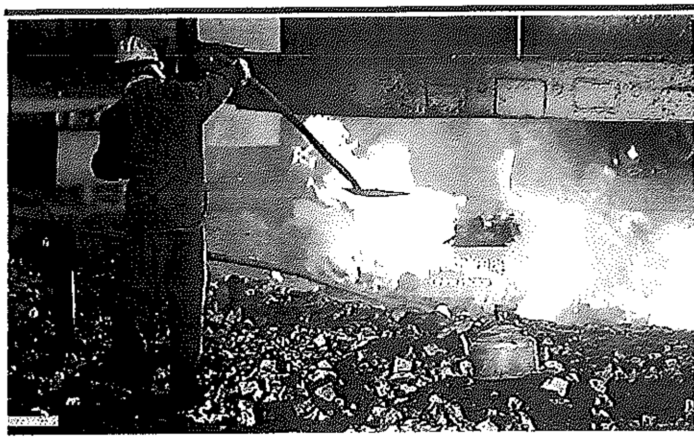


Figure 1. Workman shovels coal and lumpy quartz (silicon ore) into a silicon smelter in China. (photo: Getty)

1. Most commercial solar PV modules use *photovoltaic cells* (solar cells) made from highly purified silicon (Si).

Since the early 1900s, silicon "metal" is reduced from quartz using **carbon** in submerged-arc furnaces, each powered by up to 45 megawatts* of electricity. (Fig 1,2)

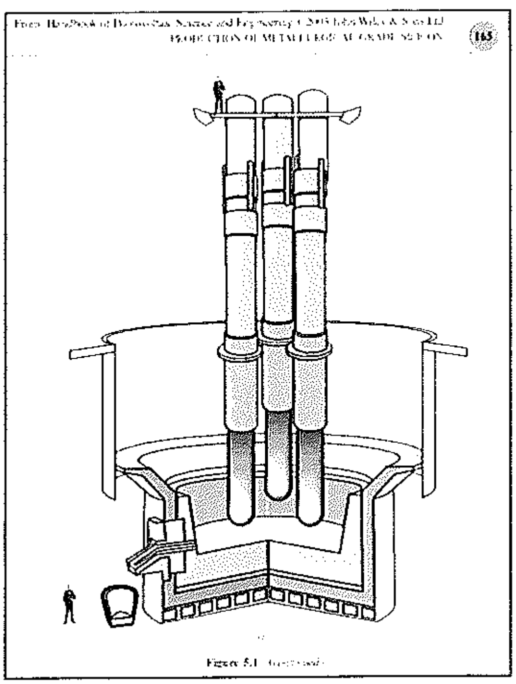


Figure 2. Diagram of a silicon smelter showing the three giant carbon electrodes that provide arc temperatures > 3,000°F for smelting quartz into 'metallurgical grade' silicon (mg-Si) using carbon as a reductant (John Wiley and Sons Ltd.)

2. Why do we need to burn carbon to make solar PV? - Elemental silicon (Si) can't be found by itself anywhere in nature. It must be extracted from quartz (SiO_2) using **carbon (C)** and heat (from an electric arc) in the "carbothermic" (**carbon+heat**) reduction process called "smelting." (**$SiO_2 + 2C = Si + 2CO$**) Several **carbon sources** are used as **reductants** in the silicon smelting plant, which requires ~20 MWh/t of electricity, and releases CO - resulting in up to 5 - 6 t of CO_2 produced per ton of metallurgical grade (mg-Si) silicon smelted. [1] Thus, **the first step** of solar PV production is gathering, transporting, and **burning millions of tons of coal, coke and petroleum coke - along with charcoal and wood chips** made from hardwood trees - to smelt >97% pure mg-Si from quartz "ore" (silica rocks). [1][2][3][4][5][6][7][8][9][10]

*45 megawatts (MW) is enough for a small town (about 33,000 homes).

Figure 3. Pouring liquid metallurgical grade (~99% pure) silicon into molds, to cool into silicon "metal" (Getty)

3. Even more fossil fuels are burned later, to generate electricity for the polysilicon, ingot, wafer, cell, and module production steps shown. [21] As a result of all these processes, the solar PV industry generates megatons of CO and CO_2. But as shown below (fig 4), some often-cited descriptions of solar module production **omit the raw materials and smelting process from the PV supply chain** which obscures the use of fossil fuels and the vast amount of deforestation necessary for solar PV production. [1][3][9][27]

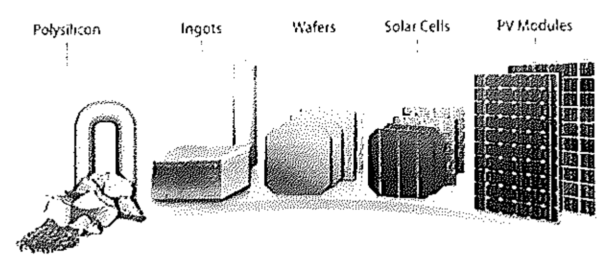


Figure 1. Schematic of c-Si PV module supply chain

Figure 4. (source: National Renewable Energy Laboratory, 2018)

4. Raw materials for metallurgical-grade silicon

Raw materials for one ton (t) MG-Si (Kato, et. al) [37]

- Quartz 2.4 t
- Coal 550 kg
- Oil coke 200 kg
- Charcoal 600 kg
- Woodchip 300 kg

Raw materials for one ton (t) MG-Si (Globe) [3]

- Quartz 2.8 t
- Coal 1.4 t
- Woodchips 2.4 t

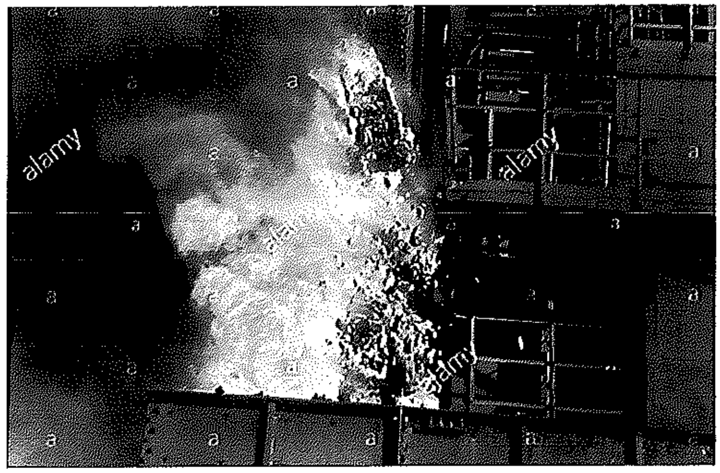
For 110,000 tpy (tons per year) MG-Si (Thorsil) [1]

- Quartz 310,000 tpy
- Coal, coke and anodes 195,000 tpy
- Wood 185,000 tpy
- Total 380,000 tpy

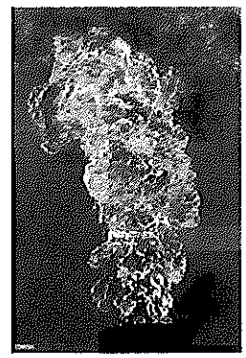
When calculating CO2 emissions from silicon smelting, "by joint agreement" some authors exclude CO2 emissions from non-fossil sources (charcoal, wood chips), power generation, and transportation of raw material. [27]

5. Sources of carbon for solar silicon smelting

• **Coal** - Is a dense, rock-like fuel. The (low ash) coal used **directly** for silicon smelting is mostly the **"Blue Gem" from Cerrajón, Columbia**, Kentucky, USA, or Venezuela. [1][2][3][5][6][7][8]

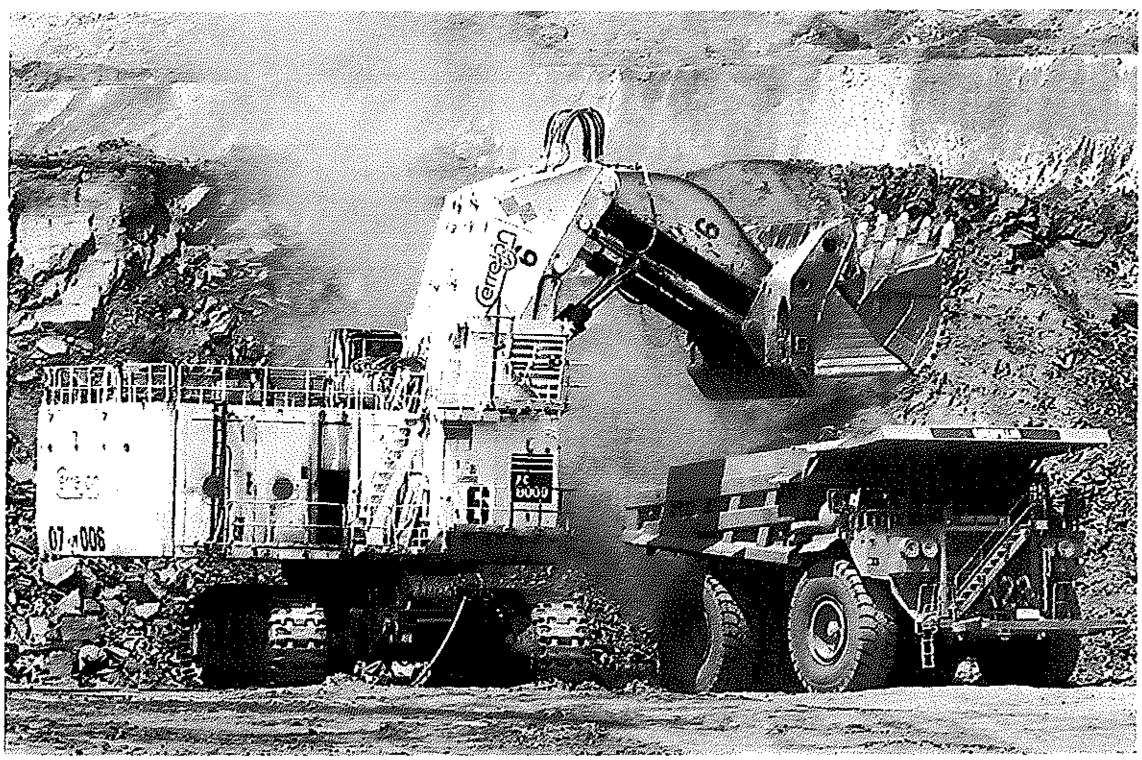


A "Slot Oven" discharging coke into a railroad car. (photo: Alamy)

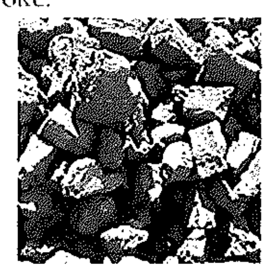


• **Metallurgical Coke** (Metcoke) is a tough, cinder-like solid fuel made by "coking" coal in large "slot ovens" - to drive out most of the volatile tars, etc. to the atmosphere as smoke, flame, carbon monoxide, carbon dioxide, sulfur dioxide, other gasses, and water vapor. (photo: Getty Images)

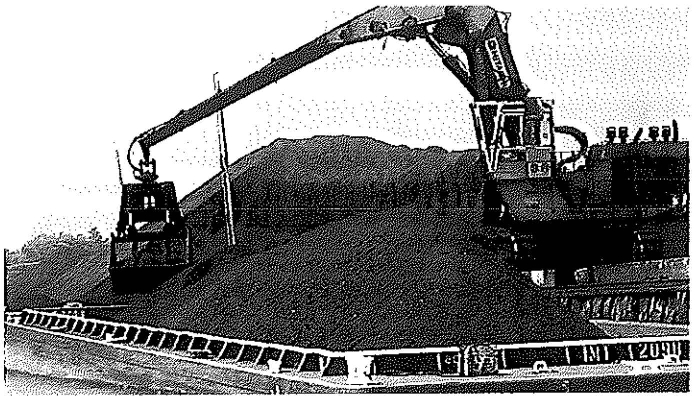
The **coking process** is nearly identical to the process used for making charcoal from wood (see charcoal production below). Restricting the air supply to a large mass of burning coal allows about 40% of the coal to "burn off" - leaving behind a solid residue (coke) with a **higher carbon content** per ton that the original coal. It takes **about 1.6 t of coal** to make a ton of coke.



The Cerrajón open-pit mine in Columbia supplies "Blue Gem" coal for silicon smelters around the world.



Metcoke looks like porous, silvery grey coal.

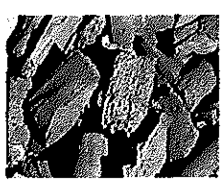


Filling barges with petcoke outside Chicago, Ill. USA (photo)

• **Petroleum Coke** (Petcoke) - is a solid fuel in the form of pellet-like granules, which are a carbon-rich byproduct of crude oil refineries. Millions of tons of petcoke are also made directly from raw bitumen (tar). Due to its low price and high carbon content, petcoke made in American refineries from "Canadian Tar Sands" is a source of carbon exported from the U.S. to silicon manufacturers in China. [9]

"Because it is considered a refinery byproduct, petcoke emissions are not included in most assessments of the climate impact of tar sands" [10]

"Beehive" charcoal ovens in Brazil (Alamy)

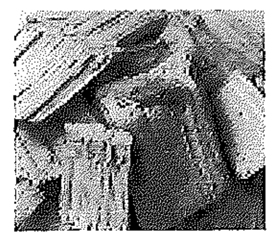


• **Wood Charcoal - Many hardwood trees must be burned to make wood charcoal.** In the traditional process, wood is stacked into "beehive ovens", ignited, then mostly smothered to prevent the wood from burning completely to ash. By weight, **about 75% of the wood is lost to the atmosphere as CO, CO_2, smoke, and heat.**

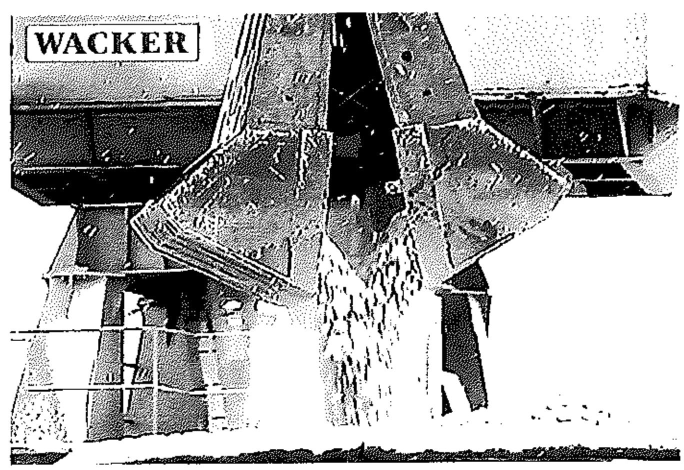
Some silicon producers use **"charcoal plantations,"** but they **only supply a fraction of the current demand** of carbon for silicon production. The rest of the carbon supply has to come from imported coal or coke, or the cutting and burning of "virgin" rainforest. **[13][14][15][16]**

In Brazil, it is estimated that more than a third of the country's charcoal is still produced illegally from protected species. [14] Brazil is a charcoal supplier to silicon producers in other countries, including the United States. Silicon smelters around the world use charcoal from many sources, so solar silicon may be smelted with charcoal made directly from rainforest not grown on plantations.

This hardwood forest in the U.S. was clear cut to make wood chips

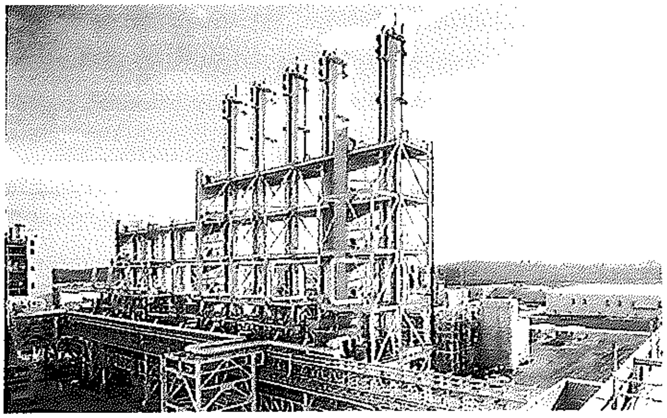


6. **Hardwood Chips** (also called Metchips) - Matchbox-sized fragments of **shredded hardwood must be mixed into the silicon smelter** "pot" for many reasons - to allow the reactive gasses to circulate, so the liquid silicon that forms can settle to the bottom for tapping, and to allow the resulting CO (and other gasses) to escape the smelter "charge" safely. [4]



Solar silicon quartz rocks (Wacker Chemie)

7. **Silicon ore - Quartz - (silica, silicon dioxide, SiO_2)** Even if sufficiently pure, **silica sand won't work in any silicon smelter**, it is too fine. Selected high-purity quartz is mined and graded into "lumpy" (fist-sized) gravel for smelting. Worldwide, "solar grade" deposits of quartz are somewhat scarce, and highly valued.

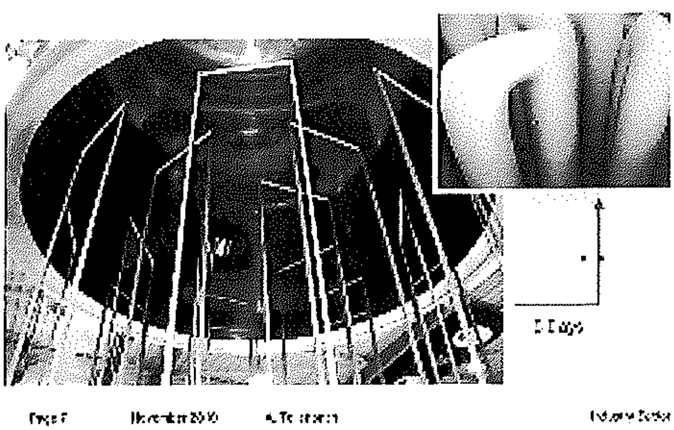


A single polysilicon plant like this one in Tennessee, USA, can draw 400 megawatts of electricity, enough power for about 300,000 homes. (Wacker Polysilicon)

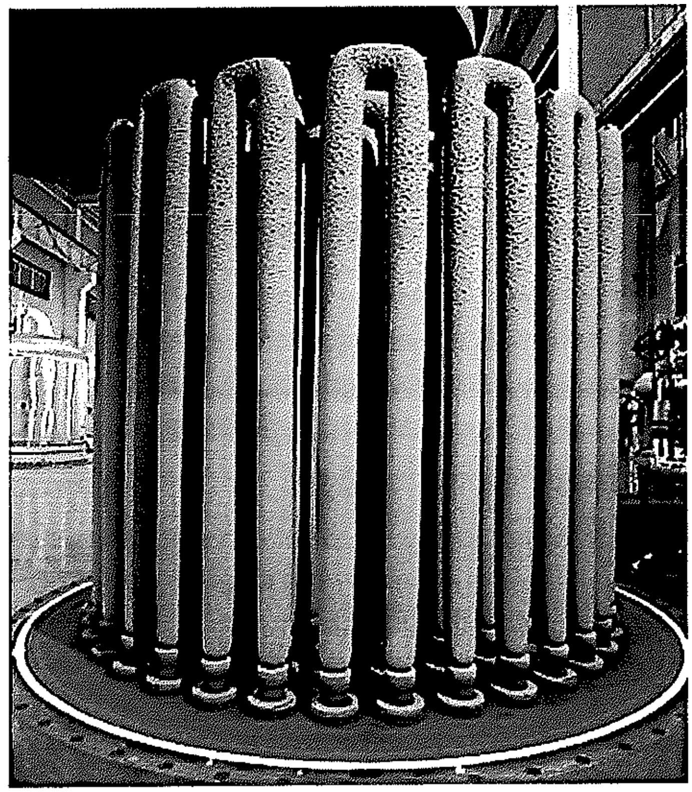
8. Polysilicon production

Metallurgical grade silicon (mg-Si) from the smelter is only about 99% pure, so it must undergo two more energy-intensive processes before it can be made into solar cells. First, **the Siemens Process converts (mg-Si) from the smelter into polycrystalline silicon (called polysilicon)** by a high-temperature vapor deposition process.

This is a bit like "growing rock candy" on hyper-pure silicon "strings" inside a pressurized-gas filled "bell-jar" reactor. As a mixture of silicon gas (made from mg-Si) and hydrogen gas passes through the reactor vessel, some of the silicon gas molecules "cling" to the electrically heated "strings" (called filaments) causing them to grow into "rods" of 99.9999% pure (or better) polysilicon.



Left: When heated to around 1100°C the polysilicon "filaments" standing beneath the reactor cover can "catch" about 20% of the silicon atoms that pass through the reactor in gaseous form. Right: Polysilicon "rods" after 5 days of growth. (Siemens AG)



Each batch of polysilicon "rods" takes several days to grow, and a continuous, 24/7 supply of electricity to each reactor is essential to prevent a costly "run abort." So **polysilicon refineries** <u>depend on highly reliable conventional power grids</u>, and usually have two incoming high-voltage supply feeds.

A polysilicon plant consumes ~1.6 - 6 t of incoming mg-Si, and requires at least **175 MWh** (or more) of **additional electricity** per ton of polysilicon produced - **about 10 times the energy already used for smelting** each ton of mg silicon from ore. **[11]** After the rods are removed from the reactor, they are sawed into sections or broken into "chunks" for loading into crucibles in the next step.

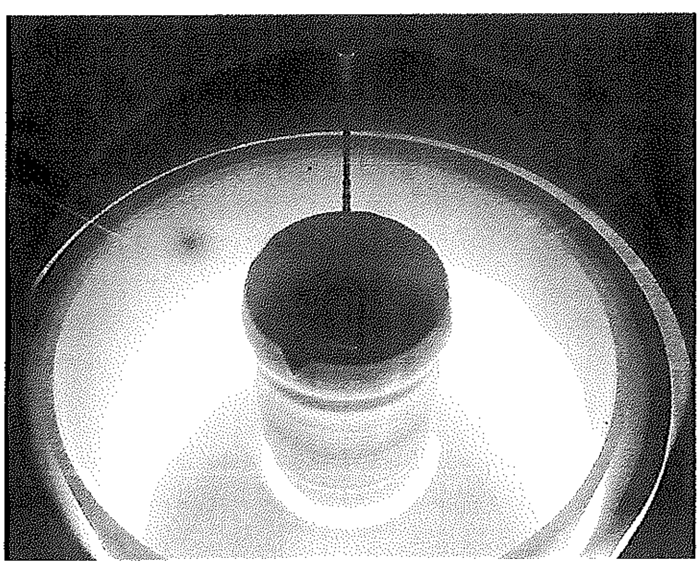
Polysilicon rods and sections being broken into chunks by hand in a clean room. (Hemlock)

Polysilicon chunks being heated in a crucible. When melted, a single crystal will be pulled out of the liquid polysilicon. (Getty)

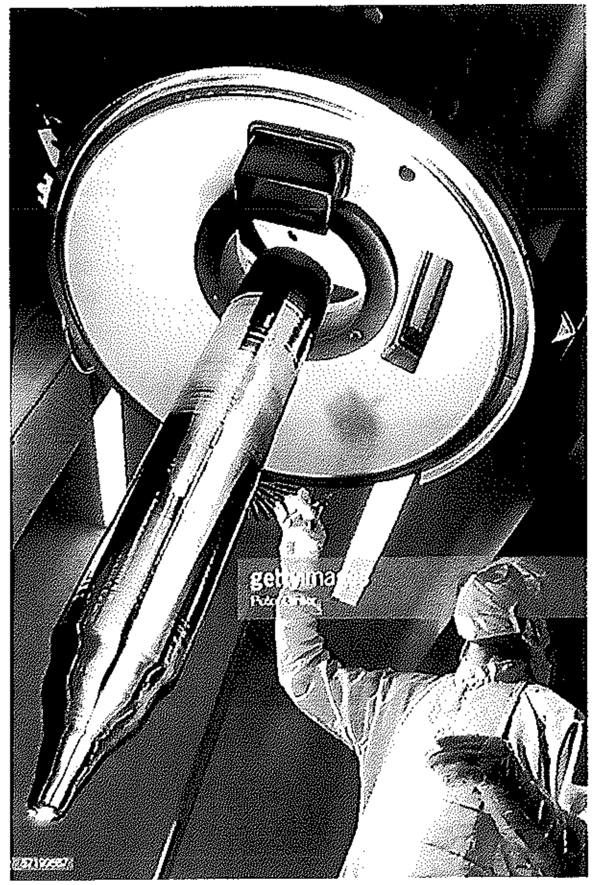
9. Crystal growing (ingot production)

For making single-crystal solar cells (called mono PV) the PV industry uses the **Czochralski process to further purify the polysilicon, and align the silicon molecules into a single-crystal form.**

First, polysilicon chunks are melted in a rotating crucible in an inert atmosphere. Then a small seed crystal of silicon is lowered into the molten polysilicon. As the seed crystal is slowly withdrawn, a single silicon crystal forms from the tip of the seed. As the crucible turns, the polysilicon continues to grow into a cylindrical ingot, leaving most of the non-silicon impurities behind in the 5-10% of "pot scrap" remaining after the crystal is drawn free.

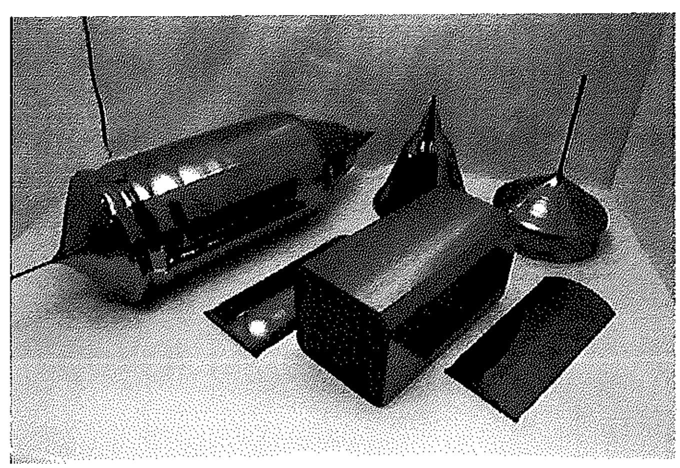


Czochralski ingot being pulled from melted polysilicon. (Image source: Siltronix)



Czochralski ingot after cooling (Image source: Getty)

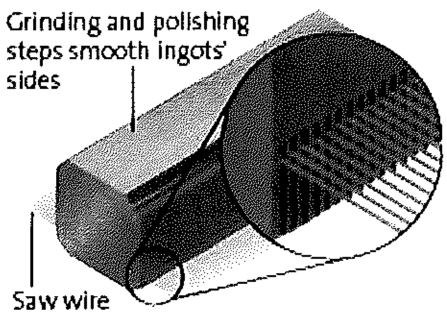
This process requires several days, and uninterrupted power. An ingot/wafer/cell plant can use more than 100 MWh additional energy per ton of incoming polysilicon, about 6 times as much as the original smelting of the silicon from ore. After slow cooling, the ingot's unusable crown and tail are cut off (about 10%), the center is then ground down, the four "chords" (long sides) are sawn off (about 25%) leaving a rectangular "brick" so the solar wafers will be almost square after slicing.



Czochralski process whole ingot (left), and brick and chords after sawing (right), crown and tail (upper right) (SVM)

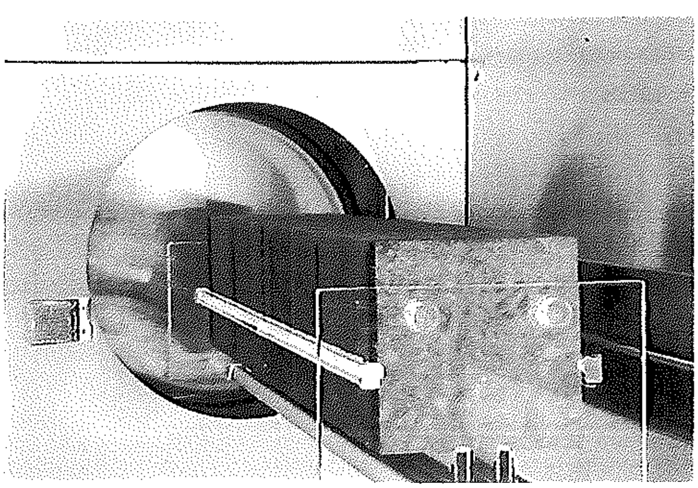
For multi-crystalline cells (called multi PV) polysilicon is melted in rectangular quartz molds, then allowed to cool slowly into a rectangular ingot of multi-crystalline silicon. which is trimmed to remove unusable portions, then sliced into bricks.

10. Wafer sawing
Then, like a loaf of bread, the silicon "bricks" are sliced with wire saws into thin wafers, which will later be processed into cells.



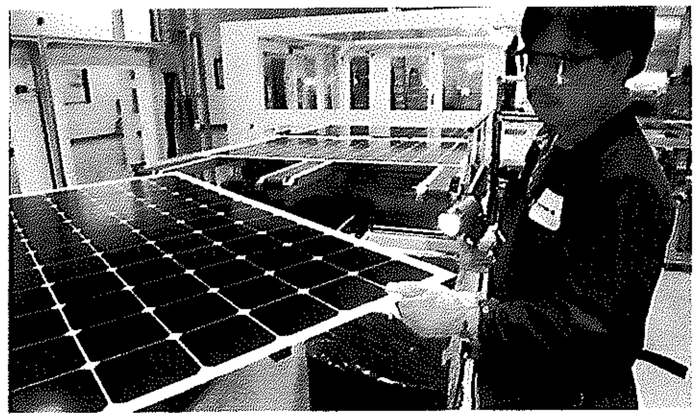
About half of the "brick" is lost as "sawdust" in the wafer slicing process, and this can't be recovered. So, after all of the energy and materials that have gone into making each "brick", much of the incoming polysilicon does not ever become finished wafers. Some of the heads, tails, chords, and trimmings can be etched (to remove contamination) and remelted **using additional energy** if the purity of the scrap is sufficient to justify the expense, otherwise they are discarded as waste.

11. Cell and module production.
Once the wafers are sliced, they are made into "cells" by adding layers of other materials and components in a series of additional production steps.



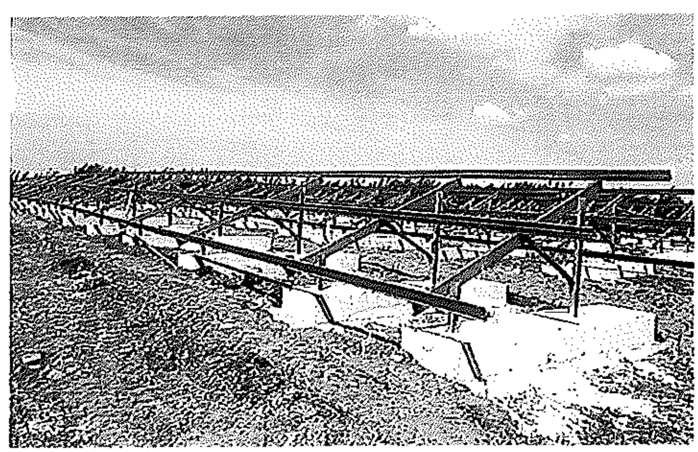
Diffusion Furnace in the PV-TEC at [illegible] Loading of the diffusion [illegible] silicon wafers. The [illegible] into the (up to [illegible] (Fraunhofer ISE)

Then the cells are assembled into modules. Beside silicon wafers, most solar PV modules also require many other energy-intensive materials - aluminum (for the frame), silver, copper, glass, plastic, highly toxic rare earth metals, acids, and dozens of other chemicals for processing the polysilicon into cells and modules. A lot of electricity is needed to power the cell production and module assembly, **a supply of natural gas** is used to provide heat in the process.



Solar module inspection on the assembly line. (Solar World)

12. Other materials and steps
Once the modules are made, the whole PV system usually needs steel or aluminum framing, concrete, and some empty land (or a rooftop) to position it securely toward the sun, a lot of wiring to connect (through DC/AC inverters and transformers) to the existing power grid, or directly to battery banks,



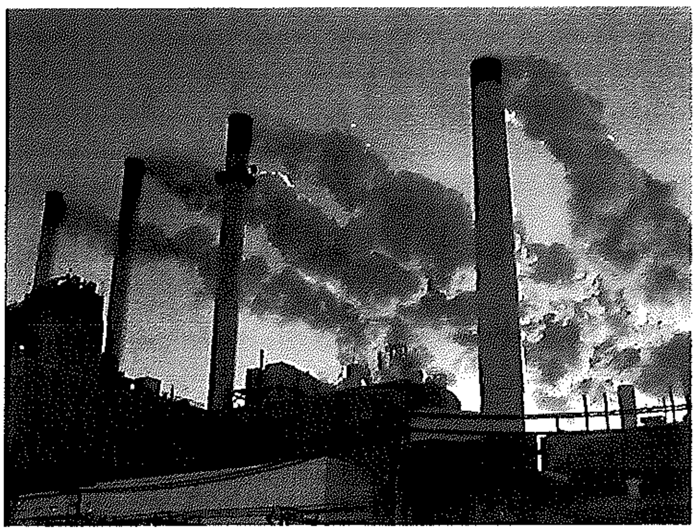
[illegible] and concrete foundation (Hill & Smith)

Of course, it takes **a lot of energy and resources** to make steel, aluminum, concrete, inverters, copper wiring, and all of these other materials. In many cases, the "balance of system" components in a PV installation can require as much (or more) "up-front" resources and energy to make as the modules. **[21]**

In addition, the amount of fossil fuels and non-renewable resources needed to construct and maintain new PV production infrastructure (smelters, polysilicon refineries, etc.) is considerable, but has been excluded from all "life cycle analysis" (LCA) of solar PV production by definition. [38]

13. Transportation

Throughout the solar PV manufacturing process all of the materials and products must be shipped **to and from more than a dozen countries** around the world in large barges, container ships, trains, or trucks - **all powered by non-renewable oil. [36]**



14. Power

Worldwide, only a few silicon smelters, like those in Norway, are powered primarily by hydro-electricity. Elsewhere, the current majority of smelters, polysilicon refineries, ingot growers, cell and module factories are running on grids **powered mostly by fossil fuels and uranium.** At present, more than 50% of all solar silicon is made in China, where the industrial grid is powered largely by fossil fuels, primarily low-grade coal. Depending on the "energy mix" available, the quantity of coal, coke, or gas that is being burned to deliver power 24/7 to the PV factories may be far greater than the amount needed as the carbon source for smelting silicon. To provide a realistic assessment of the total environmental impact of PV manufacturing, this **must be added to the "fossil fuel bill"** for solar PV production - along with the "embodied energy" of PV factories. **[11][12][21]**

15. Conclusions

Every step in the production of solar photovoltaic (PV) power systems requires a perpetual input of fossil fuels - as carbon reductants for smelting metals from ore, for process heat and power, international transport, and deployment. Silicon smelters, polysilicon refineries, and crystal growers around the world all depend on uninterrupted, 24/7 power that comes mostly from coal and uranium. **The only "renewable" materials consumed in PV production are obtained by deforestation** - for wood chips, and by burning vast areas of tropical rainforest for charcoal used as a source of carbon for silicon smelters. So far, both **media and journal claims** that solar PV can somehow "replace fossil fuels" **have not addressed the non-renewable reality of global supply chains** necessary for mining, manufacturing, and distribution of PV power systems. Based on current world production levels of solar PV, an attempt to replace conventional electricity production with solar PV would require a **dramatic increase in the amount of coal and petcoke needed for silicon smelting**, along with the **increased cutting of vast areas of forest** for charcoal and wood chips.

Readers are encouraged to **examine all of the references below**, to become aware of other aspects with solar pv manufacturing and deployment that are beyond the scope of this paper.

References

[1] Thorsil (2015) "Metallurgical Grade Silicon Plant - Helguvík, Reykjanes municipality (Reykjanesbær), Reykjanes peninsula, Iceland Environmental Impact Assessment (EIA) Capacity: 110,000 tons" https://www.giek.no/getfile.php/133565/web/Dokumenter/Prosjekter%20under%20vurdering/EIA-Thorsil_Lingua-2-%20konsekvensutredning.pdf (1) "Thorsil's initial assessment report was based on using...**Coal from El Cerrajon in Columbia**...for an annual production...of 110,000 tpy [of mg-Si]...**would correspond to 605,000 tpy of carbon dioxide...The Environment Agency feels that...such exhaust would significantly increase Iceland's overall emissions"**

[2] Efla (2013) "Environmental Impact Assessment of a SILICON METAL PLANT AT BAKKI IN HÚSAVÍK"https://www.agaportal.de/_Resources/Persistent/856d55b1a3c1948e5f856f800195760741faa93b/eia_island_silizium.pdf (2) "The main raw materials used for the production of Silicon Metal are quartzite... **coals (mainly from [Cerrejón] Columbia, Venezuela, and USA)**, charcoal, wood chips"

[3] "New York State Department of Environmental Conservation - Facility DEC ID: 9291100078 PERMIT Under the Environmental Conservation Law (ECL) Permit Issued To: GLOBE METALLURGICAL INC" http://www.dec.ny.gov/dardata/boss/afs/permits/929110007800009_r3.pdf **(3) "Globe Metallurgical produces high purity silicon metal...The facility is a major source of emissions of sulfur dioxide, carbon monoxide, hydrogen chloride and nitrogen oxides...** "The submerged electric arc process is a reduction smelting operation...**Reactants consisting of coal, charcoal, petroleum coke, or other forms of coke, wood chips, and quartz are mixed and added at the top of each furnace... At high temperatures in the reaction zone, the carbon sources react with silicon dioxide and oxygen to form carbon monoxide and reduce the ore to the base metal silicon."**

[4] "The Use and Market for WOOD in the ELECTROMETALLURGICAL Industry" https://www.fs.usda.gov/treesearch/pubs/23800 (4) [woodchips are used in smelters]...**to provide a large surface area for chemical reaction to take place more completely and at improved rates...To maintain a porous charge, thereby promoting gentle and uniform - instead of violent - gas venting**...To help regulate smelting temperatures...To keep the furnace burning smoothly on top...To reduce conductivity...To promote deep electrode penetration...To prevent bridging, crusting, and agglomeration of the mix...To reduce dust, metal vapor, and heat loss; and as a result to improve working conditions near the furnace.

[5] Healy, N., Stephens, J. C., & Malin, S. A. (2019). "Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains." *Energy Research & Social Science*, *48*, 219-234. (link) (5)"**Cerrejón is one of the world's largest open-pit coal mines [supplying silicon manufacturers]**...energy extraction often entails the physical displacement of populations or the "slow violence" of landscape destruction, water contamination and livelihood disruption"

[6] What Terrible Injustices Are Hiding Behind American Energy Habits? By Itai Vardi • Friday, November 16, 2018 (link) (6) "**There is a clear 'consumer blindness' and citizens and residents are often unaware of where the fuel they consume is coming from** and what injustices were inflicted on communities within those sites of fossil fuel extraction," said Healy. "Exposing these **injustices of energy 'sacrifice zones' — like [the Cerrejón open-pit coal mine] in La Guajira, Colombia** ...— could be critical for future energy policy decision-making."

[7] 2017/06/18/why-this-part-of-coal-country-loves-solar-power-215272 (7)"**the seam in Whitley County [Kentucky] is an even more valuable variety of metallurgic coal known as "blue gem."..."You need the blue gem to make the solar panels, and that's what people don't know,"** Moses told me, articulating a simple truth: **"Without Coal Valley, there's no Silicon Valley"**

[8] **https://www.prnewswire.com/news-releases/new-colombia-resources-inc-discovers-huge-new-metallurgical-coal-seam-at-their-property-in-colombia-as-the-company-prepares-to-begin-production-while-coal-prices-continue-to-soar-600823111.html** (8) "Colombian coal accounts for close to 75% of coal imports to the U.S... New Colombia Resources' Blue Gem coal is only found on the KY-TN border and central Colombia and is used to produce specialty metals **such as Silicon to make solar panels**, electric car batteries, and many more next generation products"

[9] https://carnegietsinghua.org/2015/05/31/managing-china-s-petcoke-problem-pub-60023 **(9) "Figure 5. [graph] Chinese Petcoke Consumption by Sector (2013 silicon=6%) (2014 silicon=7%)** A significant share of the petcoke used in China [which was made in U.S. refineries] is imported from the United States, ..."According to the U.S. Energy Information Administration (EIA), **U.S. petcoke exports to China... a staggering 7 million metric tons in 2013...accounting for nearly 75 percent of Chinese petcoke.**

[10] Petroleum Coke: The Coal Hiding in the Tar Sands (10) "Because it is considered a refinery byproduct, **petcoke emissions are not included in most assessments of the climate impact of tar sands**"...

[11] https://www.sightline.org/2018/06/25/small-town-silicon-smelter-plan-tees-up-big-questions/ (11) "**these furnaces would have a voracious appetite for electricity: around 105 megawatts on a continuous basis, roughly the equivalent of 68,000 homes...the facility would demand more power than the dam could provide**....Producing one ton of silicon metal requires about six tons of raw materials...Nearby sawmills would send seven or eight trucks per day to deliver wood chips, which are integral to the smelting process...."**The smelting process requires a rare type of metallurgic coal known as "blue gem," ... Operations at the smelter would demand approximately 48,000 metric tons of coal per year—roughly 40 rail cars each month.**"

[12] https://siteselection.com/theEnergyReport/2009/apr/Wacker-Chemie/ (12) "A nuclear plant is 1200 megawatts. **Fully built out, [Wacker Polysilicon] could be a third of a nuclear plant [400 MW]**...Not everybody out there can handle that size of a load. We're selling the fact that we [TVA] have the reliability, and we have a very diverse portfolio across **coal, nuclear and hydro.**"

[13] Jungbluth, N., M. Stucki, R. Frischknecht, S. Büsser, and ESU-services Ltd. & Swiss Centre for Life Cycle Inventories. (2009) "Part XII photovoltaics." *Swiss Centre for Life Cycle Inventories* (link) (13) "An issue of concern... **is the use of charcoal in this [photovoltaic silicon] process that originates from Asia or South America and might have been produced from clear cutting rainforest wood**"

[14] Eikeland, Inger Johanne, B. Monsen, and Ingunn S. Modahl.(2001) "Reducing CO2 emissions in Norwegian ferroalloy production." *Greenhouse Gases in the Metallurgical Industries: Policies, Abatement and Treatment, (Met. Soc. CIM), Toronto* 325 . (link) (14) **Most of the charcoal used...[for silicon production]...is imported from Asia and South America.** The crude, traditional methods of charcoal making, which are still widely used in these continents, are inefficient and strongly pollute the environment."

[15] Nisgoski, Silvana & Muniz, Graciela & Morrone, Simone & Schardosin, Felipe & França, Ramiro. (2015). NIR and anatomy of wood and charcoal from Moraceae and Euphorbiaceae species. Revista Ciência da Madeira - RCM. 6. 183-190. 10.12953/2177-6830/rcm.v6n3p183-190. (link) (15) "**charcoal supply is still present in illegal cutting of native forests, which represented 30-35% of total output [in Brazil]**... charcoal consumption represents the deforestation of approximately 1.6 million hectares or 16.000 km² of the Cerrado Biome"

[16] 2017/10/burning-down-the-house-myanmars-destructive-charcoal-trade/ (16) "**Dehong's silicon industry ... "has caused a serious damage to forest resources,**" and estimated that "119,700 tons of charcoal were consumed in the production of industrial silicon in Dehong prefecture **in 2014... 31 square miles—"of forests were cut down. (...) In 2016, the [silicon] industry consumed nearly twice that amount** (216,273 tons of charcoal)

[17] BP Statistical Review of World Energy, 67th Edition, June 2018 (17) "despite the huge policy push encouraging a switch away from coal and the rapid expansion of renewable energy in recent years, **there has been no improvement in the mix of fuels feeding the global power sector over the past 20 years. Astonishingly, the share of coal in 2017 was exactly the same as in 1998. The share of non-fossil fuels was actually lower,** as growth in renewables has failed to compensate for the decline in nuclear energy."

[18] De Castro, Carlos, Margarita Mediavilla, Luis Javier Miguel, and Fernando Frechoso. "Global solar electric potential: A review of their technical and sustainable limits." *Renewable and Sustainable Energy Reviews* 28 (2013): 824-835. (link) (18) "**based on real examples...our results show that present and foreseeable future density power of solar infrastructures are much less (4–10 times) than most published studies...** an overview of the land and materials needed for large scale implementation show that many of the estimations found in the literature are hardly compatible with the rest of human activities."

[19] Koomey, J. G., Calwell, C., Laitner, S., Thornton, J., Brown, R. E., Eto, J. H., ... & Cullicott, C. (2002). Sorry, wrong number: The use and misuse of numerical facts in analysis and media reporting of energy issues. *Annual review of energy and the environment*, *27*(1), 119-158. (link) (19) "Unfortunately, numbers that prove decisive in policy debates are not always carefully developed, credibly documented, or correct...**A common mistake in the media has been to apply this statistic (1000 homes per MW) to intermittent renewable power sources**...Intermittent renewables generally produce far fewer kilowatt-hours per MW than conventional power

plants...**this widely used equivalence between homes and MW should generally not be applied to intermittent renewables such as...PVs."**

[20] Shaner, Matthew R., Steven J. Davis, Nathan S. Lewis, and Ken Caldeira. (2018) "Geophysical constraints on the reliability of solar and wind power in the United States." *Energy & Environmental Science* 11, no. 4 (2018): 914-925 (link) **(20) "Achieving 99.97% reliability with a system consisting solely of solar and wind generation... would require** a storage capacity equivalent to several weeks of average demand...**Three weeks of storage (227 TW h) [which] results in ~6500 years of the annual Tesla Gigafactory production capacity** or a **~900x increase** in the pumped hydro capacity of the U.S."

[21] Carbajales-Dale, Michael, Charles J. Barnhart, and Sally M. Benson.(2014) "Can we afford storage? A dynamic net energy analysis of renewable electricity generation supported by energy storage." *Energy & Environmental Science* 7, no. 5 (2014): 1538-1544. (link) (21) **"PV technologies (CIGS and sc-Si)**...cannot 'afford' any storage while still supplying an energy surplus to society... **since they are already operating at a deficit**...These technologies require large, 'up-front' energetic investments...A fractional [energy] re-investment of greater than 100% ... means that **the industry consumes more electricity than it produces** on an annual basis, i.e. running an energy deficit"

[22] Milligan, M., Ela, E., Hein, J., Schneider, T., Brinkman, G., & Denholm, P. (2012). *Renewable Electricity Futures Study. Volume 4: Bulk Electric Power Systems: Operations and Transmission Planning* (No. NREL/TP-6A20-52409-4). National Renewable Energy Lab.(NREL), Golden, CO (United States). (link) (22) "although **RE Futures** describes the system characteristics needed to accommodate high levels of renewable generation, it **does not address the institutional, market, and regulatory changes that may be needed to facilitate such a transformation**...[and] **a full cost-benefit analysis was not conducted** to comprehensively evaluate the relative impacts of renewable and non-renewable electricity generation options.

[23] Lithium Ion batteries for Stationary Energy Storage - The Office of Electricity Delivery and Energy Reliability, Pacific Northwest National Laboratory **(23)** "Despite their success in mobile applications, **Li-ion technologies have not demonstrated sufficient grid-scale energy storage feasibility "**

[24] Lessons Learned Report - Electrical Energy Storage DOCUMENT NUMBER CLNR-L163 AUTHORS John Baker, James Cross, EA Technology Ltd, Ian Lloyd, Northern Powergrid PUBLISHED 08 December 2014 **(24) "The round trip efficiencies for the [Li-ion] EES systems have been calculated [in actual use]... between 41% and 69% where parasitic loads are included"**

[25] https://energy.stanford.edu/news/calculating-energetic-cost-grid-scale-storage **(25) "using the kind of lead-acid batteries available today to provide storage for the worldwide power grid is impractical."**

[26] Luque, A., & Hegedus, S. (Eds.). (2011). *Handbook of photovoltaic science and engineering.* John Wiley & Sons. (link) **(26) "Photovoltaics is polluting just like all high-technology or high-energy industries only with different toxic emissions** ... Manufacturing of PV modules on a large scale requires the handling of large quantities of hazardous or potentially hazardous materials (e.g. heavy metals, reactive chemical solutions, toxic gases"

[27] https://www.researchgate.net/publication/311440469_CO2_Emissions_from_the_Production_of_Ferrosilicon_and_Silicon_metal_in_Norway (27) "These emission factors only include CO2 emitted from fossil raw materials in the reduction process. **CO2 from biological, renewable sources is not included (according to joint agreement). Neither is CO2 emitted from electric power production or during transportation of raw materials."**

[28] Cleaning Up Clean Energy - https://web.stanford.edu/group/sjir/pdf/Solar_11.2.pdf **(28) "the (PV) industry has largely overlooked investigative reports revealing current problems with production waste,** particularly pertaining to Chinese manufacturing. Until these concerns receive more attention, **promises of panel recycling will quell any public anxiety, preventing the creation of necessary safeguards** to stop rogue firms from unsafe manufacturing practices"

[29] https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/#256668c121cc **(29) "We estimate there are 100,000 pounds of cadmium contained in the 1.8 million panels,"** Sean Fogarty of the group told me.

"Leaching from broken panels damaged during natural events – hail storms, tornadoes, hurricanes, earthquakes, etc. – and at decommissioning is a big concern."

[30] https://www.scmp.com/news/china/society/article/2104162/chinas-ageing-solar-panels-are-going-be-big-environmental-problem (30) Lu Fang, secretary general of the photovoltaics decision in the China Renewable Energy Society, wrote...**By 2050 these waste panels would add up to 20 million tonnes, or 2,000 times the weight of the Eiffel Tower**...Tian Min, general manager of Nanjing Fangrun Materials, a recycling company in Jiangsu province that collects retired solar panels, said **the solar power industry was a ticking time bomb."It will explode with full force in two or three decades and wreck the environment, if the estimate is correct,"**

[31] https://www.solarpowerworldonline.com/2018/04/its-time-to-plan-for-solar-panel-recycling-in-the-united-states/ (31) "We've conducted some toxicity testing on modules, and we have seen results showing that **the presence of lead is higher than the threshold allowed by the TCLP (toxicity characteristic leaching procedure)**...There is a potential for leaching of toxic materials such as lead in landfill environments. **If modules are intact, it's a low risk, but as soon as they're broken or crushed, then the potential for leaching is increased."**

[32] https://www.welt.de/wirtschaft/article176294243/Studie-Umweltrisiken-durch-Schadstoffe-in-Solarmodulen.html (32) "Based on installed power and performance weight, we can estimate that **by the year 2016, photovoltaics has spread about 11,000 tonnes of lead and about 800 tonnes of Cd (cadmium),"** the study said"

[33] https://www.solarpowerinternational.com/wp-content/uploads/2016/09/N253_9-14-1530.pdf (33) "disposal in "regular landfills [is] not recommended **in case modules break and toxic materials leach into the soil"** and so "disposal is potentially a major issue."

[34] Tao, Coby S., Jiechao Jiang, and Meng Tao. "Natural resource limitations to terawatt-scale solar cells." *Solar Energy Materials and Solar Cells* 95, no. 12 (2011): 3176-3180. https://doi.org/10.1016/j.solmat.2011.06.013 **"Material scarcity prevents most current solar cell technologies from reaching terawatt scales.** (...) Scarce materials in solar cells include indium, gallium, tellurium, ruthenium, and silver. - Natural resource limitations to terawatt-scale solar cells."

[35] Metal-demand-for-renewable-electricity-generation-in-the-netherlands **"The current global supply of several critical metals is insufficient to transition to a renewable energy system.** ...production of wind turbines and photovoltaic (PV) solar panels already requires a significant share of the annual global production of some critical metals... Furthermore, mining is often associated with significant environmental and social costs"

[36] INCREASES IN EFFICIENCY HAVE NOT REDUCED ABSOLUTE CO2 EMISSIONS FROM SHIPS **"Although the CO2 intensity of many major ship classes decreased (i.e., they became more efficient) from 2013 to 2015, total CO2 emissions from ships increased**. For example, although the CO2 intensity of general cargo ships (measured as emissions per unit of transport supply) decreased by 5%, CO2 emissions increased by 9% **Thus, increases in distance traveled due to a greater demand for shipping more than offset gains in operational efficiency during the period studied"**

[37] Kato, K., Murata, A., & Sakuta, K. (1998). Energy pay-back time and life-cycle CO2 emission of residential PV power system with silicon PV module. *Progress in Photovoltaics: Research and Applications*, *6*(2), 105-115.

[38] Fthenakis, V., Kim, H., Frischknecht, R., Raugei, M., Sinha, P., & Stucki, M. (2011). Life cycle inventories and life cycle assessment of photovoltaic systems. *International Energy Agency (IEA) PVPS Task*, *12*. http://www.clca.columbia.edu/Task12_LCI_LCA_10_21_Final_Report.pdf

Energy + Environment
Legislature

Grain Belt Express takes first resistant Missouri landowner to court

Progress on the $2 billion transmission line is accelerating as 65% of the route in Missouri and Kansas has been acquired voluntarily

By: Lukas Vanacker - December 21, 2021 12:00 pm

Evergy's Flat Ridge Wind Farm in Kansas (photo submitted).

A $2 billion wind energy project spanning the length of northern Missouri is for the first time asking a judge to force a resistant landowner to sell the company an easement on their land.

Grain Belt Express, a proposed high-voltage transmission line that would carry 4,000 megawatts of renewable energy from Western Kansas to Indiana, has faced fierce criticism from some Missouri landowners and elected officials.

In September, it filed a petition for condemnation against a farmer from Gower named Bradley Horn. A hearing in the case was originally scheduled last week in the Circuit Court of Buchanan County but was delayed until Feb. 2.

The company is arguing that Horn "did not accept the written offer for the property interests," and later "negotiations were unsuccessful." It marks the first time Grain Belt Express has taken a resistant landowner to court.

The judge can appoint three disinterested residents of the county, who have to assess the just compensation for Horn.

Horn's attorneys declined to comment.

Payments

When the Grain Belt Express got its approval from the Missouri Public Service Commission in 2019, the decision was criticized by some because it granted the private company the right to obtain easements through eminent domain.

Yet the company has always insisted it would only use that procedure as a last resort to acquire 1,700 parcels of land in Kansas and Missouri.

According to Patrick Whitty, vice president of the project's parent company, Invenergy Transmission, Grain Belt Express has "now completed right-of-way acquisition through voluntary easement agreements for approximately 65% of the route in Missouri and Kansas, compared to only one third completed at the start of

the year."

At the beginning of this year, the company had made payments of $4.9 million to landowners in Missouri combined. As it stands today, that figure is $8.5 million.

Grain Belt Express offers landowners compensation of 110% of the market value of land, plus $18,000 per tower structure. That offer was recently increased, Whitty said, to reflect "rising farmland values." For example, one farmer from Madison in northeast Missouri was offered $98,000 to allow two tower structures on nine acres of cropland.

Donna and Kenneth Inglis, a retired couple from Huntsville, were happy to close a deal with Grain Belt Express a year ago.

"I strongly support the project because I strongly believe in green energy," Donna Inglis said. "If our ancestors wouldn't have accepted rural electricity, we would still be working with kerosine lamps."

Inglis didn't want to disclose the details of the financial offer, but she said "it's a lot of money."

However, while some landowners are more than willing to grant the company access to their land, others continue to resist the transmission structures, which are 40 feet by 40 feet wide and between 130 to 160 feet tall.

"Some people have been farming here for more than 100 years," says Marilyn O'Bannon, western district commissioner in Monroe County. "Their land is their heritage. And now, they want to build something through the middle of our land, next to an existing electricity line. We can't farm efficiently around obstacles. And show me where the value for our state is."

O'Bannon's family owns land on the future transmission line. Whereas Inglis praises the professionalism of Grain Belt Express agents, O'Bannon says there has been a lack of transparency.

"The potential dangers and unknowns as well as lack of project details are overwhelming," O'Bannon said. "Landowners are left in the dark as long as possible. I can't describe the emotional impact."

Risks

The road ahead to complete the Grain Belt Express project remains long and bumpy.

In the summer of 2020, Invenergy announced the transmission line would deliver more energy to Missouri than originally anticipated, doubling its investment in the state to $1 billion.

The Public Service Commission still has to approve the extended plan. And after years of litigation and regulatory proceedings involving the project, that could once again stir up opposition to the transmission line.

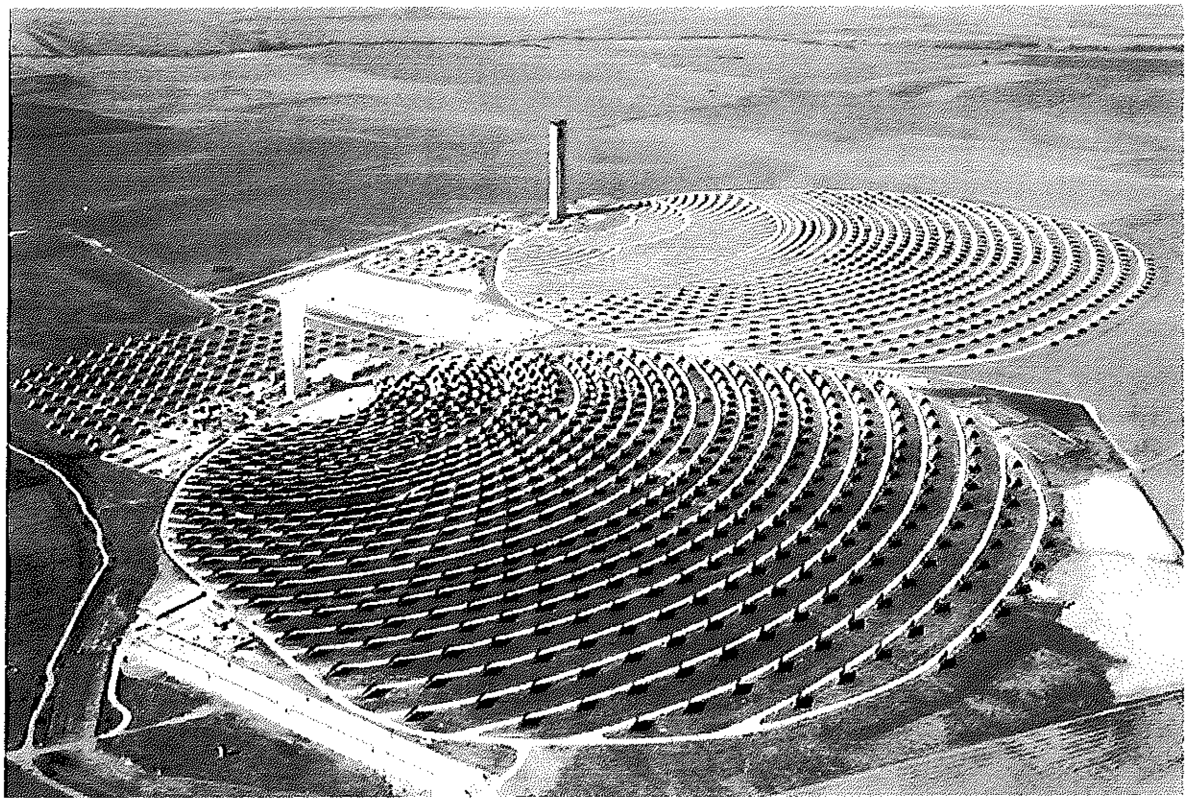
It could also fuel continued efforts by Grain Belt Express critics to push Missouri lawmakers to pass legislation undermining the project.

Earlier this year, a bill requiring that Grain Belt Express gets resolutions of support from county commissions in each of the counties in the project's path cleared the Missouri House but died in the Senate.

This story has been updated since it originally published.

Analysis: 41 Inconvenient Truths on the "New Energy Economy"

Heartland Author August 19, 2022 2



By Mark P. Mills

A week doesn't pass without a mayor, governor, policymaker or pundit joining the rush to demand, or predict, an energy future that is entirely based on wind/solar and batteries, freed from the "burden" of the hydrocarbons that have fueled societies for centuries. Regardless of one's opinion about whether, or why, an energy "transformation" is called for, the physics and economics of energy combined with scale realities make it clear that there is no possibility of anything resembling a radically "new energy economy" in the foreseeable future. Bill Gates has said that when it comes to understanding energy realities "we need to bring math to the problem."

He's right. So, in my recent Manhattan Institute report, "The New Energy Economy: An Exercise in Magical Thinking," I did just that.

Herein, then, is a summary of some of the bottom-line realities from the underlying math. (See the full report for explanations, documentation, and citations.)

Realities About the Scale of Energy Demand

1. Hydrocarbons supply over 80 percent of world energy: If all that were in the form of oil, the barrels would line up from Washington, D.C., to Los Angeles, and that entire line would grow by the height of the Washington Monument every week.

2. The small two-percentage-point decline in the hydrocarbon share of world energy use entailed over $2 trillion in cumulative global spending on alternatives over that period; solar and wind today supply less than two percent of the global energy.

3. When the world's four billion poor people increase energy use to just one-third of Europe's per capita level, global demand rises by an amount equal to twice America's total consumption.

4. A 100x growth in the number of electric vehicles to 400 million on the roads by 2040 would displace five percent of global oil demand.

5. Renewable energy would have to expand 90-fold to replace global hydrocarbons in two decades. It took a half-century for global petroleum production to expand "only" ten-fold.

6. Replacing U.S. hydrocarbon-based electric generation over the next 30 years would require a construction program building out the grid at a rate 14-fold greater than any time in history.

7. Eliminating hydrocarbons to make U.S. electricity (impossible soon, infeasible for decades) would leave untouched 70 percent of U.S. hydrocarbons use—America uses 16 percent of world energy.

8. Efficiency increases energy demand by making products & services cheaper: since 1990, global energy efficiency improved 33 percent, the economy grew 80 percent and global energy use is up 40 percent.

9. Efficiency increases energy demand: Since 1995, aviation fuel use/passenger-mile is down 70 percent, air traffic rose more than 10-fold, and global aviation fuel use rose over 50 percent.

10. Efficiency increases energy demand: since 1995, energy used per byte is down about 10,000-fold, but global data traffic rose about a million-fold; global electricity used for computing soared.

11. Since 1995, total world energy use rose by 50 percent, an amount equal to adding two entire United States' worth of demand.

12. For security and reliability, an average of two months of national demand for hydrocarbons are in storage at any time. Today, barely two *hours* of national electricity demand can be stored in all utility-scale batteries plus all batteries in one million electric cars in America.

13. Batteries produced annually by the Tesla Gigafactory (world's biggest battery factory) can store three *minutes* worth of annual U.S. electric demand.

14. To make enough batteries to store two day's worth of U.S. electricity demand would require 1,000 years of production by the Gigafactory (world's biggest battery factory).

15. Every $1 billion in aircraft produced leads to some $5 billion in aviation fuel consumed over two decades to operate them. Global spending on new jets is more than $50 billion a year—and rising.

16. Every $1 billion spent on data centers leads to $7 billion in electricity consumed over two decades. Global spending on data centers is more than $100 billion a year—and rising.

Realities about Energy Economics

17. Over a 30-year period, $1 million worth of utility-scale solar or wind produces 40 million and 55 million kWh respectively: $1 million worth of shale well produces enough natural gas to generate 300 million kWh over 30 years.

18. It costs about the same to build one shale well or two wind turbines: the latter, combined, produces 0.7 barrels of oil (equivalent energy) per hour, the shale rig averages 10 barrels of oil per hour.

19. It costs less than $0.50 to store a barrel of oil, or its equivalent in natural gas, but it costs $200 to store the equivalent energy of a barrel of oil in batteries.

20. Cost models for wind and solar assume, respectively, 41 percent and 29 percent capacity factors (i.e., how often they produce electricity). Real-world data reveal as much as ten percentage points less for both. That translates into $3 million less energy produced than assumed over a 20-year life of a 2-MW $3 million wind turbine.

21. In order to compensate for episodic wind/solar output, U.S. utilities are using oil- and gas-burning reciprocating engines (big cruise-ship-like diesels); three times as many have been added to the grid since 2000 as in the 50 years prior to that.

22. Wind-farm capacity factors have improved at about 0.7 percent per year; this small gain comes mainly from reducing the number of turbines per acre leading to a 50 percent increase in average land used to produce a wind-kilowatt-hour.

23. Over 90 percent of America's electricity, and 99 percent of the power used in transportation, comes from sources that can easily supply energy to the economy any time the market demands it.

24. Wind and solar machines produce energy an average of 25 percent–30 percent of the time, and only when nature permits. Conventional power plants can operate nearly continuously and are available when needed.

25. The shale revolution collapsed the prices of natural gas & coal, the two fuels that produce 70 percent of U.S. electricity. But electric rates haven't gone down, rising instead 20 percent since 2008. Direct and indirect subsidies for solar and wind consumed those savings.

Energy Physics… Inconvenient Realities

26. Politicians and pundits like to invoke "moonshot" language. But transforming the energy economy is not like putting a few people on the moon a few times. It is like putting all of humanity on the moon—permanently.

27. The common cliché: an energy tech disruption will echo the digital tech disruption. But *information*-producing machines and *energy*-producing machines involve profoundly different physics; the cliché is sillier than comparing apples to bowling balls.

28. If solar power scaled like computer-tech, a single postage-stamp-size solar array would power the Empire State Building. That only happens in comic books.

29. If batteries scaled like digital tech, a battery the size of a book, costing three cents, could power a jetliner to Asia. That only happens in comic books.

30. If combustion engines scaled like computers, a car engine would shrink to the size of an ant and produce a thousand-fold more horsepower; actual ant-sized engines produce 100,000 times less power.

31. No digital-like 10x gains exist for solar tech. Physics limit for solar cells (the Shockley-Queisser limit) is a max conversion of about 33 percent of photons into electrons; commercial cells today are at 26 percent.

32. No digital-like 10x gains exist for wind tech. Physics limit for wind turbines (the Betz limit) is a max capture of 60 percent of energy in moving air; commercial turbines achieve 45 percent.

33. No digital-like 10x gains exist for batteries: maximum theoretical energy in a pound of oil is 1,500 percent greater than max theoretical energy in the best pound of battery chemicals.

34. About 60 pounds of batteries are needed to store the energy equivalent of one pound of hydrocarbons.

35. At least 100 pounds of materials are mined, moved and processed for every pound of battery fabricated.

36. Storing the energy equivalent of one barrel of oil, which weighs 300 pounds, requires 20,000 pounds of Tesla batteries ($200,000 worth).

37. Carrying the energy equivalent of the aviation fuel used by an aircraft flying to Asia would require $60 million worth of Tesla-type batteries weighing five times more than that aircraft.

38. It takes the energy equivalent of 100 barrels of oil to fabricate a quantity of batteries that can store the energy equivalent of a single barrel of oil.

39. A battery-centric grid and car world means mining gigatons more of the earth to access lithium, copper, nickel, graphite, rare earths, cobalt, etc.—and using millions of tons of oil and coal both in mining and to fabricate metals and concrete.

40. China dominates global battery production with its grid 70 percent coal-fueled: EVs using Chinese batteries will create *more* carbon-dioxide than saved by replacing oil-burning engines.

41. One would no more use helicopters for regular trans-Atlantic travel—doable with elaborately expensive logistics—than employ a nuclear reactor to power a train or photovoltaic systems to power a nation.

Mark P. Mills is a senior fellow at the Manhattan Institute, a McCormick School of Engineering Faculty Fellow at Northwestern University, and author of Work in the Age of Robots, published by Encounter Books.

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For more the Green New Deal, click here and here.

Commissioner Maida Coleman
200 Madison Street
Jefferson City, MO
65102-0360

Commissioner Maida Coleman

200 Madison Street, P O Box 360

Jefferson City, MO 65102-0360 August 22,2022

My husband and I have been grain farmers in Central Missouri, since 1976. We have worked very hard, struggled through 1980's, managed to pay our loans, taxes and farm payments on time. We have also been good stewards of the land. On July 12, 2022 we received a letter in the mail from a company called Invenergy Transmission, based out of Chicago, IL informing us that they had plans to possibly run a 140 x 140 ft electric transmission towers through our farm. This notice was very upsetting for us. The towers would ruin our farm, the property would be devalued and there is no amount of money to compensate us for the permanent loss. We went to their public meeting, we asked a lot of questions and received very few straightforward answers. We left the meeting feeling frustrated and determined to do our homework; to find out as much as we could. The first thing we learned is there are lots of groups all over Missouri that have organized to fight Invenergy and companies like them. There are also lots of other states that are being impacted and resisting their plans. We attended the Audrain County landowner meeting, where Presiding Commissioner, Wiley Hibbard, said "Invenergy Transmission has no money yet, they are waiting for government subsidy." Lynn Thompson, General Manager at Consolidated Electric Cooperative of Mexico, MO told us they have no interest in purchasing the Invenergy's energy. Consolidated is one of the cooperatives in the Associated Electric Cooperative group, they service over 2 million people in Missouri, Iowa and Oklahoma, they will be forced to let Invenergy hook up to their substation. I believe this is an intrusion on the amazing system that already exists here in our area. We have very reasonable electric rates. Invenergy has filed several condemnations (taking) court cases against landowners who refused to sign an easement. Sure, doesn't sound like the friendly, we'll-work-it-with-you -company they try to portray. They are taking land by force, even though they don't have an approved route and interconnection, or enough customers to make the project economic! What country do we live in? China? I can't imagine how devastating the proud farmers and families I know are feeling about this. Where is their protection? Since they have not gotten enough customers for the Grain Belt Express and Illinois will not let them come through their state, why are you even considering letting them have permission to make the Tiger Connection here in Audrain and Callaway? By the way, it sounds like the Illinois commissioners are protecting their farm landowners.

Keryn Newman, Stoppathwv.com, reports MJMEUC agreed purchase a very small amount of capacity (up to 200 MW) at a loss leader price below GBE's (Grain Belt Express) cost to provide the service. MJMEUC only agreed because it was basically getting something for free, but it was also a very small portion of the available capacity. Since then, GBE has not found any other customers. Nobody wants to buy their service still. In order to be viable GBE needs permission to connect it's 4000 MW transmission project to the existing electric grid. After 10 years, why are we still having this discussion? Looks obvious to me the people of Missouri and the electric cooperatives do not want their kind of power. It is my opinion that intermittent power is not practical because it cannot sustain itself, it relies on the consistent AC energy from coal power and natural gas. The average electric energy produced from solar is 20-30% because of daylight. If we are forced to take payment for the easement on our land, that money is considered capital gains, therefore we would have an added burden at tax time. If Invenergy

does come down to the McCredie substation, they would have to add a second substation to convert their DC electric coming from the solar panels to AC. I repeat; they must have a backup energy source so if their so-called green energy goes dark because of clouds, snow and nighttime. I don't have to tell you that the peak demands for electricity is what causes our electric to rates go up! The government is printing money to pay for these expensive wind turbines and solar farms and high transmission towers. We the taxpayers will get changed for that as well! What I have been told is most of the energy produced isn't even for Missouri. So why are we ruining prime farmland in Missouri for another state to use? Isn't it your job to protect us? And understand, your family will be paying more too. This going to affect every electric consumer and business in the state. Commissioner Colman please allow the citizens affected a chance to share with you, their concerns, conside r having one or two hearings to give people a chance to share their opinion with you. We heard a healthcare provider worried about the tower lines emitting EMF's (Electric Magnetic Frequencies) and EMR's (Electric Magnetic Radiation) she believes they will be harmful to our health. Another farmer and his wife are worried that the towers will interfere with the radio and cell service. We don't know what side effects of living near these transmission towers will be. We do know it will forever ruin the beauty of the country side that we all love so much. As a farmer works his land, the towers will be a constant pain when he works the ground near them. He will have to be extra careful when using his large equipment, his drones for spraying, the hired helicopters and small planes. He won't be able to irrigate his land near the towers. As I said it will certainly devalue the land, no one wants to build their home near a high tower electric line, there is not enough money to compensate us. According to the Constitution, it protects We the People, from an unregulated merchant like Invenergy from using eminent domain. Granting eminent domain authority to an unregulated merchant for speculative projects that may never be placed in service violates the Fifth Amendment's requirement that property taken for public use. Looks to me like CEO Michael Polsky will be the one that gains the most from this project if it goes through. Protect the landowners and the non-profit utility companies from the unregulated merchant that only care about money. I am trusting you to do the right thing for We the People. I have not heard one person that is in favor of this project. Their proposal cuts right through prime Missouri farmland acres that are presently producing crops for ethanol and biodiesel. Both of them are helping to reduce the fuel emissions in St. Louis, Columbia and Kansas City; truly renewable fuels.

We are asking you Commissioner Coleman and the other commissioners to deny Invenergy's extravagant filing on the grounds that they have not proven demand for their energy; they have not told us who their customers are and their energy is not cost effective for this area and definitely not wanted. Thank you for your time, I have included some supporting information that backs up my request.

Why do we burn coal and trees to make solar panels?

Thomas A. Troszak (2019/11/14 revision)

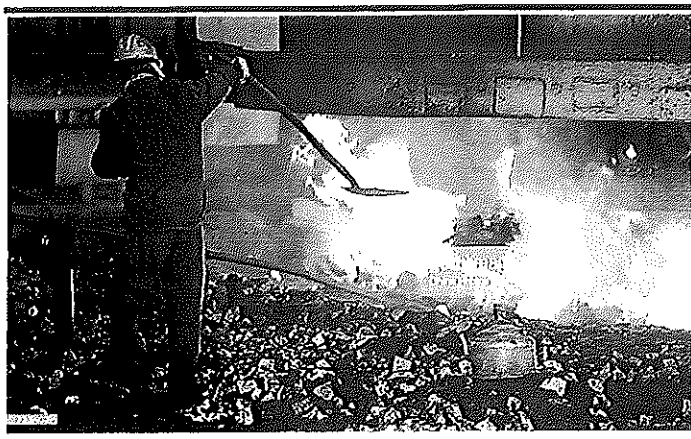


Figure 1. Workman shovels coal and lumpy quartz (silicon ore) into a silicon smelter in China. (photo: Getty)

1. Most commercial solar PV modules use *photovoltaic cells* (solar cells) made from highly purified silicon (Si).

Since the early 1900s, silicon "metal" is reduced from quartz using **carbon** in submerged-arc furnaces, each powered by up to 45 megawatts* of electricity. (Fig 1,2)

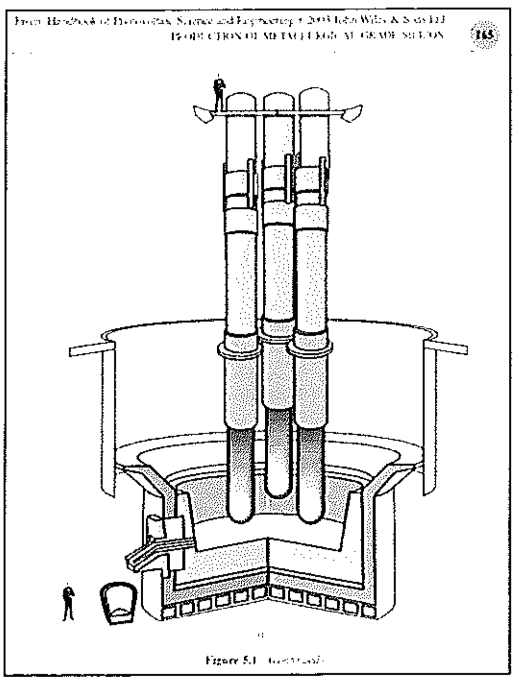


Figure 2. Diagram of a silicon smelter showing the three giant carbon electrodes that provide arc temperatures > 3,000°F for smelting quartz into "metallurgical grade" silicon (mg-Si) using carbon as a reductant (John Wiley and Sons, Ltd.)

2. Why do we need to burn carbon to make solar PV? - Elemental silicon (Si) can't be found by itself anywhere in nature. It must be extracted from quartz (SiO_2) using **carbon (C)** and heat (from an electric arc) in the "carbothermic" **(carbon+heat)** reduction process called "smelting." **($SiO_2 + 2C = Si + 2CO$)** Several **carbon sources** are used as **reductants** in the silicon smelting plant, which requires ~20 MWh/t of electricity, and releases CO - resulting in up to 5 - 6 t of CO_2 produced per ton of metallurgical grade (mg-Si) silicon smelted. [1] Thus, **the first step** of solar PV production is gathering, transporting, and **burning millions of tons of coal, coke and petroleum coke - along with charcoal and wood chips** made from hardwood trees - to smelt >97% pure mg-Si from quartz "ore" (silica rocks). [1][2][3][4][5][6][7][8][9][10]

*45 megawatts (MW) is enough for a small town (about 33,000 homes).

Figure 3. Pouring liquid metallurgical grade (~99% pure) silicon into molds, to cool into silicon "metal" (Getty)

3. Even more fossil fuels are burned later, to generate electricity for the polysilicon, ingot, wafer, cell, and module production steps shown. [21] As a result of all these processes, the solar PV industry generates megatons of CO and CO_2. But as shown below (fig 4), some often-cited descriptions of solar module production **omit the raw materials and smelting process from the PV supply chain** which obscures the use of fossil fuels and the vast amount of deforestation necessary for solar PV production. [1][3][9][27]

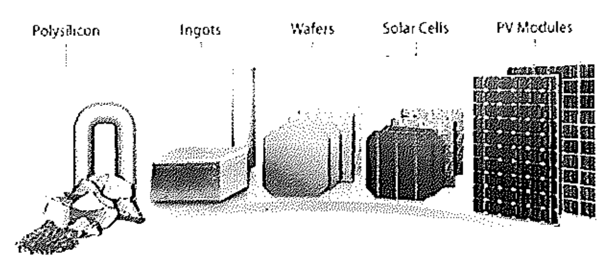


Figure 1. Schematic of c-Si PV module supply chain

Figure 4. (source: National Renewable Energy Laboratory, 2018)

4. Raw materials for metallurgical-grade silicon

Raw materials for one ton (t) MG-Si (Kato, et. al) [37]

- Quartz 2.4 t
- Coal 550 kg
- Oil coke 200 kg
- Charcoal 600 kg
- Woodchip 300 kg

Raw materials for one ton (t) MG-Si (Globe) [3]

- Quartz 2.8 t
- Coal 1.4 t
- Woodchips 2.4 t

For 110,000 tpy (tons per year) MG-Si (Thorsil) [1]

- Quartz 310,000 tpy
- Coal, coke and anodes 195,000 tpy
- Wood 185,000 tpy
- Total 380,000 tpy

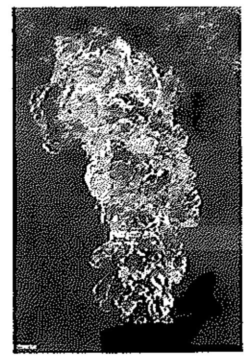
When calculating CO2 emissions from silicon smelting, "by joint agreement" some authors exclude CO2 emissions from non-fossil sources (charcoal, wood chips), power generation, and transportation of raw material. [27]

5. Sources of carbon for solar silicon smelting

• **Coal** - Is a dense, rock-like fuel. The (low ash) coal used **directly** for silicon smelting is mostly the **"Blue Gem" from Cerrajón, Columbia**, Kentucky, USA, or Venezuela. [1][2][3][5][6][7][8]

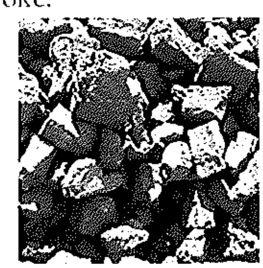
A 'Slot Oven' discharging coke into a railroad car. (photo: Alamy)

• **Metallurgical Coke** (Metcoke) is a tough, cinder-like solid fuel made by "coking" coal in large "slot ovens" - to drive out most of the volatile tars, etc. to the atmosphere as smoke, flame, carbon monoxide, carbon dioxide, sulfur dioxide, other gasses, and water vapor.

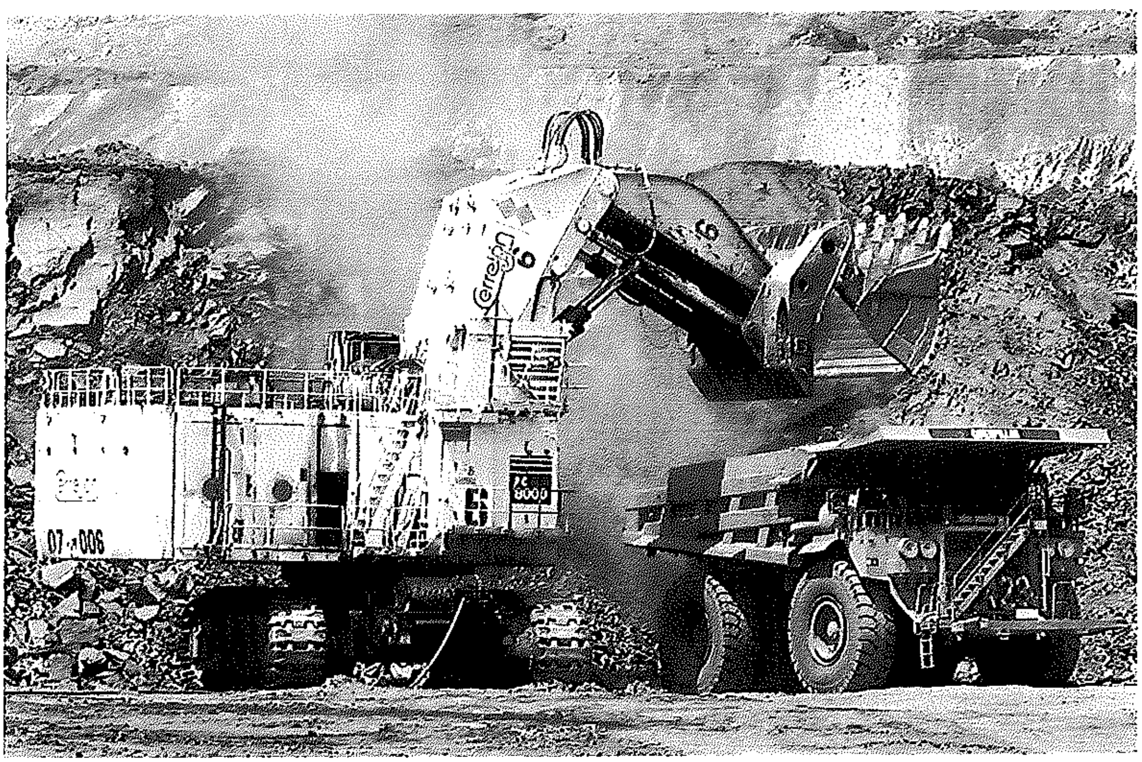


(photo: Getty Images)

The **coking process** is nearly identical to the process used for making charcoal from wood (see charcoal production below). Restricting the air supply to a large mass of burning coal allows about 40% of the coal to "burn off" - leaving behind a solid residue (coke) with a **higher carbon content** per ton that the original coal. It takes **about 1.6 t of coal** to make a ton of coke.



Metcoke looks like porous, silvery grey coal.



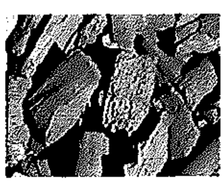
The Cerrajón open-pit mine in Columbia supplies "Blue Gem" coal for silicon smelters around the world.

Filling barges with petcoke outside Chicago, Ill. USA (photo)

• **Petroleum Coke** (Petcoke) - is a solid fuel in the form of pellet-like granules, which are a carbon-rich byproduct of crude oil refineries. Millions of tons of petcoke are also made directly from raw bitumen (tar). Due to its low price and high carbon content, petcoke made in American refineries from "Canadian Tar Sands" is a source of carbon exported from the U.S. to silicon manufacturers in China. [9]

"Because it is considered a refinery byproduct, petcoke emissions are not included in most assessments of the climate impact of tar sands" [10]

"Beehive" charcoal ovens in Brazil (Alamy)

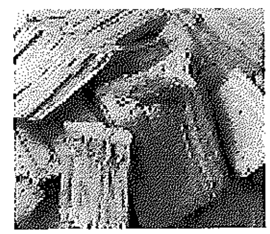


• **Wood Charcoal - Many hardwood trees must be burned to make wood charcoal.** In the traditional process, wood is stacked into "beehive ovens", ignited, then mostly smothered to prevent the wood from burning completely to ash. By weight, **about 75% of the wood is lost to the atmosphere as CO, CO_2, smoke, and heat.**

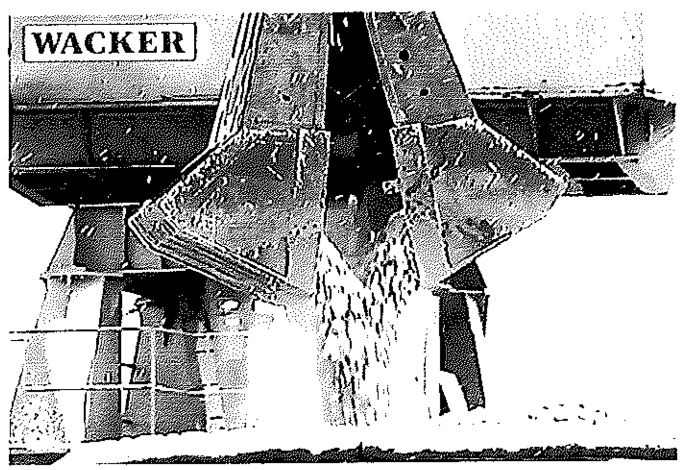
Some silicon producers use **"charcoal plantations,"** but they **only supply a fraction of the current demand** of carbon for silicon production. The rest of the carbon supply has to come from imported coal or coke, or the cutting and burning of "virgin" rainforest. [13][14][15][16]

In Brazil, it is estimated that more than a third of the country's charcoal is still produced illegally from protected species. [14] Brazil is a charcoal supplier to silicon producers in other countries, including the United States. Silicon smelters around the world use charcoal from many sources, so solar silicon may be smelted with charcoal made directly from rainforest not grown on plantations.

This hardwood forest in the U.S. was clear cut to make wood chips

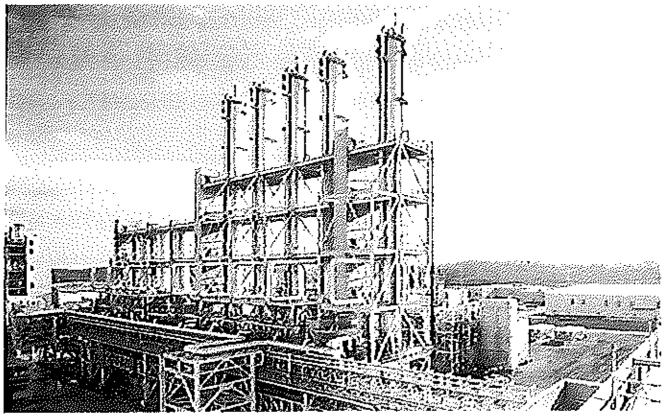


6. **Hardwood Chips** (also called Metchips) - Matchbox-sized fragments of **shredded hardwood must be mixed into the silicon smelter** "pot" for many reasons - to allow the reactive gasses to circulate, so the liquid silicon that forms can settle to the bottom for tapping, and to allow the resulting CO (and other gasses) to escape the smelter "charge" safely. [4]



Solar silicon quartz rocks (Wacker Chemie)

7. **Silicon ore - Quartz - (silica, silicon dioxide, SiO_2)** Even if sufficiently pure, **silica sand won't work in any silicon smelter**, it is too fine. Selected high-purity quartz is mined and graded into "lumpy" (fist-sized) gravel for smelting. Worldwide, "solar grade" deposits of quartz are somewhat scarce, and highly valued.

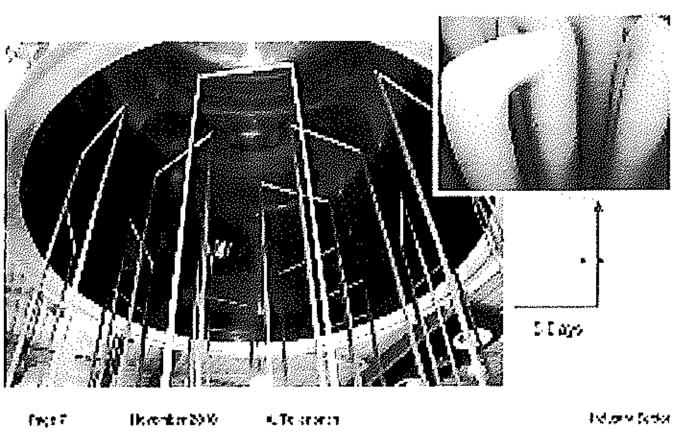


A single polysilicon plant like this one in Tennessee, USA, can draw 400 megawatts of electricity, enough power for about 300,000 homes. (Wacker Polysilicon)

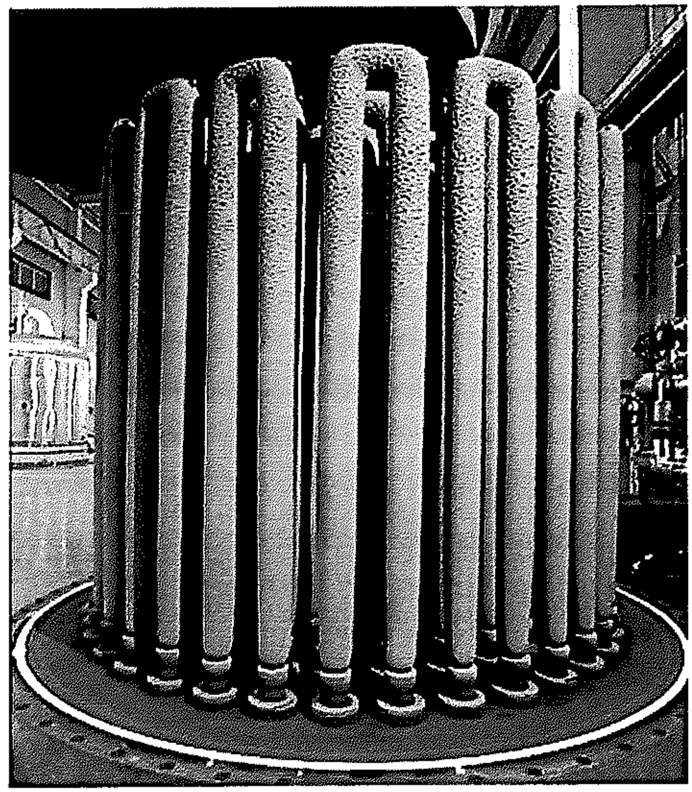
8. Polysilicon production

Metallurgical grade silicon (mg-Si) from the smelter is only about 99% pure, so it must undergo two more energy-intensive processes before it can be made into solar cells. First, **the Siemens Process converts (mg-Si) from the smelter into polycrystalline silicon (called polysilicon)** by a high-temperature vapor deposition process.

This is a bit like "growing rock candy" on hyper-pure silicon "strings" inside a pressurized-gas filled "bell-jar" reactor. As a mixture of silicon gas (made from mg-Si) and hydrogen gas passes through the reactor vessel, some of the silicon gas molecules "cling" to the electrically heated "strings" (called filaments) causing them to grow into "rods" of 99.9999% pure (or better) polysilicon.



Left: When heated to around 1100°C the polysilicon "filaments" standing beneath the reactor cover can "catch" about 20% of the silicon atoms that pass through the reactor in gaseous form. Right: Polysilicon "rods" after 5 days of growth. (Siemens AG)



Each batch of polysilicon "rods" takes several days to grow, and a continuous, 24/7 supply of electricity to each reactor is essential to prevent a costly "run abort." So **polysilicon refineries** depend on highly reliable conventional power grids, and usually have two incoming high-voltage supply feeds.

A polysilicon plant consumes ~1.6 - 6 t of incoming mg-Si, and requires at least **175 MWh** (or more) of **additional electricity** per ton of polysilicon produced - **about 10 times the energy already used for smelting** each ton of mg silicon from ore. **[11]** After the rods are removed from the reactor, they are sawed into sections or broken into "chunks" for loading into crucibles in the next step.

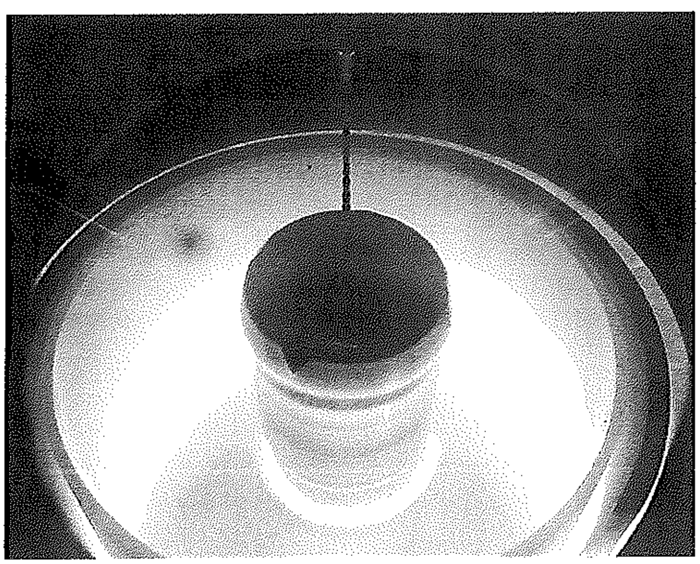
Polysilicon rods and sections being broken into chunks by hand in a clean room. (Hemlock)

Polysilicon chunks being heated in a crucible. When melted, a single crystal will be pulled out of the liquid polysilicon. (Getty)

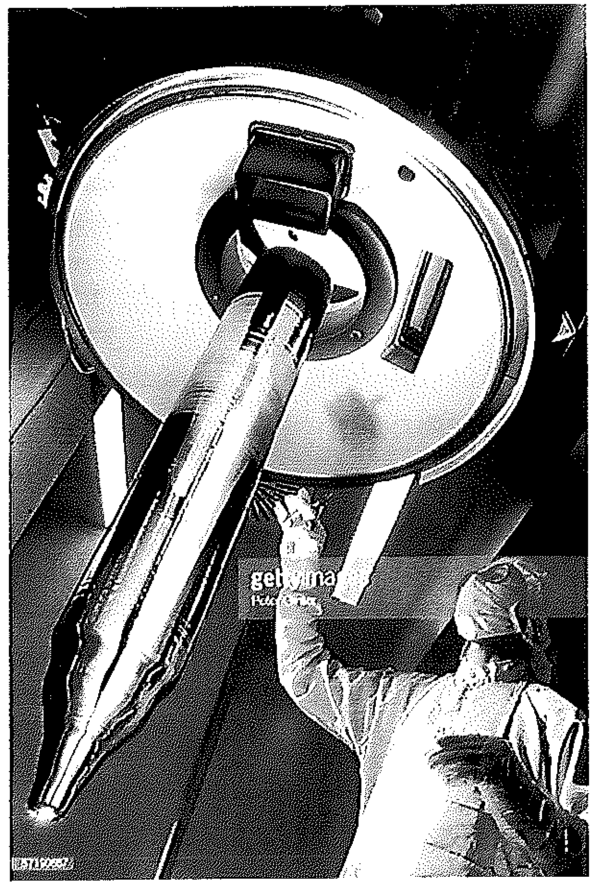
9. Crystal growing (ingot production)

For making single-crystal solar cells (called mono PV) the PV industry uses the **Czochralski process to further purify the polysilicon, and align the silicon molecules into a single-crystal form.**

First, polysilicon chunks are melted in a rotating crucible in an inert atmosphere. Then a small seed crystal of silicon is lowered into the molten polysilicon. As the seed crystal is slowly withdrawn, a single silicon crystal forms from the tip of the seed. As the crucible turns, the polysilicon continues to grow into a cylindrical ingot, leaving most of the non-silicon impurities behind in the 5-10% of "pot scrap" remaining after the crystal is drawn free.

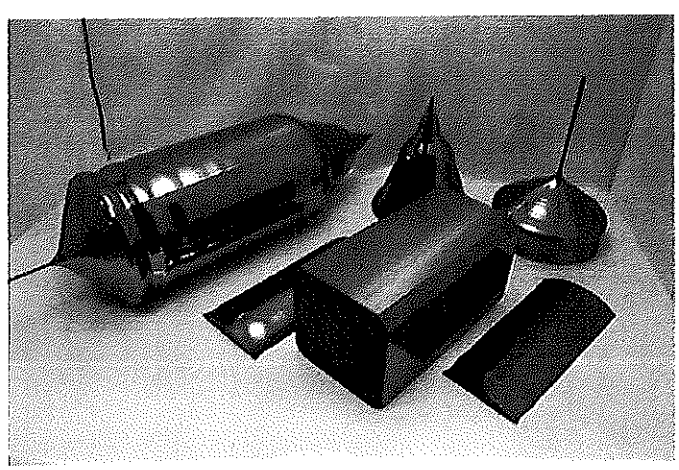


Czochralski ingot being pulled from melted polysilicon. (Image source: Siltronix)



Czochralski ingot after cooling (Image source: Getty)

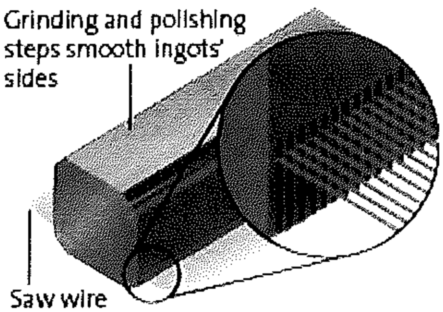
This process requires several days, and uninterrupted power. An ingot/wafer/cell plant can use more than 100 MWh additional energy per ton of incoming polysilicon, about 6 times as much as the original smelting of the silicon from ore. After slow cooling, the ingot's unusable crown and tail are cut off (about 10%), the center is then ground down, the four "chords" (long sides) are sawn off (about 25%) leaving a rectangular "brick" so the solar wafers will be almost square after slicing.



Czochralski process whole ingot (left), and brick and chords after sawing (right), crown and tail (upper right) (SVM)

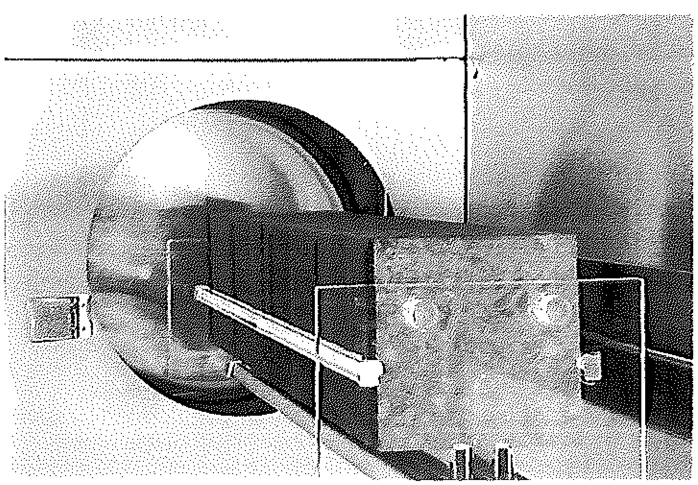
For multi-crystalline cells (called multi PV) polysilicon is melted in rectangular quartz molds, then allowed to cool slowly into a rectangular ingot of multi-crystalline silicon. which is trimmed to remove unusable portions, then sliced into bricks.

10. Wafer sawing
Then, like a loaf of bread, the silicon "bricks" are sliced with wire saws into thin wafers, which will later be processed into cells.



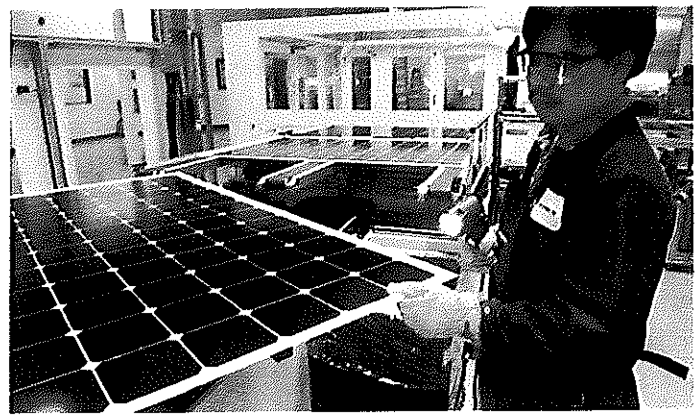
About half of the "brick" is lost as "sawdust" in the wafer slicing process, and this can't be recovered. So, after all of the energy and materials that have gone into making each "brick", much of the incoming polysilicon does not ever become finished wafers. Some of the heads, tails, chords, and trimmings can be etched (to remove contamination) and remelted **using additional energy** if the purity of the scrap is sufficient to justify the expense, otherwise they are discarded as waste.

11. Cell and module production.
Once the wafers are sliced, they are made into "cells" by adding layers of other materials and components in a series of additional production steps.



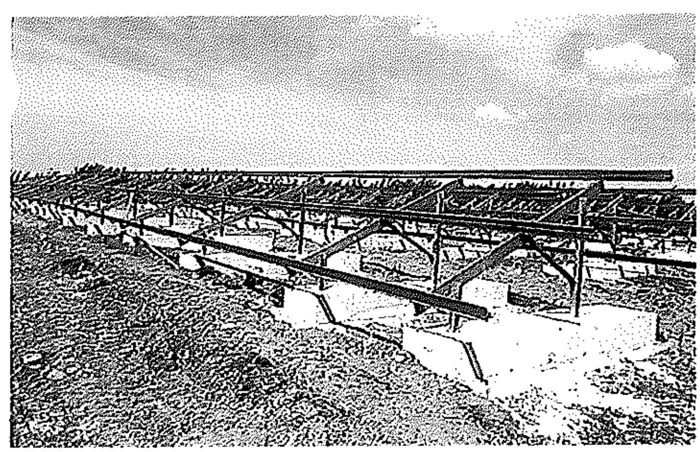
Diffusion Furnace in the PV-TEC at Fraunhofer ISE. Loading of the diffusion tubes with batches of [illegible] silicon wafers. The wafers [illegible] into the (up to) 1000 °C hot quartz tubes. (Fraunhofer ISE)

Then the cells are assembled into modules. Beside silicon wafers, most solar PV modules also require many other energy-intensive materials - aluminum (for the frame), silver, copper, glass, plastic, highly toxic rare earth metals, acids, and dozens of other chemicals for processing the polysilicon into cells and modules. A lot of electricity is needed to power the cell production and module assembly, **a supply of natural gas** is used to provide heat in the process.



Solar module inspection on the assembly line. (Solar World)

12. Other materials and steps
Once the modules are made, the whole PV system usually needs steel or aluminum framing, concrete, and some empty land (or a rooftop) to position it securely toward the sun, a lot of wiring to connect (through DC/AC inverters and transformers) to the existing power grid, or directly to battery banks,



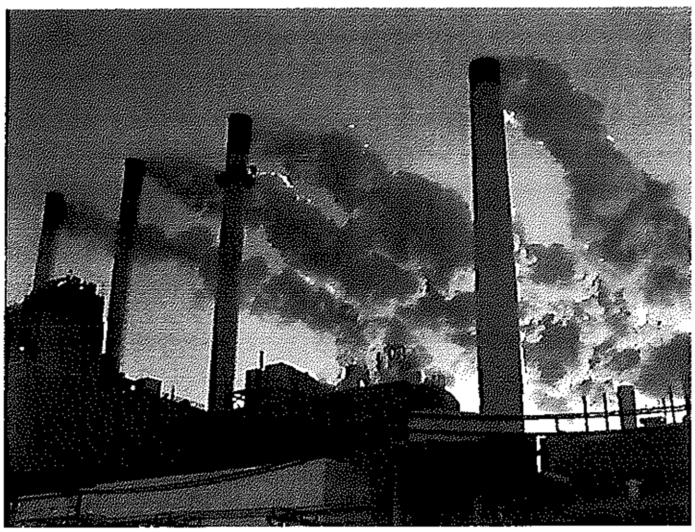
PV support structure and concrete foundation (Hill & Smith)

Of course, it takes **a lot of energy and resources** to make steel, aluminum, concrete, inverters, copper wiring, and all of these other materials. In many cases, the "balance of system" components in a PV installation can require as much (or more) "up-front" resources and energy to make as the modules. **[21]**

In addition, the amount of fossil fuels and non-renewable resources needed to construct and maintain new PV production infrastructure (smelters, polysilicon refineries, etc.) is considerable, but has been excluded from all "life cycle analysis" (LCA) of solar PV production by definition. [38]

13. Transportation

Throughout the solar PV manufacturing process all of the materials and products must be shipped **to and from more than a dozen countries** around the world in large barges, container ships, trains, or trucks - **all powered by non-renewable oil. [36]**



14. Power

Worldwide, only a few silicon smelters, like those in Norway, are powered primarily by hydro-electricity. Elsewhere, the current majority of smelters, polysilicon refineries, ingot growers, cell and module factories are running on grids **powered mostly by fossil fuels and uranium.** At present, more than 50% of all solar silicon is made in China, where the industrial grid is powered largely by fossil fuels, primarily low-grade coal. Depending on the "energy mix" available, the quantity of coal, coke, or gas that is being burned to deliver power 24/7 to the PV factories may be far greater than the amount needed as the carbon source for smelting silicon. To provide a realistic assessment of the total environmental impact of PV manufacturing, this **must be added to the "fossil fuel bill"** for solar PV production - along with the "embodied energy" of PV factories. **[11][12][21]**

15. Conclusions

Every step in the production of solar photovoltaic (PV) power systems requires a perpetual input of fossil fuels - as carbon reductants for smelting metals from ore, for process heat and power, international transport, and deployment. Silicon smelters, polysilicon refineries, and crystal growers around the world all depend on uninterrupted, 24/7 power that comes mostly from coal and uranium. **The only "renewable" materials consumed in PV production are obtained by deforestation** - for wood chips, and by burning vast areas of tropical rainforest for charcoal used as a source of carbon for silicon smelters. So far, both **media and journal claims** that solar PV can somehow "replace fossil fuels" **have not addressed the non-renewable reality of global supply chains** necessary for mining, manufacturing, and distribution of PV power systems. Based on current world production levels of solar PV, an attempt to replace conventional electricity production with solar PV would require a **dramatic increase in the amount of coal and petcoke needed for silicon smelting**, along with the **increased cutting of vast areas of forest** for charcoal and wood chips.

Readers are encouraged to **examine all of the references below**, to become aware of other aspects with solar pv manufacturing and deployment that are beyond the scope of this paper.

References

[1] Thorsil (2015) "Metallurgical Grade Silicon Plant - Helguvík, Reykjanes municipality (Reykjanesbær), Reykjanes peninsula, Iceland Environmental Impact Assessment (EIA) Capacity: 110,000 tons" https://www.giek.no/getfile.php/133565/web/Dokumenter/Prosjekter%20under%20vurdering/EIA-Thorsil_Lingua-2-%20konsekvensutredning.pdf (1) "Thorsil's initial assessment report was based on using...**Coal from El Cerrajon in Columbia**...for an annual production...of 110,000 tpy [of mg-Si]...**would correspond to 605,000 tpy of carbon dioxide...The Environment Agency feels that...such exhaust would significantly increase Iceland's overall emissions"**

[2] Efla (2013) "Environmental Impact Assessment of a SILICON METAL PLANT AT BAKKI IN HÚSAVÍK"https://www.agaportal.de/_Resources/Persistent/856d55b1a3c1948e5f856f800195760741faa93b/eia_island_silizium.pdf (2) "The main raw materials used for the production of Silicon Metal are quartzite... **coals (mainly from [Cerrejón] Columbia, Venezuela, and USA)**, charcoal, wood chips"

[3] "New York State Department of Environmental Conservation - Facility DEC ID: 9291100078 PERMIT Under the Environmental Conservation Law (ECL) Permit Issued To: GLOBE METALLURGICAL INC" http://www.dec.ny.gov/dardata/boss/afs/permits/929110007800009_r3.pdf **(3) "Globe Metallurgical produces high purity silicon metal...The facility is a major source of emissions of sulfur dioxide, carbon monoxide, hydrogen chloride and nitrogen oxides...** "The submerged electric arc process is a reduction smelting operation...**Reactants consisting of coal, charcoal, petroleum coke, or other forms of coke, wood chips, and quartz are mixed and added at the top of each furnace... At high temperatures in the reaction zone, the carbon sources react with silicon dioxide and oxygen to form carbon monoxide and reduce the ore to the base metal silicon."**

[4] "The Use and Market for WOOD in the ELECTROMETALLURGICAL Industry" https://www.fs.usda.gov/treesearch/pubs/23800 (4) [woodchips are used in smelters]...**to provide a large surface area for chemical reaction to take place more completely and at improved rates...To maintain a porous charge, thereby promoting gentle and uniform - instead of violent - gas venting**...To help regulate smelting temperatures...To keep the furnace burning smoothly on top...To reduce conductivity...To promote deep electrode penetration...To prevent bridging, crusting, and agglomeration of the mix...To reduce dust, metal vapor, and heat loss; and as a result to improve working conditions near the furnace.

[5] Healy, N., Stephens, J. C., & Malin, S. A. (2019). "Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains." *Energy Research & Social Science*, *48*, 219-234. (link) (5)**"Cerrejón is one of the world's largest open-pit coal mines [supplying silicon manufacturers]**...energy extraction often entails the physical displacement of populations or the "slow violence" of landscape destruction, water contamination and livelihood disruption"

[6] What Terrible Injustices Are Hiding Behind American Energy Habits? By Itai Vardi • Friday, November 16, 2018 (link) (6) **"There is a clear 'consumer blindness' and citizens and residents are often unaware of where the fuel they consume is coming from** and what injustices were inflicted on communities within those sites of fossil fuel extraction," said Healy. "Exposing these **injustices of energy 'sacrifice zones' — like [the Cerrejón open-pit coal mine] in La Guajira, Colombia** ...— could be critical for future energy policy decision-making."

[7] 2017/06/18/why-this-part-of-coal-country-loves-solar-power-215272 (7)**"the seam in Whitley County [Kentucky] is an even more valuable variety of metallurgic coal known as "blue gem."..."You need the blue gem to make the solar panels, and that's what people don't know,"** Moses told me, articulating a simple truth: **"Without Coal Valley, there's no Silicon Valley"**

[8] **https://www.prnewswire.com/news-releases/new-colombia-resources-inc-discovers-huge-new-metallurgical-coal-seam-at-their-property-in-colombia-as-the-company-prepares-to-begin-production-while-coal-prices-continue-to-soar-600823111.html** (8) "Colombian coal accounts for close to 75% of coal imports to the U.S... New Colombia Resources' Blue Gem coal is only found on the KY-TN border and central Colombia and is used to produce specialty metals **such as Silicon to make solar panels**, electric car batteries, and many more next generation products"

[9] https://carnegietsinghua.org/2015/05/31/managing-china-s-petcoke-problem-pub-60023 **(9) "Figure 5. [graph] Chinese Petcoke Consumption by Sector (2013 silicon=6%) (2014 silicon=7%)** A significant share of the petcoke used in China [which was made in U.S. refineries] is imported from the United States, ..."According to the U.S. Energy Information Administration (EIA), **U.S. petcoke exports to China... a staggering 7 million metric tons in 2013...accounting for nearly 75 percent of Chinese petcoke.**

[10] Petroleum Coke: The Coal Hiding in the Tar Sands (10) "Because it is considered a refinery byproduct, **petcoke emissions are not included in most assessments of the climate impact of tar sands**"...

[11] https://www.sightline.org/2018/06/25/small-town-silicon-smelter-plan-tees-up-big-questions/ (11) "**these furnaces would have a voracious appetite for electricity: around 105 megawatts on a continuous basis, roughly the equivalent of 68,000 homes...the facility would demand more power than the dam could provide**....Producing one ton of silicon metal requires about six tons of raw materials...Nearby sawmills would send seven or eight trucks per day to deliver wood chips, which are integral to the smelting process...."**The smelting process requires a rare type of metallurgic coal known as "blue gem," ... Operations at the smelter would demand approximately 48,000 metric tons of coal per year—roughly 40 rail cars each month.**"

[12] **https://siteselection.com/theEnergyReport/2009/apr/Wacker-Chemie/** (12) "A nuclear plant is 1200 megawatts. **Fully built out, [Wacker Polysilicon] could be a third of a nuclear plant [400 MW]**...Not everybody out there can handle that size of a load. We're selling the fact that we [TVA] have the reliability, and we have a very diverse portfolio across **coal, nuclear and hydro.**"

[13] Jungbluth, N., M. Stucki, R. Frischknecht, S. Büsser, and ESU-services Ltd. & Swiss Centre for Life Cycle Inventories. (2009) "Part XII photovoltaics." *Swiss Centre for Life Cycle Inventories* (link) (13) "An issue of concern... **is the use of charcoal in this [photovoltaic silicon] process that originates from Asia or South America and might have been produced from clear cutting rainforest wood**"

[14] Eikeland, Inger Johanne, B. Monsen, and Ingunn S. Modahl.(2001) "Reducing CO2 emissions in Norwegian ferroalloy production." *Greenhouse Gases in the Metallurgical Industries: Policies, Abatement and Treatment, (Met. Soc. CIM), Toronto* 325 . (link) (14) **Most of the charcoal used...[for silicon production]...is imported from Asia and South America.** The crude, traditional methods of charcoal making, which are still widely used in these continents, are inefficient and strongly pollute the environment."

[15] Nisgoski, Silvana & Muniz, Graciela & Morrone, Simone & Schardosin, Felipe & França, Ramiro. (2015). NIR and anatomy of wood and charcoal from Moraceae and Euphorbiaceae species. Revista Ciência da Madeira - RCM. 6. 183-190. 10.12953/2177-6830/rcm.v6n3p183-190. (link) (15) "**charcoal supply is still present in illegal cutting of native forests, which represented 30-35% of total output [in Brazil]**... charcoal consumption represents the deforestation of approximately 1.6 million hectares or 16.000 km² of the Cerrado Biome"

[16] 2017/10/burning-down-the-house-myanmars-destructive-charcoal-trade/ (16) "**Dehong's silicon industry ... "has caused a serious damage to forest resources,**" and estimated that "119,700 tons of charcoal were consumed in the production of industrial silicon in Dehong prefecture **in 2014... 31 square miles—"of forests were cut down. (...) In 2016, the [silicon] industry consumed nearly twice that amount** (216,273 tons of charcoal)

[17] BP Statistical Review of World Energy. 67th Edition. June 2018 (17) "despite the huge policy push encouraging a switch away from coal and the rapid expansion of renewable energy in recent years, **there has been no improvement in the mix of fuels feeding the global power sector over the past 20 years. Astonishingly, the share of coal in 2017 was exactly the same as in 1998. The share of non-fossil fuels was actually lower,** as growth in renewables has failed to compensate for the decline in nuclear energy."

[18] De Castro, Carlos, Margarita Mediavilla, Luis Javier Miguel, and Fernando Frechoso. "Global solar electric potential: A review of their technical and sustainable limits." *Renewable and Sustainable Energy Reviews* 28 (2013): 824-835. (link) (18) "**based on real examples...our results show that present and foreseeable future density power of solar infrastructures are much less (4–10 times) than most published studies**... an overview of the land and materials needed for large scale implementation show that many of the estimations found in the literature are hardly compatible with the rest of human activities."

[19] Koomey, J. G., Calwell, C., Laitner, S., Thornton, J., Brown, R. E., Eto, J. H., ... & Cullicott, C. (2002). Sorry, wrong number: The use and misuse of numerical facts in analysis and media reporting of energy issues. *Annual review of energy and the environment*, *27*(1), 119-158. (link) (19) "Unfortunately, numbers that prove decisive in policy debates are not always carefully developed, credibly documented, or correct...**A common mistake in the media has been to apply this statistic (1000 homes per MW) to intermittent renewable power sources**...Intermittent renewables generally produce far fewer kilowatt-hours per MW than conventional power

plants...**this widely used equivalence between homes and MW should generally not be applied to intermittent renewables such as...PVs.**"

[20] Shaner, Matthew R., Steven J. Davis, Nathan S. Lewis, and Ken Caldeira. (2018) "Geophysical constraints on the reliability of solar and wind power in the United States." *Energy & Environmental Science* 11, no. 4 (2018): 914-925 (link) **(20) "Achieving 99.97% reliability with a system consisting solely of solar and wind generation... would require** a storage capacity equivalent to several weeks of average demand...**Three weeks of storage (227 TW h) [which] results in ~6500 years of the annual Tesla Gigafactory production capacity** or a **~900x increase** in the pumped hydro capacity of the U.S."

[21] Carbajales-Dale, Michael, Charles J. Barnhart, and Sally M. Benson.(2014) "Can we afford storage? A dynamic net energy analysis of renewable electricity generation supported by energy storage." *Energy & Environmental Science* 7, no. 5 (2014): 1538-1544. (link) (21) **"PV technologies (CIGS and sc-Si)**...cannot 'afford' any storage while still supplying an energy surplus to society... **since they are already operating at a deficit**...These technologies require large, 'up-front' energetic investments...A fractional [energy] re-investment of greater than 100% ... means that **the industry consumes more electricity than it produces** on an annual basis, i.e. running an energy deficit"

[22] Milligan, M., Ela, E., Hein, J., Schneider, T., Brinkman, G., & Denholm, P. (2012). *Renewable Electricity Futures Study. Volume 4: Bulk Electric Power Systems: Operations and Transmission Planning* (No. NREL/TP-6A20-52409-4). National Renewable Energy Lab.(NREL), Golden, CO (United States). (link) (22) "although **RE Futures** describes the system characteristics needed to accommodate high levels of renewable generation, it **does not address the institutional, market, and regulatory changes that may be needed to facilitate such a transformation**...[and] **a full cost-benefit analysis was not conducted** to comprehensively evaluate the relative impacts of renewable and non-renewable electricity generation options.

[23] Lithium Ion batteries for Stationary Energy Storage - The Office of Electricity Delivery and Energy Reliability, Pacific Northwest National Laboratory **(23)** "Despite their success in mobile applications, **Li-ion technologies have not demonstrated sufficient grid-scale energy storage feasibility** "

[24] Lessons Learned Report - Electrical Energy Storage DOCUMENT NUMBER CLNR-L163 AUTHORS John Baker, James Cross, EA Technology Ltd, Ian Lloyd, Northern Powergrid PUBLISHED 08 December 2014 **(24) "The round trip efficiencies for the [Li-ion] EES systems have been calculated [in actual use]... between 41% and 69% where parasitic loads are included"**

[25] https://energy.stanford.edu/news/calculating-energetic-cost-grid-scale-storage **(25) "using the kind of lead-acid batteries available today to provide storage for the worldwide power grid is impractical."**

[26] Luque, A., & Hegedus, S. (Eds.). (2011). *Handbook of photovoltaic science and engineering.* John Wiley & Sons. (link) **(26) "Photovoltaics is polluting just like all high-technology or high-energy industries only with different toxic emissions** ... Manufacturing of PV modules on a large scale requires the handling of large quantities of hazardous or potentially hazardous materials (e.g. heavy metals, reactive chemical solutions, toxic gases"

[27] https://www.researchgate.net/publication/311440469_CO2_Emissions_from_the_Production_of_Ferrosilicon_and_Silicon_metal_in_Norway (27) "These emission factors only include CO2 emitted from fossil raw materials in the reduction process. **CO2 from biological, renewable sources is not included (according to joint agreement). Neither is CO2 emitted from electric power production or during transportation of raw materials."**

[28] Cleaning Up Clean Energy - https://web.stanford.edu/group/sjir/pdf/Solar_11.2.pdf **(28) "the (PV) industry has largely overlooked investigative reports revealing current problems with production waste,** particularly pertaining to Chinese manufacturing. Until these concerns receive more attention, **promises of panel recycling will quell any public anxiety, preventing the creation of necessary safeguards** to stop rogue firms from unsafe manufacturing practices"

[29] https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/#256668c121cc **(29) "We estimate there are 100,000 pounds of cadmium contained in the 1.8 million panels,"** Sean Fogarty of the group told me.

"Leaching from broken panels damaged during natural events – hail storms, tornadoes, hurricanes, earthquakes, etc. – and at decommissioning is a big concern."

[30] https://www.scmp.com/news/china/society/article/2104162/chinas-ageing-solar-panels-are-going-be-big-environmental-problem (30) Lu Fang, secretary general of the photovoltaics decision in the China Renewable Energy Society, wrote...**By 2050 these waste panels would add up to 20 million tonnes, or 2,000 times the weight of the Eiffel Tower**...Tian Min, general manager of Nanjing Fangrun Materials, a recycling company in Jiangsu province that collects retired solar panels, said **the solar power industry was a ticking time bomb."It will explode with full force in two or three decades and wreck the environment, if the estimate is correct,"**

[31] https://www.solarpowerworldonline.com/2018/04/its-time-to-plan-for-solar-panel-recycling-in-the-united-states/ (31) "We've conducted some toxicity testing on modules, and we have seen results showing that **the presence of lead is higher than the threshold allowed by the TCLP (toxicity characteristic leaching procedure)**...There is a potential for leaching of toxic materials such as lead in landfill environments. **If modules are intact, it's a low risk, but as soon as they're broken or crushed, then the potential for leaching is increased."**

[32] https://www.welt.de/wirtschaft/article176294243/Studie-Umweltrisiken-durch-Schadstoffe-in-Solarmodulen.html (32) "Based on installed power and performance weight, we can estimate that **by the year 2016, photovoltaics has spread about 11,000 tonnes of lead and about 800 tonnes of Cd (cadmium),"** the study said"

[33] https://www.solarpowerinternational.com/wp-content/uploads/2016/09/N253_9-14-1530.pdf (33) "disposal in "regular landfills [is] not recommended **in case modules break and toxic materials leach into the soil"** and so "disposal is potentially a major issue."

[34] Tao, Coby S., Jiechao Jiang, and Meng Tao. "Natural resource limitations to terawatt-scale solar cells." *Solar Energy Materials and Solar Cells* 95, no. 12 (2011): 3176-3180. https://doi.org/10.1016/j.solmat.2011.06.013 **"Material scarcity prevents most current solar cell technologies from reaching terawatt scales.** (...) Scarce materials in solar cells include indium, gallium, tellurium, ruthenium, and silver. - Natural resource limitations to terawatt-scale solar cells."

[35] Metal-demand-for-renewable-electricity-generation-in-the-netherlands **"The current global supply of several critical metals is insufficient to transition to a renewable energy system.** ...production of wind turbines and photovoltaic (PV) solar panels already requires a significant share of the annual global production of some critical metals... Furthermore, mining is often associated with significant environmental and social costs"

[36] INCREASES IN EFFICIENCY HAVE NOT REDUCED ABSOLUTE CO2 EMISSIONS FROM SHIPS **"Although the CO2 intensity of many major ship classes decreased (i.e., they became more efficient) from 2013 to 2015, total CO2 emissions from ships increased**. For example, although the CO2 intensity of general cargo ships (measured as emissions per unit of transport supply) decreased by 5%, CO2 emissions increased by 9% **Thus, increases in distance traveled due to a greater demand for shipping more than offset gains in operational efficiency during the period studied"**

[37] Kato, K., Murata, A., & Sakuta, K. (1998). Energy pay-back time and life-cycle CO2 emission of residential PV power system with silicon PV module. *Progress in Photovoltaics: Research and Applications*, *6*(2), 105-115.

[38] Fthenakis, V., Kim, H., Frischknecht, R., Raugei, M., Sinha, P., & Stucki, M. (2011). Life cycle inventories and life cycle assessment of photovoltaic systems. *International Energy Agency (IEA) PVPS Task, 12.* http://www.clca.columbia.edu/Task12_LCI_LCA_10_21_Final_Report.pdf

Energy + Environment
Legislature

Grain Belt Express takes first resistant Missouri landowner to court

Progress on the $2 billion transmission line is accelerating as 65% of the route in Missouri and Kansas has been acquired voluntarily

By: Lukas Vanacker - December 21, 2021 12:00 pm

Evergy's Flat Ridge Wind Farm in Kansas (photo submitted).

A $2 billion wind energy project spanning the length of northern Missouri is for the first time asking a judge to force a resistant landowner to sell the company an easement on their land.

Grain Belt Express, a proposed high-voltage transmission line that would carry 4,000 megawatts of renewable energy from Western Kansas to Indiana, has faced fierce criticism from some Missouri landowners and elected officials.

In September, it filed a petition for condemnation against a farmer from Gower named Bradley Horn. A hearing in the case was originally scheduled last week in the Circuit Court of Buchanan County but was delayed until Feb. 2.

The company is arguing that Horn "did not accept the written offer for the property interests," and later "negotiations were unsuccessful." It marks the first time Grain Belt Express has taken a resistant landowner to court.

The judge can appoint three disinterested residents of the county, who have to assess the just compensation for Horn.

Horn's attorneys declined to comment.

Payments

When the Grain Belt Express got its approval from the Missouri Public Service Commission in 2019, the decision was criticized by some because it granted the private company the right to obtain easements through eminent domain.

Yet the company has always insisted it would only use that procedure as a last resort to acquire 1,700 parcels of land in Kansas and Missouri.

According to Patrick Whitty, vice president of the project's parent company, Invenergy Transmission, Grain Belt Express has "now completed right-of-way acquisition through voluntary easement agreements for approximately 65% of the route in Missouri and Kansas, compared to only one third completed at the start of

the year."

At the beginning of this year, the company had made payments of $4.9 million to landowners in Missouri combined. As it stands today, that figure is $8.5 million.

Grain Belt Express offers landowners compensation of 110% of the market value of land, plus $18,000 per tower structure. That offer was recently increased, Whitty said, to reflect "rising farmland values." For example, one farmer from Madison in northeast Missouri was offered $98,000 to allow two tower structures on nine acres of cropland.

Donna and Kenneth Inglis, a retired couple from Huntsville, were happy to close a deal with Grain Belt Express a year ago.

"I strongly support the project because I strongly believe in green energy," Donna Inglis said. "If our ancestors wouldn't have accepted rural electricity, we would still be working with kerosine lamps."

Inglis didn't want to disclose the details of the financial offer, but she said "it's a lot of money."

However, while some landowners are more than willing to grant the company access to their land, others continue to resist the transmission structures, which are 40 feet by 40 feet wide and between 130 to 160 feet tall.

"Some people have been farming here for more than 100 years," says Marilyn O'Bannon, western district commissioner in Monroe County. "Their land is their heritage. And now, they want to build something through the middle of our land, next to an existing electricity line. We can't farm efficiently around obstacles. And show me where the value for our state is."

O'Bannon's family owns land on the future transmission line. Whereas Inglis praises the professionalism of Grain Belt Express agents, O'Bannon says there has been a lack of transparency.

"The potential dangers and unknowns as well as lack of project details are overwhelming," O'Bannon said. "Landowners are left in the dark as long as possible. I can't describe the emotional impact."

Risks

The road ahead to complete the Grain Belt Express project remains long and bumpy.

In the summer of 2020, Invenergy announced the transmission line would deliver more energy to Missouri than originally anticipated, doubling its investment in the state to $1 billion.

The Public Service Commission still has to approve the extended plan. And after years of litigation and regulatory proceedings involving the project, that could once again stir up opposition to the transmission line.

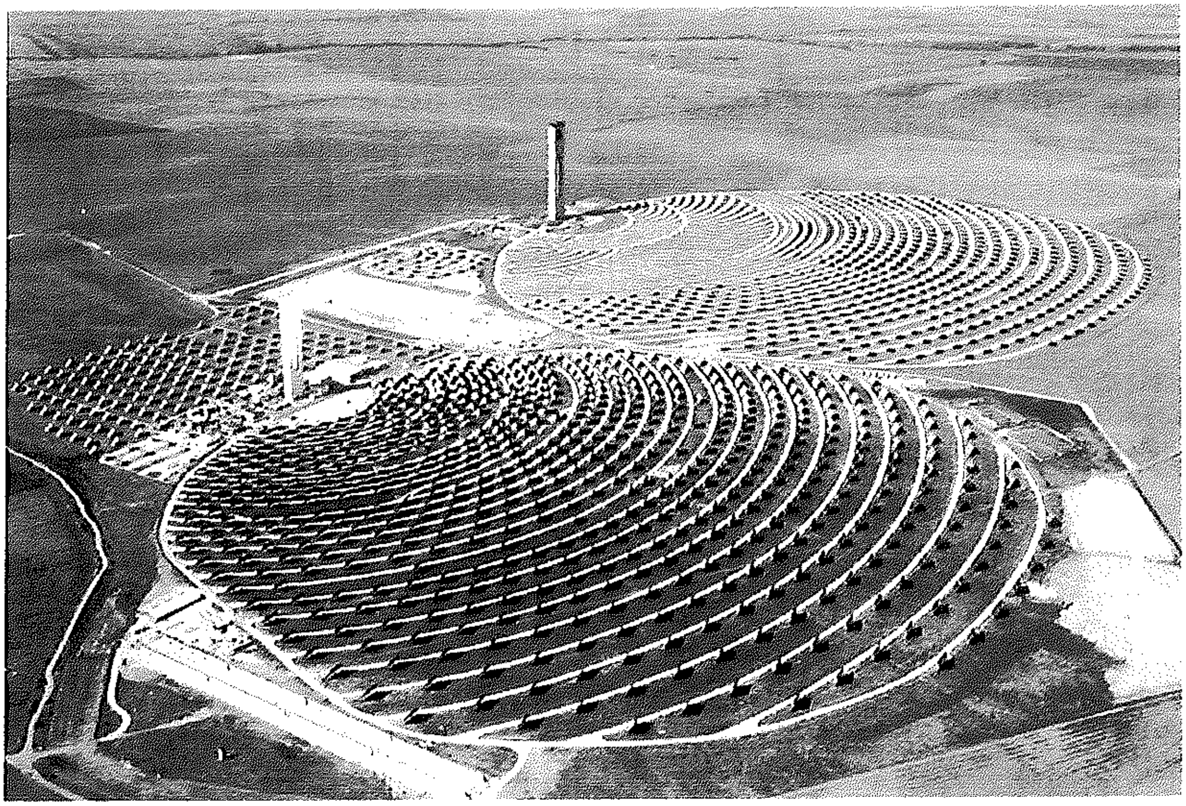
It could also fuel continued efforts by Grain Belt Express critics to push Missouri lawmakers to pass legislation undermining the project.

Earlier this year, a bill requiring that Grain Belt Express gets resolutions of support from county commissions in each of the counties in the project's path cleared the Missouri House but died in the Senate.

This story has been updated since it originally published.

Analysis: 41 Inconvenient Truths on the "New Energy Economy"

Heartland Author August 19, 2022



By Mark P. Mills

A week doesn't pass without a mayor, governor, policymaker or pundit joining the rush to demand, or predict, an energy future that is entirely based on wind/solar and batteries, freed from the "burden" of the hydrocarbons that have fueled societies for centuries. Regardless of one's opinion about whether, or why, an energy "transformation" is called for, the physics and economics of energy combined with scale realities make it clear that there is no possibility of anything resembling a radically "new energy economy" in the foreseeable future. Bill Gates has said that when it comes to understanding energy realities "we need to bring math to the problem."

He's right. So, in my recent Manhattan Institute report, "The New Energy Economy: An Exercise in Magical Thinking," I did just that.

Herein, then, is a summary of some of the bottom-line realities from the underlying math. (See the full report for explanations, documentation, and citations.)

Realities About the Scale of Energy Demand

1. Hydrocarbons supply over 80 percent of world energy: If all that were in the form of oil, the barrels would line up from Washington, D.C., to Los Angeles, and that entire line would grow by the height of the Washington Monument every week.

2. The small two-percentage-point decline in the hydrocarbon share of world energy use entailed over $2 trillion in cumulative global spending on alternatives over that period; solar and wind today supply less than two percent of the global energy.

3. When the world's four billion poor people increase energy use to just one-third of Europe's per capita level, global demand rises by an amount equal to twice America's total consumption.

4. A 100x growth in the number of electric vehicles to 400 million on the roads by 2040 would displace five percent of global oil demand.

5. Renewable energy would have to expand 90-fold to replace global hydrocarbons in two decades. It took a half-century for global petroleum production to expand "only" ten-fold.

6. Replacing U.S. hydrocarbon-based electric generation over the next 30 years would require a construction program building out the grid at a rate 14-fold greater than any time in history.

7. Eliminating hydrocarbons to make U.S. electricity (impossible soon, infeasible for decades) would leave untouched 70 percent of U.S. hydrocarbons use—America uses 16 percent of world energy.

8. Efficiency increases energy demand by making products & services cheaper: since 1990, global energy efficiency improved 33 percent, the economy grew 80 percent and global energy use is up 40 percent.

9. Efficiency increases energy demand: Since 1995, aviation fuel use/passenger-mile is down 70 percent, air traffic rose more than 10-fold, and global aviation fuel use rose over 50 percent.

10. Efficiency increases energy demand: since 1995, energy used per byte is down about 10,000-fold, but global data traffic rose about a million-fold; global electricity used for computing soared.

11. Since 1995, total world energy use rose by 50 percent, an amount equal to adding two entire United States' worth of demand.

12. For security and reliability, an average of two months of national demand for hydrocarbons are in storage at any time. Today, barely two *hours* of national electricity demand can be stored in all utility-scale batteries plus all batteries in one million electric cars in America.

13. Batteries produced annually by the Tesla Gigafactory (world's biggest battery factory) can store three *minutes* worth of annual U.S. electric demand.

14. To make enough batteries to store two day's worth of U.S. electricity demand would require 1,000 years of production by the Gigafactory (world's biggest battery factory).

15. Every $1 billion in aircraft produced leads to some $5 billion in aviation fuel consumed over two decades to operate them. Global spending on new jets is more than $50 billion a year—and rising.

16. Every $1 billion spent on data centers leads to $7 billion in electricity consumed over two decades. Global spending on data centers is more than $100 billion a year—and rising.

Realities about Energy Economics

17. Over a 30-year period, $1 million worth of utility-scale solar or wind produces 40 million and 55 million kWh respectively: $1 million worth of shale well produces enough natural gas to generate 300 million kWh over 30 years.

18. It costs about the same to build one shale well or two wind turbines: the latter, combined, produces 0.7 barrels of oil (equivalent energy) per hour, the shale rig averages 10 barrels of oil per hour.

19. It costs less than $0.50 to store a barrel of oil, or its equivalent in natural gas, but it costs $200 to store the equivalent energy of a barrel of oil in batteries.

20. Cost models for wind and solar assume, respectively, 41 percent and 29 percent capacity factors (i.e., how often they produce electricity). Real-world data reveal as much as ten percentage points less for both. That translates into $3 million less energy produced than assumed over a 20-year life of a 2-MW $3 million wind turbine.

21. In order to compensate for episodic wind/solar output, U.S. utilities are using oil- and gas-burning reciprocating engines (big cruise-ship-like diesels); three times as many have been added to the grid since 2000 as in the 50 years prior to that.

22. Wind-farm capacity factors have improved at about 0.7 percent per year; this small gain comes mainly from reducing the number of turbines per acre leading to a 50 percent increase in average land used to produce a wind-kilowatt-hour.

23. Over 90 percent of America's electricity, and 99 percent of the power used in transportation, comes from sources that can easily supply energy to the economy any time the market demands it.

24. Wind and solar machines produce energy an average of 25 percent–30 percent of the time, and only when nature permits. Conventional power plants can operate nearly continuously and are available when needed.

25. The shale revolution collapsed the prices of natural gas & coal, the two fuels that produce 70 percent of U.S. electricity. But electric rates haven't gone down, rising instead 20 percent since 2008. Direct and indirect subsidies for solar and wind consumed those savings.

Energy Physics... Inconvenient Realities

26. Politicians and pundits like to invoke "moonshot" language. But transforming the energy economy is not like putting a few people on the moon a few times. It is like putting all of humanity on the moon—permanently.

27. The common cliché: an energy tech disruption will echo the digital tech disruption. But *information*-producing machines and *energy*-producing machines involve profoundly different physics; the cliché is sillier than comparing apples to bowling balls.

28. If solar power scaled like computer-tech, a single postage-stamp-size solar array would power the Empire State Building. That only happens in comic books.

29. If batteries scaled like digital tech, a battery the size of a book, costing three cents, could power a jetliner to Asia. That only happens in comic books.

30. If combustion engines scaled like computers, a car engine would shrink to the size of an ant and produce a thousand-fold more horsepower; actual ant-sized engines produce 100,000 times less power.

31. No digital-like 10x gains exist for solar tech. Physics limit for solar cells (the Shockley-Queisser limit) is a max conversion of about 33 percent of photons into electrons; commercial cells today are at 26 percent.

32. No digital-like 10x gains exist for wind tech. Physics limit for wind turbines (the Betz limit) is a max capture of 60 percent of energy in moving air; commercial turbines achieve 45 percent.

33. No digital-like 10x gains exist for batteries: maximum theoretical energy in a pound of oil is 1,500 percent greater than max theoretical energy in the best pound of battery chemicals.

34. About 60 pounds of batteries are needed to store the energy equivalent of one pound of hydrocarbons.

35. At least 100 pounds of materials are mined, moved and processed for every pound of battery fabricated.

36. Storing the energy equivalent of one barrel of oil, which weighs 300 pounds, requires 20,000 pounds of Tesla batteries ($200,000 worth).

37. Carrying the energy equivalent of the aviation fuel used by an aircraft flying to Asia would require $60 million worth of Tesla-type batteries weighing five times more than that aircraft.

38. It takes the energy equivalent of 100 barrels of oil to fabricate a quantity of batteries that can store the energy equivalent of a single barrel of oil.

39. A battery-centric grid and car world means mining gigatons more of the earth to access lithium, copper, nickel, graphite, rare earths, cobalt, etc.—and using millions of tons of oil and coal both in mining and to fabricate metals and concrete.

40. China dominates global battery production with its grid 70 percent coal-fueled: EVs using Chinese batteries will create *more* carbon-dioxide than saved by replacing oil-burning engines.

41. One would no more use helicopters for regular trans-Atlantic travel—doable with elaborately expensive logistics—than employ a nuclear reactor to power a train or photovoltaic systems to power a nation.

Mark P. Mills is a senior fellow at the Manhattan Institute, a McCormick School of Engineering Faculty Fellow at Northwestern University, and author of Work in the Age of Robots, published by Encounter Books.

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For more the Green New Deal, click here and here.

Commissioner Jason Holsman
200 Madison Street
Jefferson City, MO
65102-0360

Commissioner Jason Holsman

200 Madison Street, P O Box 360

Jefferson City, MO 65102-0360 August 22, 2022

My husband and I have been grain farmers in Central Missouri, since 1976. We have worked very hard, struggled through 1980's, managed to pay our loans, taxes and farm payments on time. We have also been good stewards of the land. On July 12, 2022 we received a letter in the mail from a company called Invenergy Transmission, based out of Chicago, IL informing us that they had plans to possibly run a 140 x 140 ft electric transmission towers through our farm. This notice was very upsetting for us. The towers would ruin our farm, the property would be devalued and there is no amount of money to compensate us for the permanent loss. We went to their public meeting, we asked a lot of questions and received very few straightforward answers. We left the meeting feeling frustrated and determined to do our homework; to find out as much as we could. The first thing we learned is there are lots of groups all over Missouri that have organized to fight Invenergy and companies like them. There are also lots of other states that are being impacted and resisting their plans. We attended the Audrain County landowner meeting, where Presiding Commissioner, Wiley Hibbard, said "Invenergy Transmission has no money yet, they are waiting for government subsidy." Lynn Thompson, General Manager at Consolidated Electric Cooperative of Mexico, MO told us they have no interest in purchasing the Invenergy's energy. Consolidated is one of the cooperatives in the Associated Electric Cooperative group, they service over 2 million people in Missouri, Iowa and Oklahoma, they will be forced to let Invenergy hook up to their substation. I believe this is an intrusion on the amazing system that already exists here in our area. We have very reasonable electric rates. Invenergy has filed several condemnations (taking) court cases against landowners who refused to sign an easement. Sure, doesn't sound like the friendly, we'll-work-it-with-you -company they try to portray. They are taking land by force, even though they don't have an approved route and interconnection, or enough customers to make the project economic! What country do we live in? China? I can't imagine how devastating the proud farmers and families I know are feeling about this. Where is their protection? Since they have not gotten enough customers for the Grain Belt Express and Illinois will not let them come through their state, why are you even considering letting them have permission to make the Tiger Connection here in Audrain and Callaway? By the way, it sounds like the Illinois commissioners are protecting their farm landowners.

Keryn Newman, Stoppathwv.com, reports MJMEUC agreed purchase a very small amount of capacity (up to 200 MW) at a loss leader price below GBE's (Grain Belt Express) cost to provide the service. MJMEUC only agreed because it was basically getting something for free, but it was also a very small portion of the available capacity. Since then, GBE has not found any other customers. Nobody wants to buy their service still. In order to be viable GBE needs permission to connect it's 4000 MW transmission project to the existing electric grid. After 10 years, why are we still having this discussion? Looks obvious to me the people of Missouri and the electric cooperatives do not want their kind of power. It is my opinion that intermittent power is not practical because it cannot sustain itself, it relies on the consistent AC energy from coal power and natural gas. The average electric energy produced from solar is 20-30% because of daylight. If we are forced to take payment for the easement on our land, that money is considered capital gains, therefore we would have an added burden at tax time. If Invenergy

does come down to the McCredie substation, they would have to add a second substation to convert their DC electric coming from the solar panels to AC. I repeat; they must have a backup energy source so if their so-called green energy goes dark because of clouds, snow and nighttime. I don't have to tell you that the peak demands for electricity is what causes our electric to rates go up! The government is printing money to pay for these expensive wind turbines and solar farms and high transmission towers. We the taxpayers will get changed for that as well! What I have been told is most of the energy produced isn't even for Missouri. So why are we ruining prime farmland in Missouri for another state to use? Isn't it your job to protect us? And understand, your family will be paying more too. This going to affect every electric consumer and business in the state. Commissioner Holsman please allow the citizens affected a chance to share with you, their concerns, consider having one or two hearings to give people a chance to share their opinion with you. We heard a healthcare provider worried about the tower lines emitting EMF's (Electric Magnetic Frequencies) and EMR's (Electric Magnetic Radiation) she believes they will be harmful to our health. Another farmer and his wife are worried that the towers will interfere with the radio and cell service. We don't know what side effects of living near these transmission towers will be. We do know it will forever ruin the beauty of the country side that we all love so much. As a farmer works his land, the towers will be a constant pain when he works the ground near them. He will have to be extra careful when using his large equipment, his drones for spraying, the hired helicopters and small planes. He won't be able to irrigate his land near the towers. As I said it will certainly devalue the land, no one wants to build their home near a high tower electric line, there is not enough money to compensate us. According to the Constitution, it protects We the People, from an unregulated merchant like Invenergy from using eminent domain. Granting eminent domain authority to an unregulated merchant for speculative projects that may never be placed in service violates the Fifth Amendment's requirement that property taken for public use. Looks to me like CEO Michael Polsky will be the one that gains the most from this project if it goes through. Protect the landowners and the non-profit utility companies from the unregulated merchant that only care about money. I am trusting you to do the right thing for We the People. I have not heard one person that is in favor of this project. Their proposal cuts right through prime Missouri farmland acres that are presently producing crops for ethanol and biodiesel. Both of them are helping to reduce the fuel emissions in St. Louis, Columbia and Kansas City; truly renewable fuels.

We are asking you Commissioner Holsman and the other commissioners to deny Invenergy's extravagant filing on the grounds that they have not proven demand for their energy; they have not told us who their customers are and their energy is not cost effective for this area and definitely not wanted. Thank you for your time, I have included some supporting information that backs up my request.

Why do we burn coal and trees to make solar panels?

Thomas A. Troszak (2019/11/14 revision)

Figure 1. Workman shovels coal and lumpy quartz (silicon ore) into a silicon smelter in China. (photo: Getty)

1. Most commercial solar PV modules use *photovoltaic cells* (solar cells) made from highly purified silicon (Si).

Since the early 1900s, silicon "metal" is reduced from quartz using **carbon** in submerged-arc furnaces, each powered by up to 45 megawatts* of electricity. (Fig 1,2)

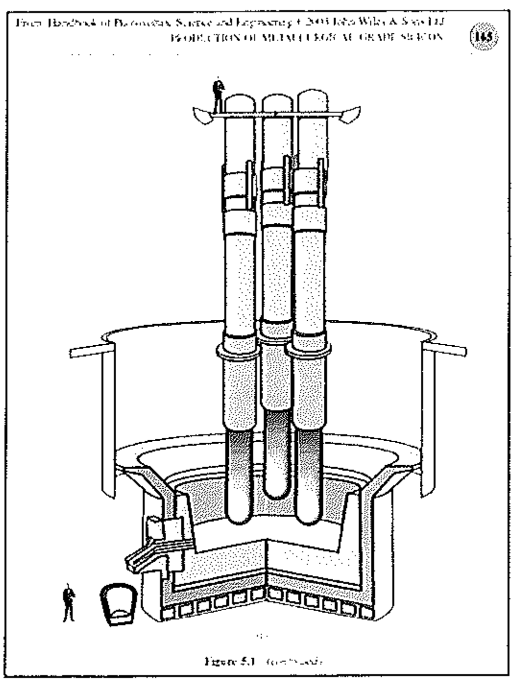


Figure 2. Diagram of a silicon smelter showing the three giant carbon electrodes that provide arc temperatures > 3,000°F for smelting quartz into "metallurgical grade" silicon (mg-Si) using carbon as a reductant (John Wiley and Sons, Ltd.)

2. Why do we need to burn carbon to make solar PV? - Elemental silicon (Si) can't be found by itself anywhere in nature. It must be extracted from quartz (SiO_2) using **carbon (C)** and heat (from an electric arc) in the "carbothermic" **(carbon+heat)** reduction process called "smelting." ($SiO_2 + 2C = Si + 2CO$) Several **carbon sources** are used as **reductants** in the silicon smelting plant, which requires ~20 MWh/t of electricity, and releases CO - resulting in up to 5 - 6 t of CO_2 produced per ton of metallurgical grade (mg-Si) silicon smelted. [1] Thus, **the first step** of solar PV production is gathering, transporting, and **burning millions of tons of coal, coke and petroleum coke - along with charcoal and wood chips** made from hardwood trees - to smelt >97% pure mg-Si from quartz "ore" (silica rocks). [1][2][3][4][5][6][7][8][9][10]

*45 megawatts (MW) is enough for a small town (about 33,000 homes).

Figure 3. Pouring liquid metallurgical grade (~99% pure) silicon into molds, to cool into silicon "metal". (Getty)

3. Even more fossil fuels are burned later, to generate electricity for the polysilicon, ingot, wafer, cell, and module production steps shown. [21] As a result of all these processes, the solar PV industry generates megatons of CO and CO_2. But as shown below (fig 4), some often-cited descriptions of solar module production **omit the raw materials and smelting process from the PV supply chain** which obscures the use of fossil fuels and the vast amount of deforestation necessary for solar PV production. [1][3][9][27]

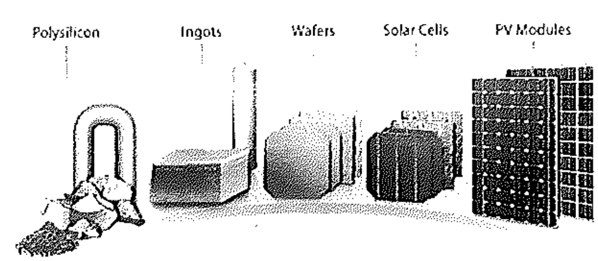


Figure 1. Schematic of c-Si PV module supply chain

Figure 4. (source: National Renewable Energy Laboratory, 2018)

4. Raw materials for metallurgical-grade silicon

Raw materials for one ton (t) MG-Si (Kato, et. al) [37]

- Quartz 2.4 t
- Coal 550 kg
- Oil coke 200 kg
- Charcoal 600 kg
- Woodchip 300 kg

Raw materials for one ton (t) MG-Si (Globe) [3]

- Quartz 2.8 t
- Coal 1.4 t
- Woodchips 2.4 t

For 110,000 tpy (tons per year) MG-Si (Thorsil) [1]

- Quartz 310,000 tpy
- Coal, coke and anodes 195,000 tpy
- Wood 185,000 tpy
- Total 380,000 tpy

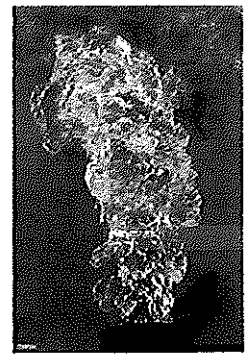
When calculating CO2 emissions from silicon smelting, "by joint agreement" some authors exclude CO2 emissions from non-fossil sources (charcoal, wood chips), power generation, and transportation of raw material. [27]

5. Sources of carbon for solar silicon smelting

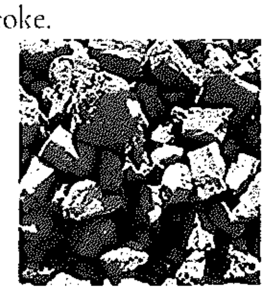
• **Coal** - Is a dense, rock-like fuel. The (low ash) coal used **directly** for silicon smelting is mostly the **"Blue Gem" from Cerrajón, Columbia**, Kentucky, USA, or Venezuela. [1][2][3][5][6][7][8]

A "Slot Oven" discharging coke into a railroad car. (photo: Alamy)

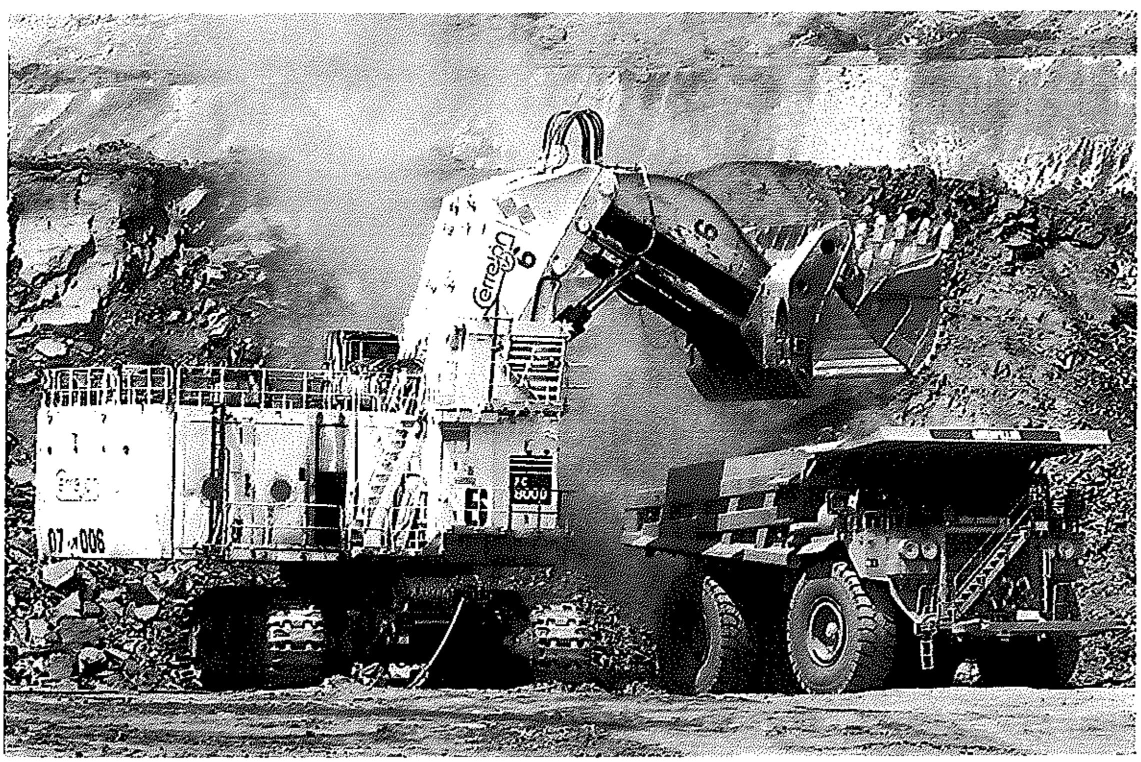
• **Metallurgical Coke** (Metcoke) is a tough, cinder-like solid fuel made by "coking" coal in large "slot ovens" - to drive out most of the volatile tars, etc. to the atmosphere as smoke, flame, carbon monoxide, carbon dioxide, sulfur dioxide, other gasses, and water vapor. (photo: Getty Images)



The **coking process** is nearly identical to the process used for making charcoal from wood (see charcoal production below). Restricting the air supply to a large mass of burning coal allows about 40% of the coal to "burn off" - leaving behind a solid residue (coke) with a **higher carbon content** per ton that the original coal. It takes **about 1.6 t of coal** to make a ton of coke.



Metcoke looks like porous, silvery grey coal.



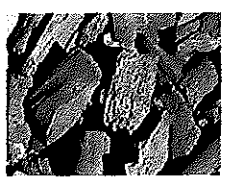
The Cerrajón open-pit mine in Columbia supplies "Blue Gem" coal for silicon smelters around the world.

Filling barges with petcoke outside Chicago. Ill. USA (photo)

• **Petroleum Coke** (Petcoke) - is a solid fuel in the form of pellet-like granules, which are a carbon-rich byproduct of crude oil refineries. Millions of tons of petcoke are also made directly from raw bitumen (tar). Due to its low price and high carbon content, petcoke made in American refineries from "Canadian Tar Sands" is a source of carbon exported from the U.S. to silicon manufacturers in China. [9]

"Because it is considered a refinery byproduct, petcoke emissions are not included in most assessments of the climate impact of tar sands" [10]

"Beehive" charcoal ovens in Brazil (Alamy)

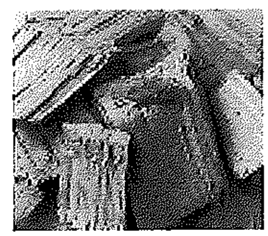


• **Wood Charcoal - Many hardwood trees must be burned to make wood charcoal.** In the traditional process, wood is stacked into "beehive ovens", ignited, then mostly smothered to prevent the wood from burning completely to ash. By weight, **about 75% of the wood is lost to the atmosphere as CO, CO_2, smoke, and heat.**

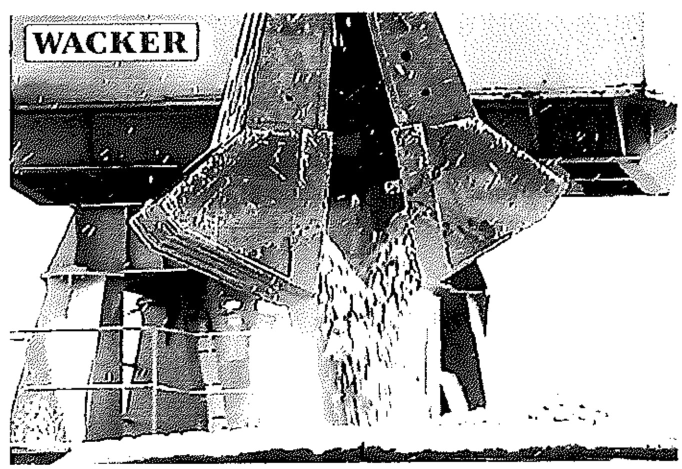
Some silicon producers use **"charcoal plantations,"** but they **only supply a fraction of the current demand** of carbon for silicon production. The rest of the carbon supply has to come from imported coal or coke, or the cutting and burning of "virgin" rainforest. **[13][14][15][16]**

In Brazil, it is estimated that more than a third of the country's charcoal is still produced illegally from protected species. [14] Brazil is a charcoal supplier to silicon producers in other countries, including the United States. Silicon smelters around the world use charcoal from many sources, so solar silicon may be smelted with charcoal made directly from rainforest not grown on plantations.

This hardwood forest in the U.S. was clear cut to make wood chips

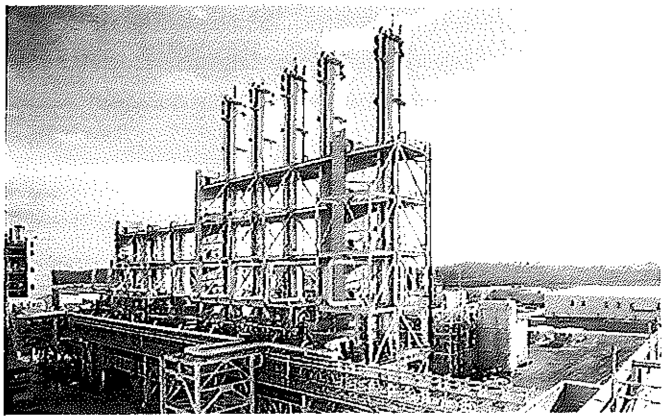


6. **Hardwood Chips** (also called Metchips) - Matchbox-sized fragments of **shredded hardwood must be mixed into the silicon smelter** "pot" for many reasons - to allow the reactive gasses to circulate, so the liquid silicon that forms can settle to the bottom for tapping, and to allow the resulting CO (and other gasses) to escape the smelter "charge" safely. [4]



Solar silicon quartz rocks (Wacker Chemie)

7. **Silicon ore - Quartz - (silica, silicon dioxide, SiO_2)** Even if sufficiently pure, **silica sand won't work in any silicon smelter**, it is too fine. Selected high-purity quartz is mined and graded into "lumpy" (fist-sized) gravel for smelting. Worldwide, "solar grade" deposits of quartz are somewhat scarce, and highly valued.

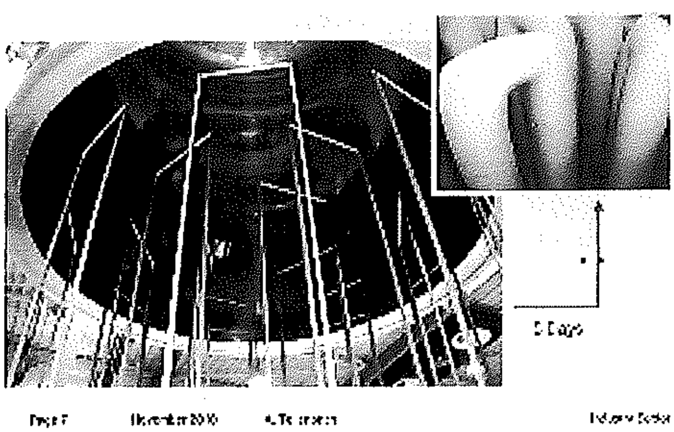


A single polysilicon plant like this one in Tennessee, USA. can draw 400 megawatts of electricity, enough power for about 300,000 homes. (Wacker Polysilicon)

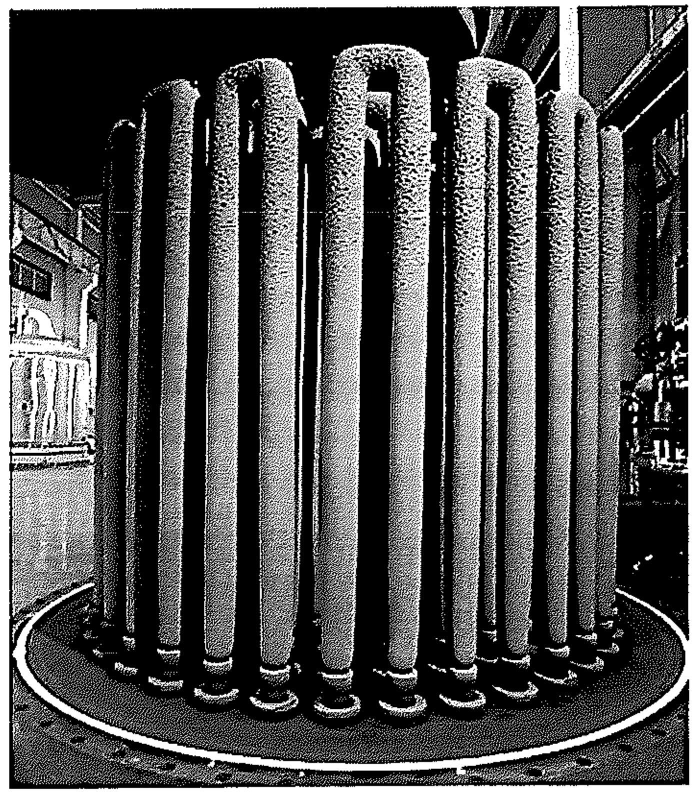
8. Polysilicon production

Metallurgical grade silicon (mg-Si) from the smelter is only about 99% pure, so it must undergo two more energy-intensive processes before it can be made into solar cells. First, **the Siemens Process converts (mg-Si) from the smelter into polycrystalline silicon (called polysilicon)** by a high-temperature vapor deposition process.

This is a bit like "growing rock candy" on hyper-pure silicon "strings" inside a pressurized-gas filled "bell-jar" reactor. As a mixture of silicon gas (made from mg-Si) and hydrogen gas passes through the reactor vessel, some of the silicon gas molecules "cling" to the electrically heated "strings" (called filaments) causing them to grow into "rods" of 99.9999% pure (or better) polysilicon.



Left: When heated to around 1100°C the polysilicon "filaments" standing beneath the reactor cover can "catch" about 20% of the silicon atoms that pass through the reactor in gaseous form. Right: Polysilicon "rods" after 5 days of growth. (Siemens AG)



Each batch of polysilicon "rods" takes several days to grow, and a continuous, 24/7 supply of electricity to each reactor is essential to prevent a costly "run abort." So **polysilicon refineries** depend on highly reliable conventional power grids, and usually have two incoming high-voltage supply feeds.

A polysilicon plant consumes ~1.6 - 6 t of incoming mg-Si, and requires at least **175 MWh** (or more) of **additional electricity** per ton of polysilicon produced - **about 10 times the energy already used for smelting** each ton of mg silicon from ore. [11] After the rods are removed from the reactor, they are sawed into sections or broken into "chunks" for loading into crucibles in the next step.

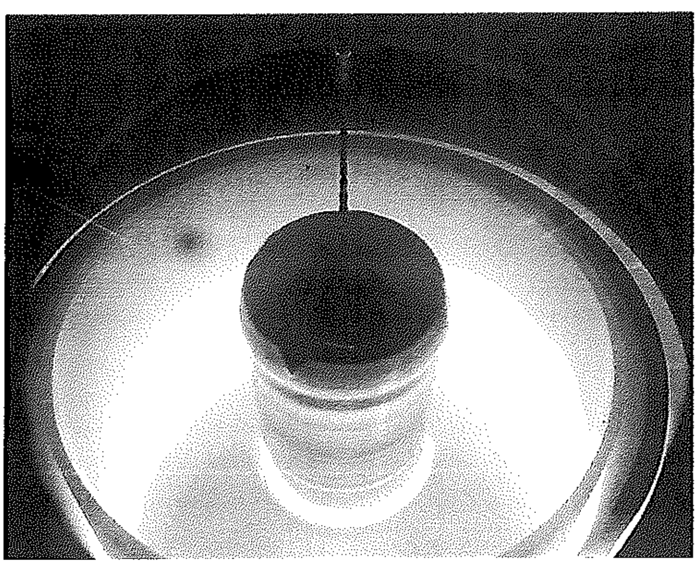
Polysilicon rods and sections being broken into chunks by hand in a clean room. (Hemlock)

Polysilicon chunks being heated in a crucible. When melted, a single crystal will be pulled out of the liquid polysilicon. (Getty)

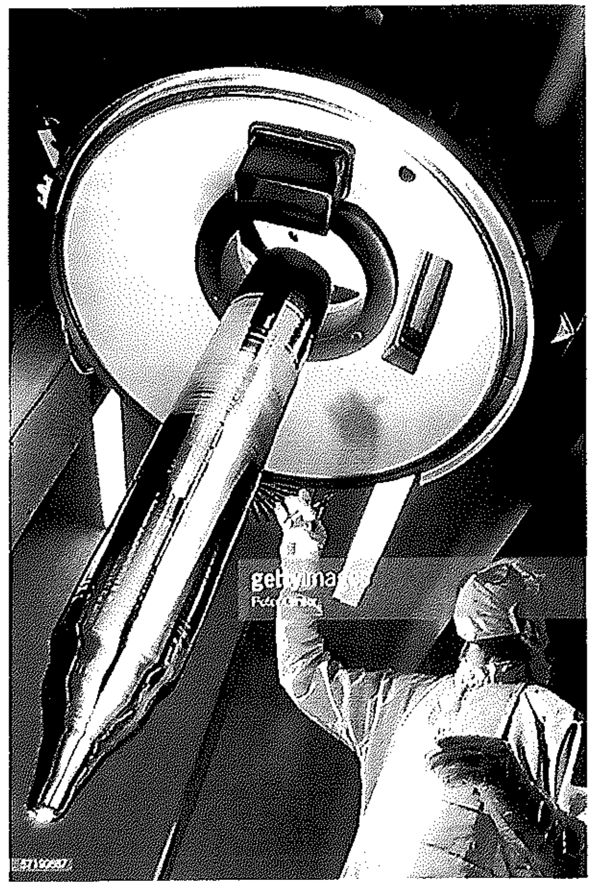
9. Crystal growing (ingot production)

For making single-crystal solar cells (called mono PV) the PV industry uses the **Czochralski process to further purify the polysilicon, and align the silicon molecules into a single-crystal form.**

First, polysilicon chunks are melted in a rotating crucible in an inert atmosphere. Then a small seed crystal of silicon is lowered into the molten polysilicon. As the seed crystal is slowly withdrawn, a single silicon crystal forms from the tip of the seed. As the crucible turns, the polysilicon continues to grow into a cylindrical ingot, leaving most of the non-silicon impurities behind in the 5-10% of "pot scrap" remaining after the crystal is drawn free.

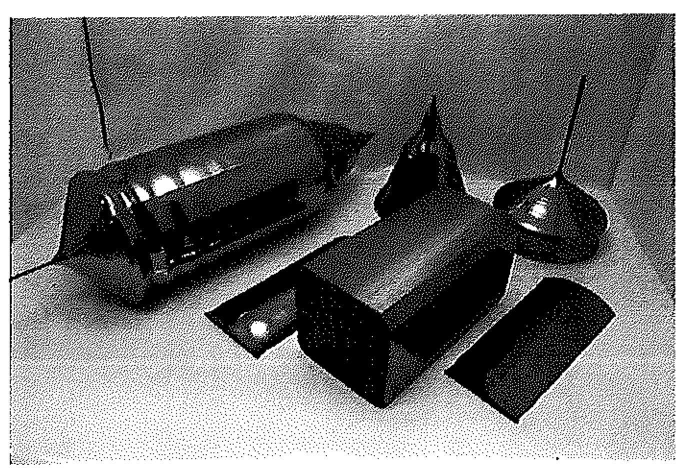


Czochralski ingot being pulled from melted polysilicon. (Image source: Siltronix)



Czochralski ingot after cooling (Image source: Getty)

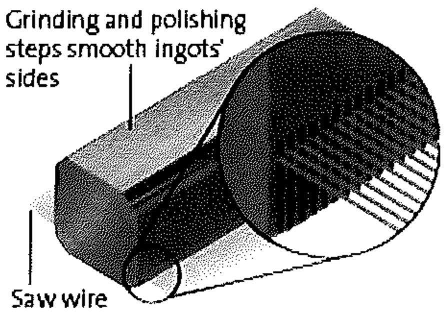
This process requires several days, and uninterrupted power. An ingot/wafer/cell plant can use more than 100 MWh additional energy per ton of incoming polysilicon, about 6 times as much as the original smelting of the silicon from ore. After slow cooling, the ingot's unusable crown and tail are cut off (about 10%), the center is then ground down, the four "chords" (long sides) are sawn off (about 25%) leaving a rectangular "brick" so the solar wafers will be almost square after slicing.



Czochralski process whole ingot (left), and brick and chords after sawing (right), crown and tail (upper right) (SVM)

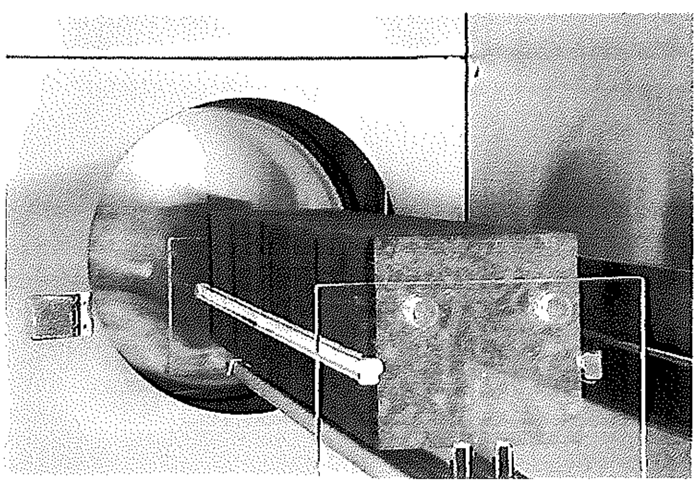
For multi-crystalline cells (called multi PV) polysilicon is melted in rectangular quartz molds, then allowed to cool slowly into a rectangular ingot of multi-crystalline silicon. which is trimmed to remove unusable portions, then sliced into bricks.

10. Wafer sawing
Then, like a loaf of bread, the silicon "bricks" are sliced with wire saws into thin wafers, which will later be processed into cells.



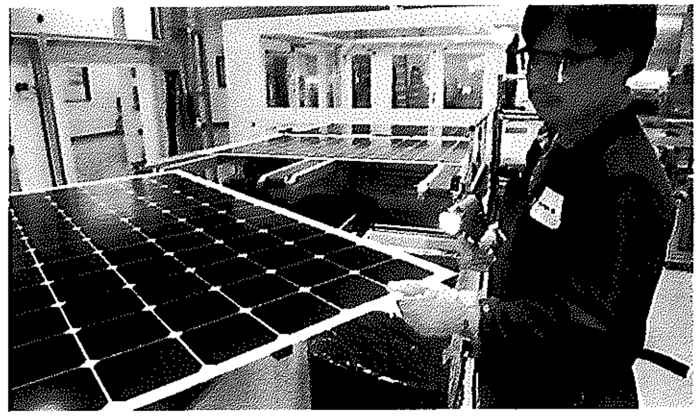
About half of the "brick" is lost as "sawdust" in the wafer slicing process, and this can't be recovered. So, after all of the energy and materials that have gone into making each "brick", much of the incoming polysilicon does not ever become finished wafers. Some of the heads, tails, chords, and trimmings can be etched (to remove contamination) and remelted **using additional energy** if the purity of the scrap is sufficient to justify the expense, otherwise they are discarded as waste.

11. Cell and module production.
Once the wafers are sliced, they are made into "cells" by adding layers of other materials and components in a series of additional production steps.



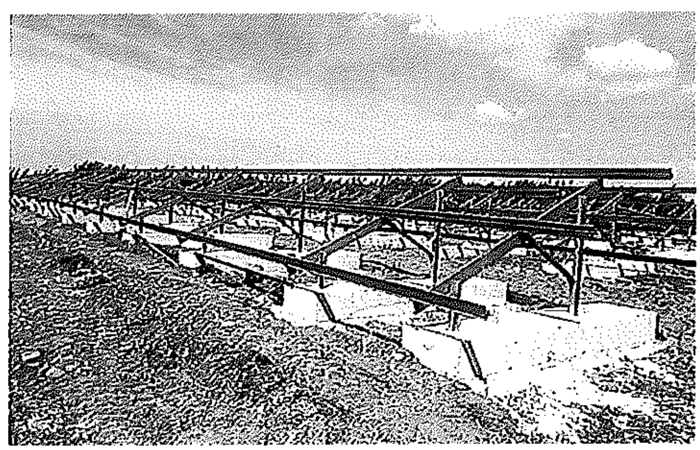
Diffusion Furnace in the PV-TEC at Fraunhofer ISE. Loading of the diffusion tubes with batches of multicrystalline silicon wafers. The wafers, sorted into quartz boats, are brought into the (up to) 1000 °C hot quartz tubes. (Fraunhofer ISE)

Then the cells are assembled into modules. Beside silicon wafers, most solar PV modules also require many other energy-intensive materials - aluminum (for the frame), silver, copper, glass, plastic, highly toxic rare earth metals, acids, and dozens of other chemicals for processing the polysilicon into cells and modules. A lot of electricity is needed to power the cell production and module assembly, **a supply of natural gas** is used to provide heat in the process.



Solar module inspection on the assembly line. (Solar World)

12. Other materials and steps
Once the modules are made, the whole PV system usually needs steel or aluminum framing, concrete, and some empty land (or a rooftop) to position it securely toward the sun, a lot of wiring to connect (through DC/AC inverters and transformers) to the existing power grid, or directly to battery banks,



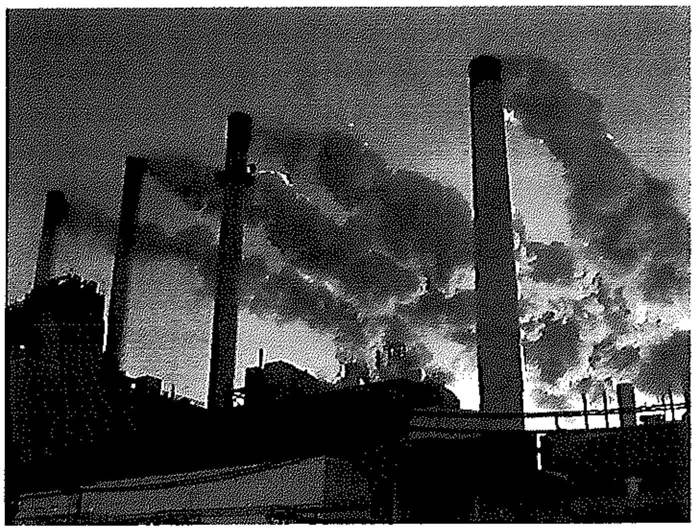
PV support structure and concrete foundation (Hill & Smith)

Of course, it takes **a lot of energy and resources** to make steel, aluminum, concrete, inverters, copper wiring, and all of these other materials. In many cases, the "balance of system" components in a PV installation can require as much (or more) "up-front" resources and energy to make as the modules. **[21]**

In addition, the amount of fossil fuels and non-renewable resources needed to construct and maintain new PV production infrastructure (smelters, polysilicon refineries, etc.) is considerable, but has been excluded from all "life cycle analysis" (LCA) of solar PV production by definition. [38]

13. Transportation

Throughout the solar PV manufacturing process all of the materials and products must be shipped **to and from more than a dozen countries** around the world in large barges, container ships, trains, or trucks - **all powered by non-renewable oil. [36]**



14. Power

Worldwide, only a few silicon smelters, like those in Norway, are powered primarily by hydro-electricity. Elsewhere, the current majority of smelters, polysilicon refineries, ingot growers, cell and module factories are running on grids **powered mostly by fossil fuels and uranium.** At present, more than 50% of all solar silicon is made in China, where the industrial grid is powered largely by fossil fuels, primarily low-grade coal. Depending on the "energy mix" available, the quantity of coal, coke, or gas that is being burned to deliver power 24/7 to the PV factories may be far greater than the amount needed as the carbon source for smelting silicon. To provide a realistic assessment of the total environmental impact of PV manufacturing, this **must be added to the "fossil fuel bill"** for solar PV production - along with the "embodied energy" of PV factories. **[11][12][21]**

15. Conclusions

Every step in the production of solar photovoltaic (PV) power systems requires a perpetual input of fossil fuels - as carbon reductants for smelting metals from ore, for process heat and power, international transport, and deployment. Silicon smelters, polysilicon refineries, and crystal growers around the world all depend on uninterrupted, 24/7 power that comes mostly from coal and uranium. **The only "renewable" materials consumed in PV production are obtained by deforestation** - for wood chips, and by burning vast areas of tropical rainforest for charcoal used as a source of carbon for silicon smelters. So far, both **media and journal claims** that solar PV can somehow "replace fossil fuels" **have not addressed the non-renewable reality of global supply chains** necessary for mining, manufacturing, and distribution of PV power systems. Based on current world production levels of solar PV, an attempt to replace conventional electricity production with solar PV would require a **dramatic increase in the amount of coal and petcoke needed for silicon smelting**, along with the **increased cutting of vast areas of forest** for charcoal and wood chips.

Readers are encouraged to **examine all of the references below**, to become aware of other aspects with solar pv manufacturing and deployment that are beyond the scope of this paper.

References

[1] Thorsil (2015) "Metallurgical Grade Silicon Plant - Helguvík, Reykjanes municipality (Reykjanesbær), Reykjanes peninsula, Iceland Environmental Impact Assessment (EIA) Capacity: 110,000 tons" https://www.giek.no/getfile.php/133565/web/Dokumenter/Prosjekter%20under%20vurdering/EIA-Thorsil_Lingua-2-%20konsekvensutredning.pdf (1) "Thorsil's initial assessment report was based on using...**Coal from El Cerrajon in Columbia**...for an annual production...of 110,000 tpy [of mg-Si]...**would correspond to 605,000 tpy of carbon dioxide...The Environment Agency feels that...such exhaust would significantly increase Iceland's overall emissions"**

[2] Efla (2013) "Environmental Impact Assessment of a SILICON METAL PLANT AT BAKKI IN HÚSAVÍK"https://www.agaportal.de/_Resources/Persistent/856d55b1a3c1948e5f856f800195760741faa93b/eia_island_silizium.pdf (2) "The main raw materials used for the production of Silicon Metal are quartzite... **coals (mainly from [Cerrejón] Columbia, Venezuela, and USA)**, charcoal, wood chips"

[3] "New York State Department of Environmental Conservation - Facility DEC ID: 9291100078 PERMIT Under the Environmental Conservation Law (ECL) Permit Issued To: GLOBE METALLURGICAL INC" http://www.dec.ny.gov/dardata/boss/afs/permits/929110007800009_r3.pdf **(3) "Globe Metallurgical produces high purity silicon metal...The facility is a major source of emissions of sulfur dioxide, carbon monoxide, hydrogen chloride and nitrogen oxides...** "The submerged electric arc process is a reduction smelting operation...**Reactants consisting of coal, charcoal, petroleum coke, or other forms of coke, wood chips, and quartz are mixed and added at the top of each furnace... At high temperatures in the reaction zone, the carbon sources react with silicon dioxide and oxygen to form carbon monoxide and reduce the ore to the base metal silicon."**

[4] "The Use and Market for WOOD in the ELECTROMETALLURGICAL Industry" https://www.fs.usda.gov/treesearch/pubs/23800 (4) [woodchips are used in smelters]...**to provide a large surface area for chemical reaction to take place more completely and at improved rates...To maintain a porous charge, thereby promoting gentle and uniform - instead of violent - gas venting**...To help regulate smelting temperatures...To keep the furnace burning smoothly on top...To reduce conductivity...To promote deep electrode penetration...To prevent bridging, crusting, and agglomeration of the mix...To reduce dust, metal vapor, and heat loss; and as a result to improve working conditions near the furnace.

[5] Healy, N., Stephens, J. C., & Malin, S. A. (2019). "Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains." *Energy Research & Social Science*, *48*, 219-234. (link) (5)"**Cerrejón is one of the world's largest open-pit coal mines [supplying silicon manufacturers]**...energy extraction often entails the physical displacement of populations or the "slow violence" of landscape destruction, water contamination and livelihood disruption"

[6] What Terrible Injustices Are Hiding Behind American Energy Habits? By Itai Vardi • Friday, November 16, 2018 (link) (6) **"There is a clear 'consumer blindness' and citizens and residents are often unaware of where the fuel they consume is coming from** and what injustices were inflicted on communities within those sites of fossil fuel extraction," said Healy. "Exposing these **injustices of energy 'sacrifice zones' — like [the Cerrejón open-pit coal mine] in La Guajira, Colombia ...—** could be critical for future energy policy decision-making."

[7] 2017/06/18/why-this-part-of-coal-country-loves-solar-power-215272 (7)**"the seam in Whitley County [Kentucky] is an even more valuable variety of metallurgic coal known as "blue gem."..."You need the blue gem to make the solar panels, and that's what people don't know,"** Moses told me, articulating a simple truth: **"Without Coal Valley, there's no Silicon Valley"**

[8] **https://www.prnewswire.com/news-releases/new-colombia-resources-inc-discovers-huge-new-metallurgical-coal-seam-at-their-property-in-colombia-as-the-company-prepares-to-begin-production-while-coal-prices-continue-to-soar-600823111.html** (8) "Colombian coal accounts for close to 75% of coal imports to the U.S... New Colombia Resources' Blue Gem coal is only found on the KY-TN border and central Colombia and is used to produce specialty metals **such as Silicon to make solar panels**, electric car batteries, and many more next generation products"

[9] https://carnegietsinghua.org/2015/05/31/managing-china-s-petcoke-problem-pub-60023 **(9) "Figure 5. [graph] Chinese Petcoke Consumption by Sector (2013 silicon=6%) (2014 silicon=7%)** A significant share of the petcoke used in China [which was made in U.S. refineries] is imported from the United States, ..."According to the U.S. Energy Information Administration (EIA), **U.S. petcoke exports to China**... a staggering 7 million metric tons in 2013...accounting for nearly 75 percent of Chinese petcoke.

[10] Petroleum Coke: The Coal Hiding in the Tar Sands (10) "Because it is considered a refinery byproduct, **petcoke emissions are not included in most assessments of the climate impact of tar sands**"...

[11] https://www.sightline.org/2018/06/25/small-town-silicon-smelter-plan-tees-up-big-questions/ (11) "**these furnaces would have a voracious appetite for electricity: around 105 megawatts on a continuous basis, roughly the equivalent of 68,000 homes...the facility would demand more power than the dam could provide**....Producing one ton of silicon metal requires about six tons of raw materials...Nearby sawmills would send seven or eight trucks per day to deliver wood chips, which are integral to the smelting process...."**The smelting process requires a rare type of metallurgic coal known as "blue gem," ... Operations at the smelter would demand approximately 48,000 metric tons of coal per year—roughly 40 rail cars each month.**"

[12] https://siteselection.com/theEnergyReport/2009/apr/Wacker-Chemie/ (12) "A nuclear plant is 1200 megawatts. **Fully built out, [Wacker Polysilicon] could be a third of a nuclear plant [400 MW]**...Not everybody out there can handle that size of a load. We're selling the fact that we [TVA] have the reliability, and we have a very diverse portfolio across **coal, nuclear and hydro.**"

[13] Jungbluth, N., M. Stucki, R. Frischknecht, S. Büsser, and ESU-services Ltd. & Swiss Centre for Life Cycle Inventories. (2009) "Part XII photovoltaics." *Swiss Centre for Life Cycle Inventories* (link) (13) "An issue of concern... **is the use of charcoal in this [photovoltaic silicon] process that originates from Asia or South America and might have been produced from clear cutting rainforest wood**"

[14] Eikeland, Inger Johanne, B. Monsen, and Ingunn S. Modahl.(2001) "Reducing CO2 emissions in Norwegian ferroalloy production." *Greenhouse Gases in the Metallurgical Industries: Policies, Abatement and Treatment, (Met. Soc. CIM), Toronto* 325 . (link) (14) **Most of the charcoal used...[for silicon production]...is imported from Asia and South America.** The crude, traditional methods of charcoal making, which are still widely used in these continents, are inefficient and strongly pollute the environment."

[15] Nisgoski, Silvana & Muniz, Graciela & Morrone, Simone & Schardosin, Felipe & França, Ramiro. (2015). NIR and anatomy of wood and charcoal from Moraceae and Euphorbiaceae species. Revista Ciência da Madeira - RCM. 6. 183-190. 10.12953/2177-6830/rcm.v6n3p183-190. (link) (15) "**charcoal supply is still present in illegal cutting of native forests, which represented 30-35% of total output [in Brazil]**... charcoal consumption represents the deforestation of approximately 1.6 million hectares or 16.000 km^2 of the Cerrado Biome"

[16] 2017/10/burning-down-the-house-myanmars-destructive-charcoal-trade/ (16) "**Dehong's silicon industry ... "has caused a serious damage to forest resources,"** and estimated that "119,700 tons of charcoal were consumed in the production of industrial silicon in Dehong prefecture **in 2014... 31 square miles—"of forests were cut down. (...) In 2016, the [silicon] industry consumed nearly twice that amount** (216,273 tons of charcoal)

[17] BP Statistical Review of World Energy, 67th Edition, June 2018 (17) "despite the huge policy push encouraging a switch away from coal and the rapid expansion of renewable energy in recent years, **there has been no improvement in the mix of fuels feeding the global power sector over the past 20 years. Astonishingly, the share of coal in 2017 was exactly the same as in 1998. The share of non-fossil fuels was actually lower,** as growth in renewables has failed to compensate for the decline in nuclear energy."

[18] De Castro, Carlos, Margarita Mediavilla, Luis Javier Miguel, and Fernando Frechoso. "Global solar electric potential: A review of their technical and sustainable limits." *Renewable and Sustainable Energy Reviews* 28 (2013): 824-835. (link) (18) "**based on real examples...our results show that present and foreseeable future density power of solar infrastructures are much less (4–10 times) than most published studies**... an overview of the land and materials needed for large scale implementation show that many of the estimations found in the literature are hardly compatible with the rest of human activities."

[19] Koomey, J. G., Calwell, C., Laitner, S., Thornton, J., Brown, R. E., Eto, J. H., ... & Cullicott, C. (2002). Sorry, wrong number: The use and misuse of numerical facts in analysis and media reporting of energy issues. *Annual review of energy and the environment*, 27(1), 119-158. (link) (19) "Unfortunately, numbers that prove decisive in policy debates are not always carefully developed, credibly documented, or correct...**A common mistake in the media has been to apply this statistic (1000 homes per MW) to intermittent renewable power sources**...Intermittent renewables generally produce far fewer kilowatt-hours per MW than conventional power

plants...**this widely used equivalence between homes and MW should generally not be applied to intermittent renewables such as...PVs."**

[20] Shaner, Matthew R., Steven J. Davis, Nathan S. Lewis, and Ken Caldeira. (2018) "Geophysical constraints on the reliability of solar and wind power in the United States." *Energy & Environmental Science* 11, no. 4 (2018): 914-925 (link) **(20) "Achieving 99.97% reliability with a system consisting solely of solar and wind generation... would require** a storage capacity equivalent to several weeks of average demand...**Three weeks of storage (227 TW h) [which] results in ~6500 years of the annual Tesla Gigafactory production capacity** or a **~900x increase** in the pumped hydro capacity of the U.S."

[21] Carbajales-Dale, Michael, Charles J. Barnhart, and Sally M. Benson.(2014) "Can we afford storage? A dynamic net energy analysis of renewable electricity generation supported by energy storage." *Energy & Environmental Science* 7, no. 5 (2014): 1538-1544. (link) (21) **"PV technologies (CIGS and sc-Si)**...cannot 'afford' any storage while still supplying an energy surplus to society... **since they are already operating at a deficit**...These technologies require large, 'up-front' energetic investments...A fractional [energy] re-investment of greater than 100% ... means that **the industry consumes more electricity than it produces** on an annual basis, i.e. running an energy deficit"

[22] Milligan, M., Ela, E., Hein, J., Schneider, T., Brinkman, G., & Denholm, P. (2012). *Renewable Electricity Futures Study. Volume 4: Bulk Electric Power Systems: Operations and Transmission Planning* (No. NREL/TP-6A20-52409-4). National Renewable Energy Lab.(NREL), Golden, CO (United States). (link) (22) "although **RE Futures** describes the system characteristics needed to accommodate high levels of renewable generation, it **does not address the institutional, market, and regulatory changes that may be needed to facilitate such a transformation**...[and] **a full cost-benefit analysis was not conducted** to comprehensively evaluate the relative impacts of renewable and non-renewable electricity generation options.

[23] Lithium Ion batteries for Stationary Energy Storage - The Office of Electricity Delivery and Energy Reliability, Pacific Northwest National Laboratory **(23)** "Despite their success in mobile applications, **Li-ion technologies have not demonstrated sufficient grid-scale energy storage feasibility "**

[24] Lessons Learned Report - Electrical Energy Storage DOCUMENT NUMBER CLNR-L163 AUTHORS John Baker, James Cross, EA Technology Ltd, Ian Lloyd, Northern Powergrid PUBLISHED 08 December 2014 **(24) "The round trip efficiencies for the [Li-ion] EES systems have been calculated [in actual use]... between 41% and 69% where parasitic loads are included"**

[25] https://energy.stanford.edu/news/calculating-energetic-cost-grid-scale-storage **(25) "using the kind of lead-acid batteries available today to provide storage for the worldwide power grid is impractical."**

[26] Luque, A., & Hegedus, S. (Eds.). (2011). *Handbook of photovoltaic science and engineering.* John Wiley & Sons. (link) **(26) "Photovoltaics is polluting just like all high-technology or high-energy industries only with different toxic emissions** ... Manufacturing of PV modules on a large scale requires the handling of large quantities of hazardous or potentially hazardous materials (e.g. heavy metals, reactive chemical solutions, toxic gases"

[27] https://www.researchgate.net/publication/311440469_CO2_Emissions_from_the_Production_of_Ferrosilicon_and_Silicon_metal_in_Norway (27) "These emission factors only include CO2 emitted from fossil raw materials in the reduction process. **CO2 from biological, renewable sources is not included (according to joint agreement). Neither is CO2 emitted from electric power production or during transportation of raw materials."**

[28] Cleaning Up Clean Energy - https://web.stanford.edu/group/sjir/pdf/Solar_11.2.pdf **(28) "the (PV) industry has largely overlooked investigative reports revealing current problems with production waste,** particularly pertaining to Chinese manufacturing. Until these concerns receive more attention, **promises of panel recycling will quell any public anxiety, preventing the creation of necessary safeguards** to stop rogue firms from unsafe manufacturing practices"

[29] https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/#256668c121cc **(29) "We estimate there are 100,000 pounds of cadmium contained in the 1.8 million panels,"** Sean Fogarty of the group told me.

"Leaching from broken panels damaged during natural events – hail storms, tornadoes, hurricanes, earthquakes, etc. – and at decommissioning is a big concern."

[30] https://www.scmp.com/news/china/society/article/2104162/chinas-ageing-solar-panels-are-going-be-big-environmental-problem (30) Lu Fang, secretary general of the photovoltaics decision in the China Renewable Energy Society, wrote...**By 2050 these waste panels would add up to 20 million tonnes, or 2,000 times the weight of the Eiffel Tower**...Tian Min, general manager of Nanjing Fangrun Materials, a recycling company in Jiangsu province that collects retired solar panels, said **the solar power industry was a ticking time bomb."It will explode with full force in two or three decades and wreck the environment, if the estimate is correct,"**

[31] https://www.solarpowerworldonline.com/2018/04/its-time-to-plan-for-solar-panel-recycling-in-the-united-states/ (31) "We've conducted some toxicity testing on modules, and we have seen results showing that **the presence of lead is higher than the threshold allowed by the TCLP (toxicity characteristic leaching procedure)**...There is a potential for leaching of toxic materials such as lead in landfill environments. **If modules are intact, it's a low risk, but as soon as they're broken or crushed, then the potential for leaching is increased."**

[32] https://www.welt.de/wirtschaft/article176294243/Studie-Umweltrisiken-durch-Schadstoffe-in-Solarmodulen.html (32) "Based on installed power and performance weight, we can estimate that **by the year 2016, photovoltaics has spread about 11,000 tonnes of lead and about 800 tonnes of Cd (cadmium),**" the study said"

[33] https://www.solarpowerinternational.com/wp-content/uploads/2016/09/N253_9-14-1530.pdf (33) "disposal in "regular landfills [is] not recommended **in case modules break and toxic materials leach into the soil"** and so "disposal is potentially a major issue."

[34] Tao, Coby S., Jiechao Jiang, and Meng Tao. "Natural resource limitations to terawatt-scale solar cells." *Solar Energy Materials and Solar Cells* 95, no. 12 (2011): 3176-3180. https://doi.org/10.1016/j.solmat.2011.06.013 **"Material scarcity prevents most current solar cell technologies from reaching terawatt scales.** (...) Scarce materials in solar cells include indium, gallium, tellurium, ruthenium, and silver. - Natural resource limitations to terawatt-scale solar cells."

[35] Metal-demand-for-renewable-electricity-generation-in-the-netherlands **"The current global supply of several critical metals is insufficient to transition to a renewable energy system.** ...production of wind turbines and photovoltaic (PV) solar panels already requires a significant share of the annual global production of some critical metals... Furthermore, mining is often associated with significant environmental and social costs"

[36] INCREASES IN EFFICIENCY HAVE NOT REDUCED ABSOLUTE CO2 EMISSIONS FROM SHIPS **"Although the CO2 intensity of many major ship classes decreased (i.e., they became more efficient) from 2013 to 2015, total CO2 emissions from ships increased.** For example, although the CO2 intensity of general cargo ships (measured as emissions per unit of transport supply) decreased by 5%, CO2 emissions increased by 9% **Thus, increases in distance traveled due to a greater demand for shipping more than offset gains in operational efficiency during the period studied"**

[37] Kato, K., Murata, A., & Sakuta, K. (1998). Energy pay-back time and life-cycle CO2 emission of residential PV power system with silicon PV module. *Progress in Photovoltaics: Research and Applications*, *6*(2), 105-115.

[38] Fthenakis, V., Kim, H., Frischknecht, R., Raugei, M., Sinha, P., & Stucki, M. (2011). Life cycle inventories and life cycle assessment of photovoltaic systems. *International Energy Agency (IEA) PVPS Task*, *12*. http://www.clca.columbia.edu/Task12_LCI_LCA_10_21_Final_Report.pdf

Energy + Environment
Legislature

Grain Belt Express takes first resistant Missouri landowner to court

Progress on the $2 billion transmission line is accelerating as 65% of the route in Missouri and Kansas has been acquired voluntarily

By: Lukas Vanacker - December 21, 2021 12:00 pm

Evergy's Flat Ridge Wind Farm in Kansas (photo submitted).

A $2 billion wind energy project spanning the length of northern Missouri is for the first time asking a judge to force a resistant landowner to sell the company an easement on their land.

Grain Belt Express, a proposed high-voltage transmission line that would carry 4,000 megawatts of renewable energy from Western Kansas to Indiana, has faced fierce criticism from some Missouri landowners and elected officials.

In September, it filed a petition for condemnation against a farmer from Gower named Bradley Horn. A hearing in the case was originally scheduled last week in the Circuit Court of Buchanan County but was delayed until Feb. 2.

The company is arguing that Horn "did not accept the written offer for the property interests," and later "negotiations were unsuccessful." It marks the first time Grain Belt Express has taken a resistant landowner to court.

The judge can appoint three disinterested residents of the county, who have to assess the just compensation for Horn.

Horn's attorneys declined to comment.

Payments

When the Grain Belt Express got its approval from the Missouri Public Service Commission in 2019, the decision was criticized by some because it granted the private company the right to obtain easements through eminent domain.

Yet the company has always insisted it would only use that procedure as a last resort to acquire 1,700 parcels of land in Kansas and Missouri.

According to Patrick Whitty, vice president of the project's parent company, Invenergy Transmission, Grain Belt Express has "now completed right-of-way acquisition through voluntary easement agreements for approximately 65% of the route in Missouri and Kansas, compared to only one third completed at the start of

the year."

At the beginning of this year, the company had made payments of $4.9 million to landowners in Missouri combined. As it stands today, that figure is $8.5 million.

Grain Belt Express offers landowners compensation of 110% of the market value of land, plus $18,000 per tower structure. That offer was recently increased, Whitty said, to reflect "rising farmland values." For example, one farmer from Madison in northeast Missouri was offered $98,000 to allow two tower structures on nine acres of cropland.

Donna and Kenneth Inglis, a retired couple from Huntsville, were happy to close a deal with Grain Belt Express a year ago.

"I strongly support the project because I strongly believe in green energy," Donna Inglis said. "If our ancestors wouldn't have accepted rural electricity, we would still be working with kerosine lamps."

Inglis didn't want to disclose the details of the financial offer, but she said "it's a lot of money."

However, while some landowners are more than willing to grant the company access to their land, others continue to resist the transmission structures, which are 40 feet by 40 feet wide and between 130 to 160 feet tall.

"Some people have been farming here for more than 100 years," says Marilyn O'Bannon, western district commissioner in Monroe County. "Their land is their heritage. And now, they want to build something through the middle of our land, next to an existing electricity line. We can't farm efficiently around obstacles. And show me where the value for our state is."

O'Bannon's family owns land on the future transmission line. Whereas Inglis praises the professionalism of Grain Belt Express agents, O'Bannon says there has been a lack of transparency.

"The potential dangers and unknowns as well as lack of project details are overwhelming," O'Bannon said. "Landowners are left in the dark as long as possible. I can't describe the emotional impact."

Risks

The road ahead to complete the Grain Belt Express project remains long and bumpy.

In the summer of 2020, Invenergy announced the transmission line would deliver more energy to Missouri than originally anticipated, doubling its investment in the state to $1 billion.

The Public Service Commission still has to approve the extended plan. And after years of litigation and regulatory proceedings involving the project, that could once again stir up opposition to the transmission line.

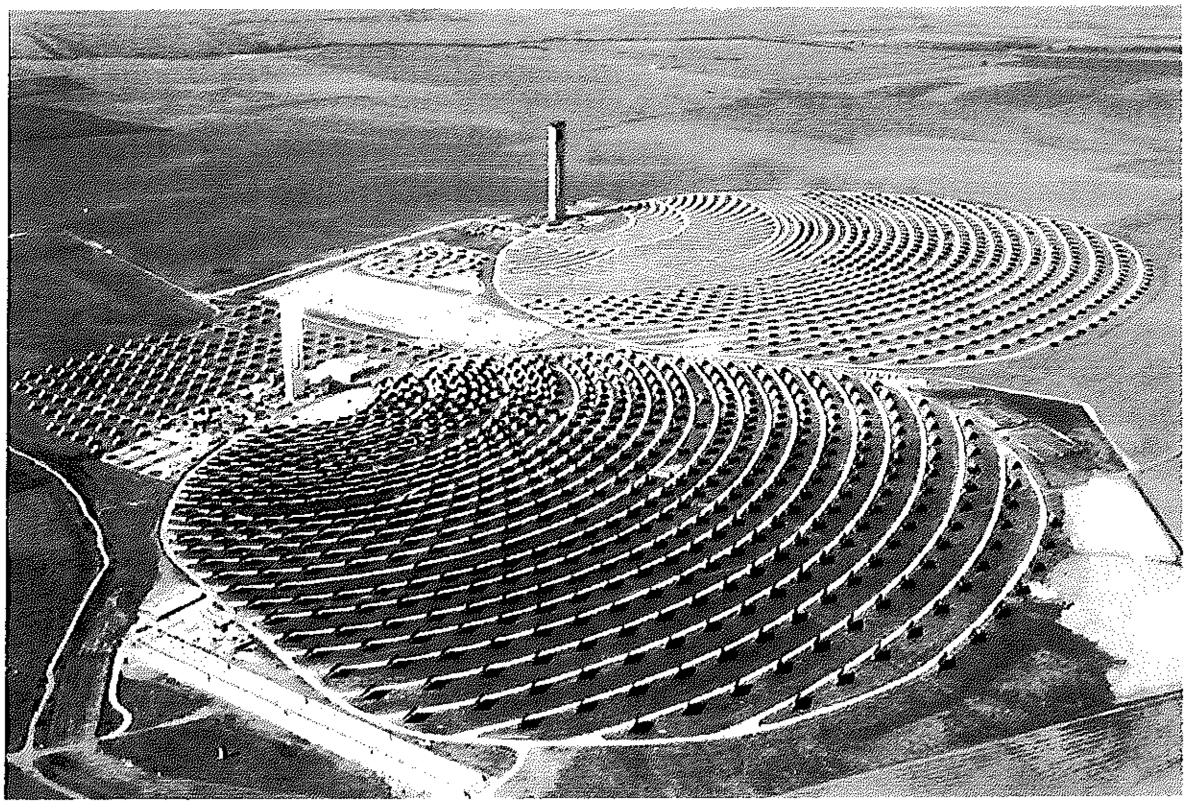
It could also fuel continued efforts by Grain Belt Express critics to push Missouri lawmakers to pass legislation undermining the project.

Earlier this year, a bill requiring that Grain Belt Express gets resolutions of support from county commissions in each of the counties in the project's path cleared the Missouri House but died in the Senate.

This story has been updated since it originally published.

Analysis: 41 Inconvenient Truths on the "New Energy Economy"

Heartland Author August 19, 2022 2



By Mark P. Mills

A week doesn't pass without a mayor, governor, policymaker or pundit joining the rush to demand, or predict, an energy future that is entirely based on wind/solar and batteries, freed from the "burden" of the hydrocarbons that have fueled societies for centuries. Regardless of one's opinion about whether, or why, an energy "transformation" is called for, the physics and economics of energy combined with scale realities make it clear that there is no possibility of anything resembling a radically "new energy economy" in the foreseeable future. Bill Gates has said that when it comes to understanding energy realities "we need to bring math to the problem."

He's right. So, in my recent Manhattan Institute report, "The New Energy Economy: An Exercise in Magical Thinking," I did just that.

Herein, then, is a summary of some of the bottom-line realities from the underlying math. (See the full report for explanations, documentation, and citations.)

Realities About the Scale of Energy Demand

1. Hydrocarbons supply over 80 percent of world energy: If all that were in the form of oil, the barrels would line up from Washington, D.C., to Los Angeles, and that entire line would grow by the height of the Washington Monument every week.

2. The small two-percentage-point decline in the hydrocarbon share of world energy use entailed over $2 trillion in cumulative global spending on alternatives over that period; solar and wind today supply less than two percent of the global energy.

3. When the world's four billion poor people increase energy use to just one-third of Europe's per capita level, global demand rises by an amount equal to twice America's total consumption.

4. A 100x growth in the number of electric vehicles to 400 million on the roads by 2040 would displace five percent of global oil demand.

5. Renewable energy would have to expand 90-fold to replace global hydrocarbons in two decades. It took a half-century for global petroleum production to expand "only" ten-fold.

6. Replacing U.S. hydrocarbon-based electric generation over the next 30 years would require a construction program building out the grid at a rate 14-fold greater than any time in history.

7. Eliminating hydrocarbons to make U.S. electricity (impossible soon, infeasible for decades) would leave untouched 70 percent of U.S. hydrocarbons use—America uses 16 percent of world energy.

8. Efficiency increases energy demand by making products & services cheaper: since 1990, global energy efficiency improved 33 percent, the economy grew 80 percent and global energy use is up 40 percent.

9. Efficiency increases energy demand: Since 1995, aviation fuel use/passenger-mile is down 70 percent, air traffic rose more than 10-fold, and global aviation fuel use rose over 50 percent.

10. Efficiency increases energy demand: since 1995, energy used per byte is down about 10,000-fold, but global data traffic rose about a million-fold; global electricity used for computing soared.

11. Since 1995, total world energy use rose by 50 percent, an amount equal to adding two entire United States' worth of demand.

12. For security and reliability, an average of two months of national demand for hydrocarbons are in storage at any time. Today, barely two *hours* of national electricity demand can be stored in all utility-scale batteries plus all batteries in one million electric cars in America.

13. Batteries produced annually by the Tesla Gigafactory (world's biggest battery factory) can store three *minutes* worth of annual U.S. electric demand.

14. To make enough batteries to store two day's worth of U.S. electricity demand would require 1,000 years of production by the Gigafactory (world's biggest battery factory).

15. Every $1 billion in aircraft produced leads to some $5 billion in aviation fuel consumed over two decades to operate them. Global spending on new jets is more than $50 billion a year—and rising.

16. Every $1 billion spent on data centers leads to $7 billion in electricity consumed over two decades. Global spending on data centers is more than $100 billion a year—and rising.

Realities about Energy Economics

17. Over a 30-year period, $1 million worth of utility-scale solar or wind produces 40 million and 55 million kWh respectively: $1 million worth of shale well produces enough natural gas to generate 300 million kWh over 30 years.

18. It costs about the same to build one shale well or two wind turbines: the latter, combined, produces 0.7 barrels of oil (equivalent energy) per hour, the shale rig averages 10 barrels of oil per hour.

19. It costs less than $0.50 to store a barrel of oil, or its equivalent in natural gas, but it costs $200 to store the equivalent energy of a barrel of oil in batteries.

20. Cost models for wind and solar assume, respectively, 41 percent and 29 percent capacity factors (i.e., how often they produce electricity). Real-world data reveal as much as ten percentage points less for both. That translates into $3 million less energy produced than assumed over a 20-year life of a 2-MW $3 million wind turbine.

21. In order to compensate for episodic wind/solar output, U.S. utilities are using oil- and gas-burning reciprocating engines (big cruise-ship-like diesels); three times as many have been added to the grid since 2000 as in the 50 years prior to that.

22. Wind-farm capacity factors have improved at about 0.7 percent per year; this small gain comes mainly from reducing the number of turbines per acre leading to a 50 percent increase in average land used to produce a wind-kilowatt-hour.

23. Over 90 percent of America's electricity, and 99 percent of the power used in transportation, comes from sources that can easily supply energy to the economy any time the market demands it.

24. Wind and solar machines produce energy an average of 25 percent–30 percent of the time, and only when nature permits. Conventional power plants can operate nearly continuously and are available when needed.

25. The shale revolution collapsed the prices of natural gas & coal, the two fuels that produce 70 percent of U.S. electricity. But electric rates haven't gone down, rising instead 20 percent since 2008. Direct and indirect subsidies for solar and wind consumed those savings.

Energy Physics... Inconvenient Realities

26. Politicians and pundits like to invoke "moonshot" language. But transforming the energy economy is not like putting a few people on the moon a few times. It is like putting all of humanity on the moon—permanently.

27. The common cliché: an energy tech disruption will echo the digital tech disruption. But *information*-producing machines and *energy*-producing machines involve profoundly different physics; the cliché is sillier than comparing apples to bowling balls.

28. If solar power scaled like computer-tech, a single postage-stamp-size solar array would power the Empire State Building. That only happens in comic books.

29. If batteries scaled like digital tech, a battery the size of a book, costing three cents, could power a jetliner to Asia. That only happens in comic books.

30. If combustion engines scaled like computers, a car engine would shrink to the size of an ant and produce a thousand-fold more horsepower; actual ant-sized engines produce 100,000 times less power.

31. No digital-like 10x gains exist for solar tech. Physics limit for solar cells (the Shockley-Queisser limit) is a max conversion of about 33 percent of photons into electrons; commercial cells today are at 26 percent.

32. No digital-like 10x gains exist for wind tech. Physics limit for wind turbines (the Betz limit) is a max capture of 60 percent of energy in moving air; commercial turbines achieve 45 percent.

33. No digital-like 10x gains exist for batteries: maximum theoretical energy in a pound of oil is 1,500 percent greater than max theoretical energy in the best pound of battery chemicals.

34. About 60 pounds of batteries are needed to store the energy equivalent of one pound of hydrocarbons.

35. At least 100 pounds of materials are mined, moved and processed for every pound of battery fabricated.

36. Storing the energy equivalent of one barrel of oil, which weighs 300 pounds, requires 20,000 pounds of Tesla batteries ($200,000 worth).

37. Carrying the energy equivalent of the aviation fuel used by an aircraft flying to Asia would require $60 million worth of Tesla-type batteries weighing five times more than that aircraft.

38. It takes the energy equivalent of 100 barrels of oil to fabricate a quantity of batteries that can store the energy equivalent of a single barrel of oil.

39. A battery-centric grid and car world means mining gigatons more of the earth to access lithium, copper, nickel, graphite, rare earths, cobalt, etc.—and using millions of tons of oil and coal both in mining and to fabricate metals and concrete.

40. China dominates global battery production with its grid 70 percent coal-fueled: EVs using Chinese batteries will create *more* carbon-dioxide than saved by replacing oil-burning engines.

41. One would no more use helicopters for regular trans-Atlantic travel—doable with elaborately expensive logistics—than employ a nuclear reactor to power a train or photovoltaic systems to power a nation.

Mark P. Mills is a senior fellow at the Manhattan Institute, a McCormick School of Engineering Faculty Fellow at Northwestern University, and author of Work in the Age of Robots, published by Encounter Books.

For more the Green New Deal, click here and here.

Commissioner Glen Kolkmeyer
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August 22,2022

My husband and I have been grain farmers in Central Missouri, since 1976. We have worked very hard, struggled through 1980's, managed to pay our loans, taxes and farm payments on time. We have also been good stewards of the land. On July 12, 2022 we received a letter in the mail from a company called Invenergy Transmission, based out of Chicago, IL informing us that they had plans to possibly run a 140 x 140 ft electric transmission towers through our farm. This notice was very upsetting for us. The towers would ruin our farm, the property would be devalued and there is no amount of money to compensate us for the permanent loss. We went to their public meeting, we asked a lot of questions and received very few straightforward answers. We left the meeting feeling frustrated and determined to do our homework; to find out as much as we could. The first thing we learned is there are lots of groups all over Missouri that have organized to fight Invenergy and companies like them. There are also lots of other states that are being impacted and resisting their plans. We attended the Audrain County landowner meeting, where Presiding Commissioner, Wiley Hibbard, said "Invenergy Transmission has no money yet, they are waiting for government subsidy." Lynn Thompson, General Manager at Consolidated Electric Cooperative of Mexico, MO told us they have no interest in purchasing the Invenergy's energy. Consolidated is one of the cooperatives in the Associated Electric Cooperative group, they service over 2 million people in Missouri, Iowa and Oklahoma, they will be forced to let Invenergy hook up to their substation. I believe this is an intrusion on the amazing system that already exists here in our area. We have very reasonable electric rates. Invenergy has filed several condemnations (taking) court cases against landowners who refused to sign an easement. Sure, doesn't sound like the friendly, we'll-work-it-with-you -company they try to portray. They are taking land by force, even though they don't have an approved route and interconnection, or enough customers to make the project economic! What country do we live in? China? I can't imagine how devastating the proud farmers and families I know are feeling about this. Where is their protection? Since they have not gotten enough customers for the Grain Belt Express and Illinois will not let them come through their state, why are you even considering letting them have permission to make the Tiger Connection here in Audrain and Callaway? By the way, it sounds like the Illinois commissioners are protecting their farm landowners.

Keryn Newman, Stoppathwv.com, reports MJMEUC agreed purchase a very small amount of capacity (up to 200 MW) at a loss leader price below GBE's (Grain Belt Express) cost to provide the service. MJMEUC only agreed because it was basically getting something for free, but it was also a very small portion of the available capacity. Since then, GBE has not found any other customers. Nobody wants to buy their service still. In order to be viable GBE needs permission to connect it's 4000 MW transmission project to the existing electric grid. After 10 years, why are we still having this discussion? Looks obvious to me the people of Missouri and the electric cooperatives do not want their kind of power. It is my opinion that intermittent power is not practical because it cannot sustain itself, it relies on the consistent AC energy from coal power and natural gas. The average electric energy produced from solar is 20-30% because of daylight. If we are forced to take payment for the easement on our land, that money is considered capital gains, therefore we would have an added burden at tax time. If Invenergy

does come down to the McCredie substation, they would have to add a second substation to convert their DC electric coming from the solar panels to AC. I repeat; they must have a backup energy source so if their so-called green energy goes dark because of clouds, snow and nighttime. I don't have to tell you that the peak demands for electricity is what causes our electric to rates go up! The government is printing money to pay for these expensive wind turbines and solar farms and high transmission towers. We the taxpayers will get changed for that as well! What I have been told is most of the energy produced isn't even for Missouri. So why are we ruining prime farmland in Missouri for another state to use? Isn't it your job to protect us? And understand, your family will be paying more too. This going to affect every electric consumer and business in the state. Commissioner Kolkmeyer please allow the citizens affected a chance to share with you, their concerns, consider having one or two hearings to give people a chance to share their opinion with you. We heard a healthcare provider worried about the tower lines emitting EMF's (Electric Magnetic Frequencies) and EMR's (Electric Magnetic Radiation) she believes they will be harmful to our health. Another farmer and his wife are worried that the towers will interfere with the radio and cell service. We don't know what side effects of living near these transmission towers will be. We do know it will forever ruin the beauty of the country side that we all love so much. As a farmer works his land, the towers will be a constant pain when he works the ground near them. He will have to be extra careful when using his large equipment, his drones for spraying, the hired helicopters and small planes. He won't be able to irrigate his land near the towers. As I said it will certainly devalue the land, no one wants to build their home near a high tower electric line, there is not enough money to compensate us. According to the Constitution, it protects We the People, from an unregulated merchant like Invenergy from using eminent domain. Granting eminent domain authority to an unregulated merchant for speculative projects that may never be placed in service violates the Fifth Amendment's requirement that property taken for public use. Looks to me like CEO Michael Polsky will be the one that gains the most from this project if it goes through. Protect the landowners and the non-profit utility companies from the unregulated merchant that only care about money. I am trusting you to do the right thing for We the People. I have not heard one person that is in favor of this project. Their proposal cuts right through prime Missouri farmland acres that are presently producing crops for ethanol and biodiesel. Both of them are helping to reduce the fuel emissions in St. Louis, Columbia and Kansas City; truly renewable fuels.

We are asking you Commissioner Kolkmeyer and the other commissioners to deny Invenergy's extravagant filing on the grounds that they have not proven demand for their energy; they have not told us who their customers are and their energy is not cost effective for this area and definitely not wanted. Thank you for your time, I have included some supporting information that backs up my request.

Why do we burn coal and trees to make solar panels?

Thomas A. Troszak (2019/11/14 revision)

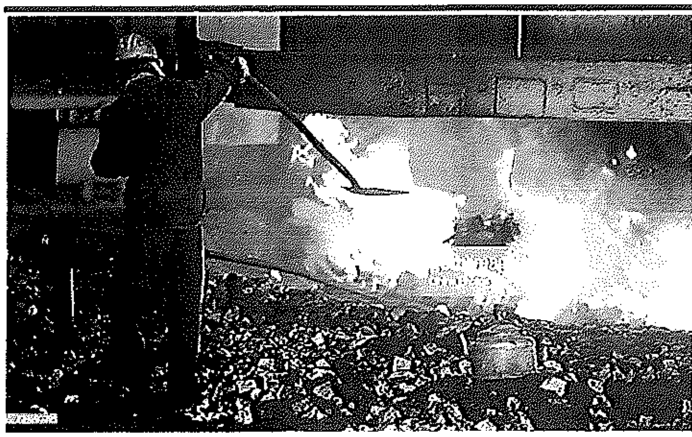


Figure 1. Workman shovels coal and lumpy quartz (silicon ore) into a silicon smelter in China. (photo: Getty)

1. Most commercial solar PV modules use *photovoltaic cells* (solar cells) made from highly purified silicon (Si).

Since the early 1900s, silicon "metal" is reduced from quartz using **carbon** in submerged-arc furnaces, each powered by up to 45 megawatts* of electricity. (Fig 1,2)

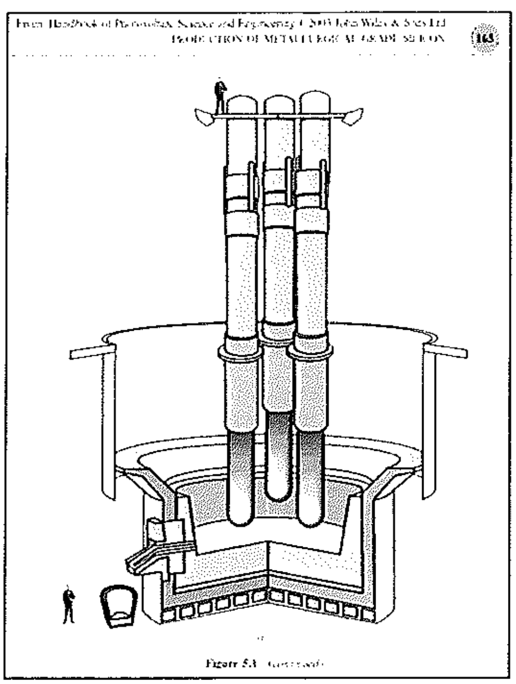


Figure 2. Diagram of a silicon smelter showing the three giant carbon electrodes that provide arc temperatures > 3,000°F for smelting quartz into "metallurgical grade" silicon (mg-Si) using carbon as a reductant. (John Wiley and Sons, Ltd.)

2. Why do we need to burn carbon to make solar PV? - Elemental silicon (Si) can't be found by itself anywhere in nature. It must be extracted from quartz (SiO_2) using **carbon (C)** and heat (from an electric arc) in the "carbothermic" **(carbon+heat)** reduction process called "smelting." **($SiO_2 + 2C = Si + 2CO$)** Several **carbon sources** are used as **reductants** in the silicon smelting plant, which requires ~20 MWh/t of electricity, and releases CO - resulting in up to 5 - 6 t of CO_2 produced per ton of metallurgical grade (mg-Si) silicon smelted. [1] Thus, **the first step** of solar PV production is gathering, transporting, and **burning millions of tons of coal, coke and petroleum coke - along with charcoal and wood chips** made from hardwood trees - to smelt >97% pure mg-Si from quartz "ore" (silica rocks). [1][2][3][4][5][6][7][8][9][10]

***45 megawatts (MW) is enough for a small town (about 33,000 homes).**

Figure 3. Pouring liquid metallurgical grade (~99% pure) silicon into molds, to cool into silicon "metal". (Getty)

3. Even more fossil fuels are burned later, to generate electricity for the polysilicon, ingot, wafer, cell, and module production steps shown. [21] As a result of all these processes, the solar PV industry generates megatons of CO and CO_2. But as shown below (fig 4), some often-cited descriptions of solar module production **omit the raw materials and smelting process from the PV supply chain** which obscures the use of fossil fuels and the vast amount of deforestation necessary for solar PV production. [1][3][9][27]

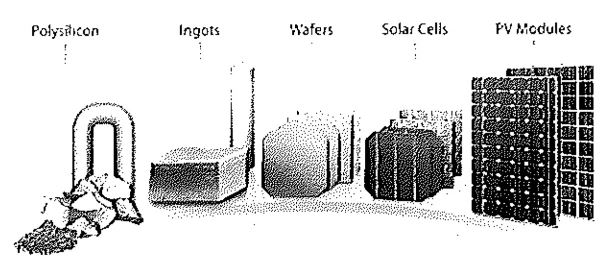


Figure 1. Schematic of c-Si PV module supply chain

Figure 4. (source: National Renewable Energy Laboratory, 2018)

4. Raw materials for metallurgical-grade silicon

Raw materials for one ton (t) MG-Si (Kato, et. al) [37]

- Quartz 2.4 t
- Coal 550 kg
- Oil coke 200 kg
- Charcoal 600 kg
- Woodchip 300 kg

Raw materials for one ton (t) MG-Si (Globe) [3]

- Quartz 2.8 t
- Coal 1.4 t
- Woodchips 2.4 t

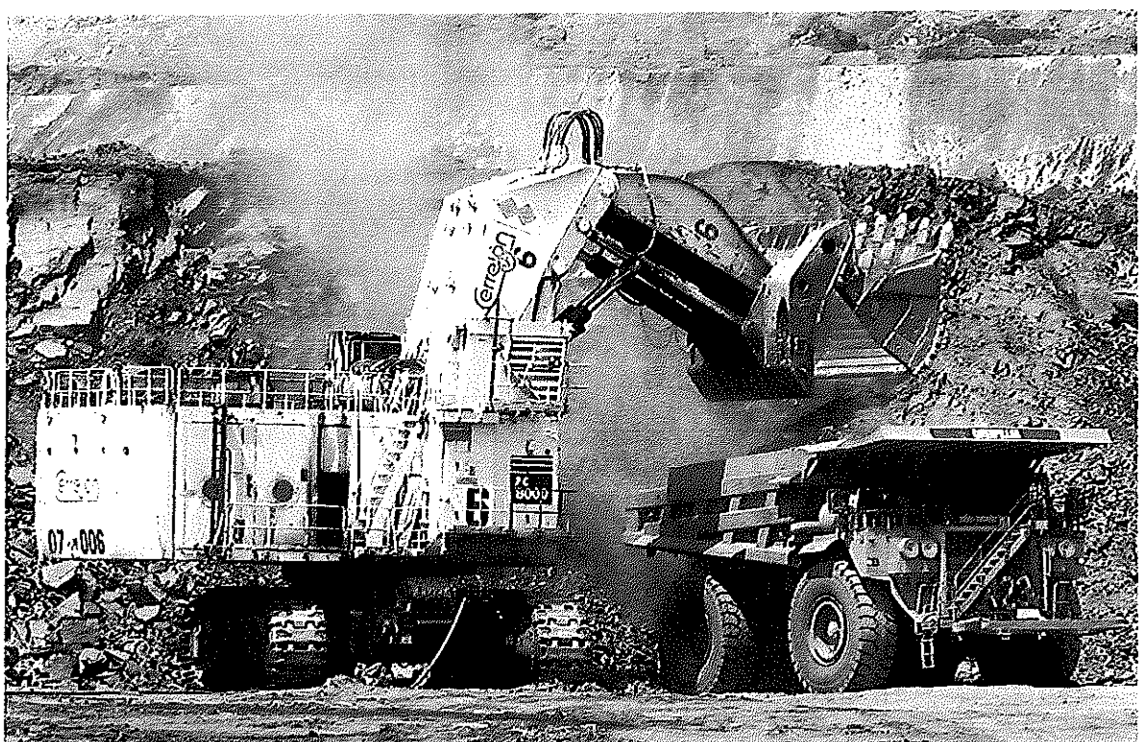
For 110,000 tpy (tons per year) MG-Si (Thorsil) [1]

- Quartz 310,000 tpy
- Coal, coke and anodes 195,000 tpy
- Wood 185,000 tpy
- Total 380,000 tpy

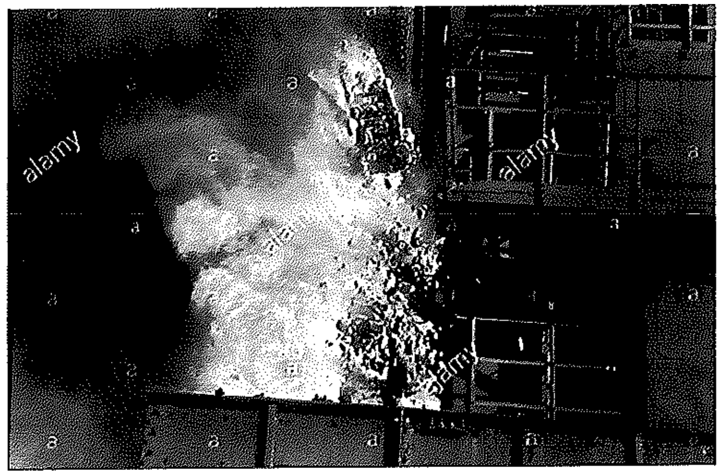
When calculating CO2 emissions from silicon smelting, "by joint agreement" some authors exclude CO2 emissions from non-fossil sources (charcoal, wood chips), power generation, and transportation of raw material. [27]

5. Sources of carbon for solar silicon smelting

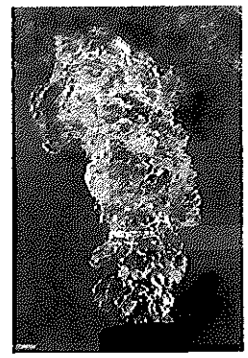
• **Coal** - Is a dense, rock-like fuel. The (low ash) coal used **directly** for silicon smelting is mostly the **"Blue Gem" from Cerrajón, Columbia**, Kentucky, USA, or Venezuela. [1][2][3][5][6][7][8]



The Cerrajón open-pit mine in Columbia supplies "Blue Gem" coal for silicon smelters around the world.

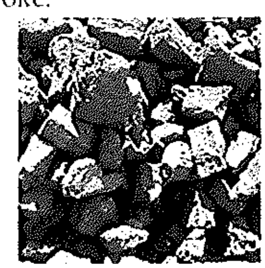


A "Slot Oven" discharging coke into a railroad car. (photo: Alamy)



• **Metallurgical Coke** (Metcoke) is a tough, cinder-like solid fuel made by "coking" coal in large "slot ovens" - to drive out most of the volatile tars, etc. to the atmosphere as smoke, flame, carbon monoxide, carbon dioxide, sulfur dioxide, other gasses, and water vapor. (photo: Getty Images)

The **coking process** is nearly identical to the process used for making charcoal from wood (see charcoal production below). Restricting the air supply to a large mass of burning coal allows about 40% of the coal to "burn off" - leaving behind a solid residue (coke) with a **higher carbon content** per ton that the original coal. It takes **about 1.6 t of coal** to make a ton of coke.



Metcoke looks like porous, silvery grey coal.

Filling barges with petcoke outside Chicago, Ill. USA (photo)

• **Petroleum Coke** (Petcoke) - is a solid fuel in the form of pellet-like granules, which are a carbon-rich byproduct of crude oil refineries. Millions of tons of petcoke are also made directly from raw bitumen (tar). Due to its low price and high carbon content, petcoke made in American refineries from "Canadian Tar Sands" is a source of carbon exported from the U.S. to silicon manufacturers in China. [9]

"Because it is considered a refinery byproduct, petcoke emissions are not included in most assessments of the climate impact of tar sands" [10]

"Beehive" charcoal ovens in Brazil (Alamy)

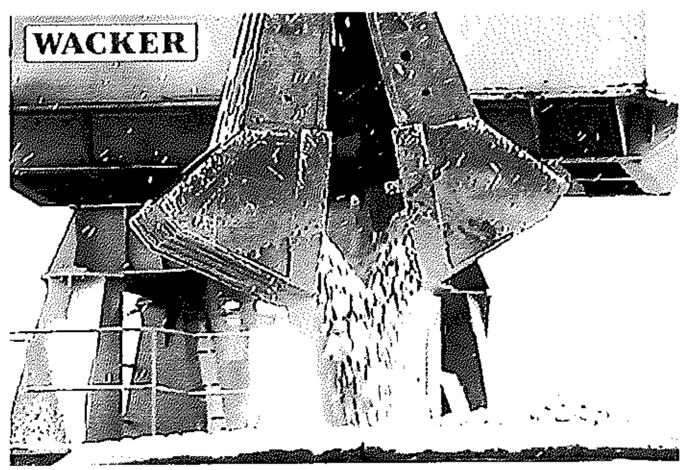
• **Wood Charcoal - Many hardwood trees must be burned to make wood charcoal.** In the traditional process, wood is stacked into "beehive ovens", ignited, then mostly smothered to prevent the wood from burning completely to ash. By weight, **about 75% of the wood is lost to the atmosphere as CO, CO_2, smoke, and heat.**

Some silicon producers use **"charcoal plantations,"** but they **only supply a fraction of the current demand** of carbon for silicon production. The rest of the carbon supply has to come from imported coal or coke, or the cutting and burning of "virgin" rainforest. **[13][14][15][16]**

In Brazil, it is estimated that more than a third of the country's charcoal is still produced illegally from protected species. [14] Brazil is a charcoal supplier to silicon producers in other countries, including the United States. Silicon smelters around the world use charcoal from many sources, so solar silicon may be smelted with charcoal made directly from rainforest not grown on plantations.

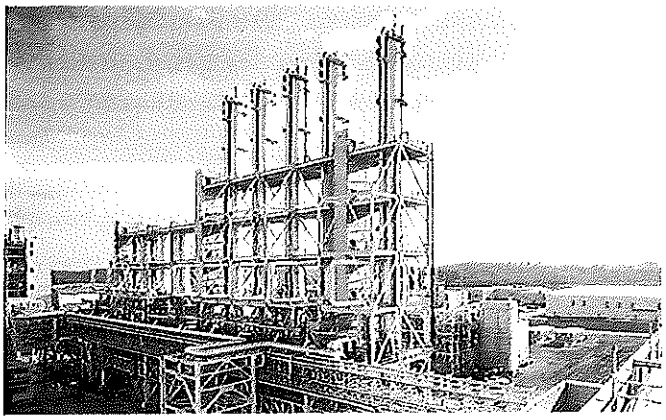
This hardwood forest in the U.S. was clear cut to make wood chips

6. **Hardwood Chips** (also called Metchips) - Matchbox-sized fragments of **shredded hardwood must be mixed into the silicon smelter** "pot" for many reasons - to allow the reactive gasses to circulate, so the liquid silicon that forms can settle to the bottom for tapping, and to allow the resulting CO (and other gasses) to escape the smelter "charge" safely. **[4]**



Solar silicon quartz rocks (Wacker Chemie)

7. **Silicon ore - Quartz - (silica, silicon dioxide, SiO_2)** Even if sufficiently pure, **silica sand won't work in any silicon smelter**, it is too fine. Selected high-purity quartz is mined and graded into "lumpy" (fist-sized) gravel for smelting. Worldwide, "solar grade" deposits of quartz are somewhat scarce, and highly valued.

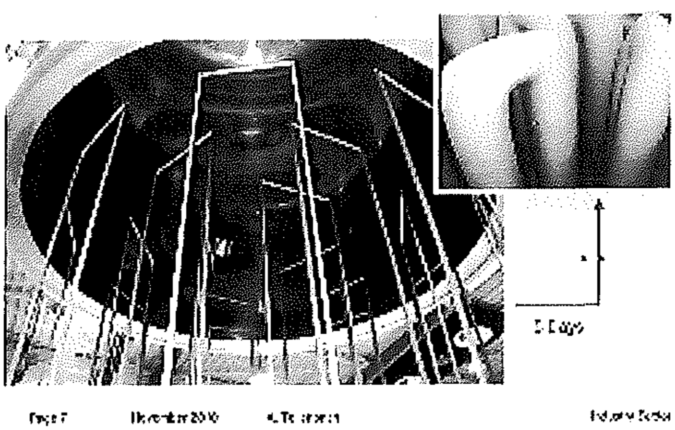


A single polysilicon plant like this one in Tennessee, USA. can draw 400 megawatts of electricity, enough power for about 300,000 homes. (Wacker Polysilicon)

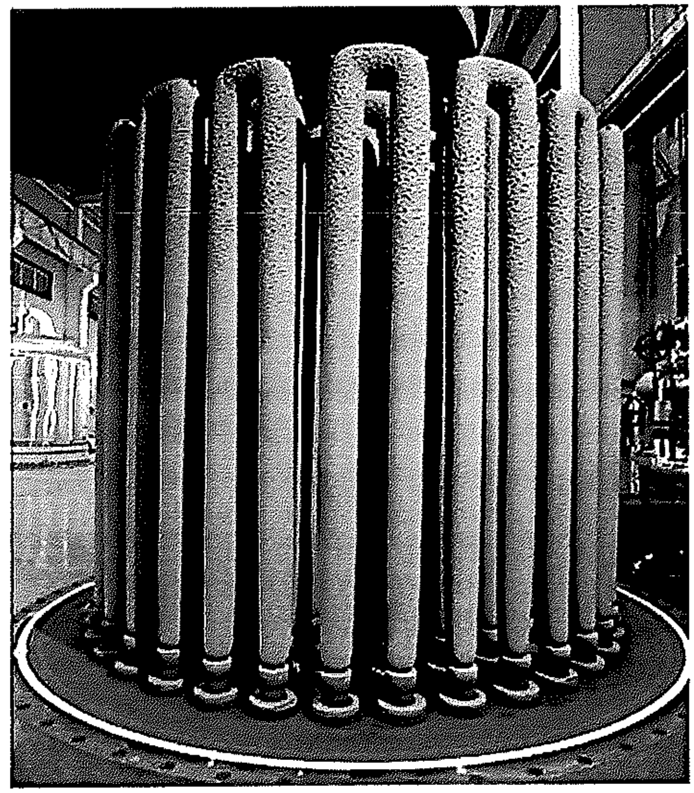
8. Polysilicon production

Metallurgical grade silicon (mg-Si) from the smelter is only about 99% pure, so it must undergo two more energy-intensive processes before it can be made into solar cells. First, **the Siemens Process converts (mg-Si) from the smelter into polycrystalline silicon (called polysilicon)** by a high-temperature vapor deposition process.

This is a bit like "growing rock candy" on hyper-pure silicon "strings" inside a pressurized-gas filled "bell-jar" reactor. As a mixture of silicon gas (made from mg-Si) and hydrogen gas passes through the reactor vessel, some of the silicon gas molecules "cling" to the electrically heated "strings" (called filaments) causing them to grow into "rods" of 99.9999% pure (or better) polysilicon.

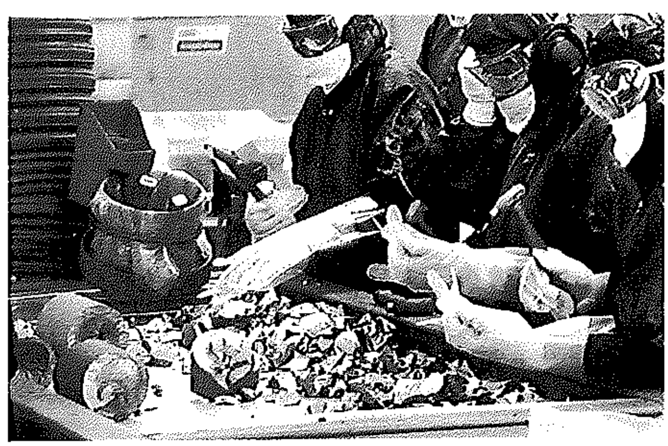


Left: When heated to around 1100°C the polysilicon "filaments" standing beneath the reactor cover can "catch" about 20% of the silicon atoms that pass through the reactor in gaseous form. Right: Polysilicon "rods" after 5 days of growth. (Siemens AG)



Each batch of polysilicon "rods" takes several days to grow, and a continuous, 24/7 supply of electricity to each reactor is essential to prevent a costly "run abort." So **polysilicon refineries** depend on highly reliable conventional power grids, and usually have two incoming high-voltage supply feeds.

A polysilicon plant consumes ~1.6 - 6 t of incoming mg-Si, and requires at least **175 MWh** (or more) of **additional electricity** per ton of polysilicon produced - **about 10 times the energy already used for smelting** each ton of mg silicon from ore. [11] After the rods are removed from the reactor, they are sawed into sections or broken into "chunks" for loading into crucibles in the next step.



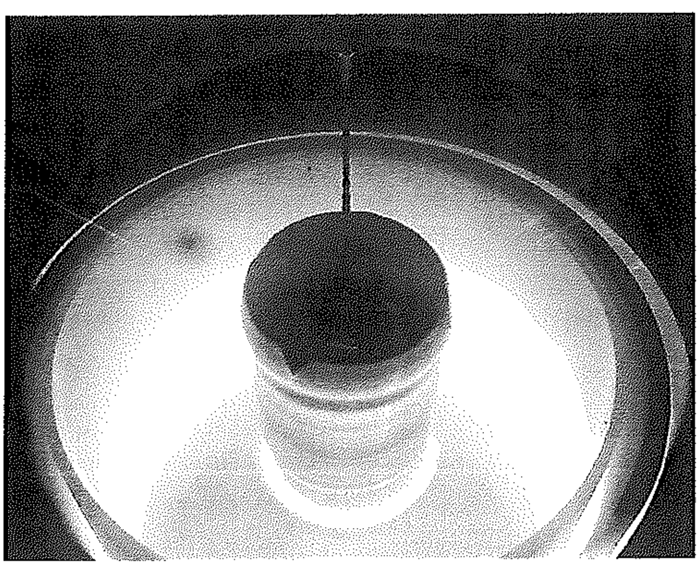
Polysilicon rods and sections being broken into chunks by hand in a clean room. (Hemlock)

Polysilicon chunks being heated in a crucible. When melted, a single crystal will be pulled out of the liquid polysilicon. (Getty)

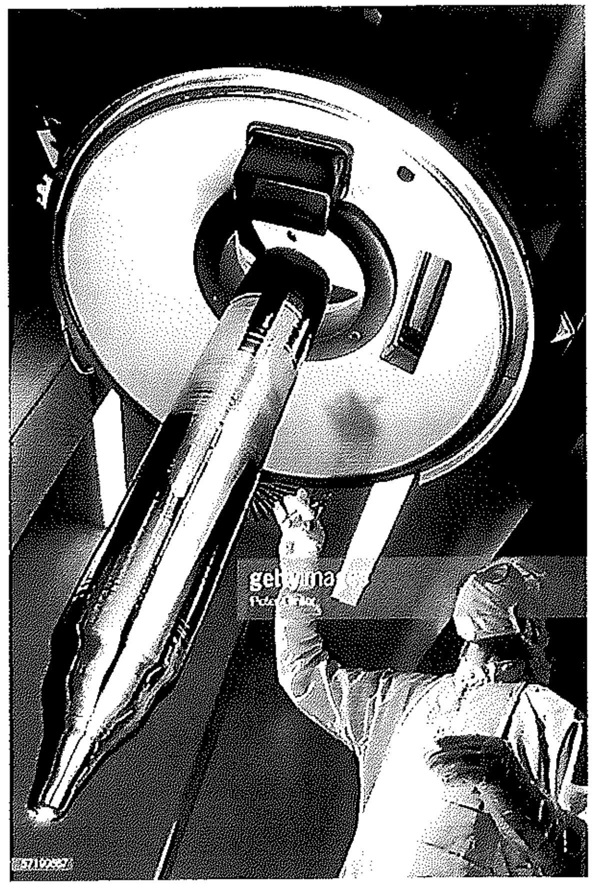
9. Crystal growing (ingot production)

For making single-crystal solar cells (called mono PV) the PV industry uses the **Czochralski process to further purify the polysilicon, and align the silicon molecules into a single-crystal form.**

First, polysilicon chunks are melted in a rotating crucible in an inert atmosphere. Then a small seed crystal of silicon is lowered into the molten polysilicon. As the seed crystal is slowly withdrawn, a single silicon crystal forms from the tip of the seed. As the crucible turns, the polysilicon continues to grow into a cylindrical ingot, leaving most of the non-silicon impurities behind in the 5-10% of "pot scrap" remaining after the crystal is drawn free.

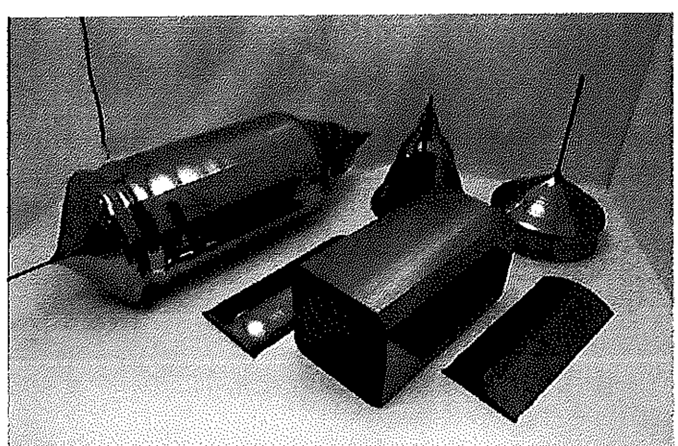


Czochralski ingot being pulled from melted polysilicon. (Image source: Siltronix)



Czochralski ingot after cooling (Image source: Getty)

This process requires several days, and uninterrupted power. An ingot/wafer/cell plant can use more than 100 MWh additional energy per ton of incoming polysilicon, about 6 times as much as the original smelting of the silicon from ore. After slow cooling, the ingot's unusable crown and tail are cut off (about 10%), the center is then ground down, the four "chords" (long sides) are sawn off (about 25%) leaving a rectangular "brick" so the solar wafers will be almost square after slicing.

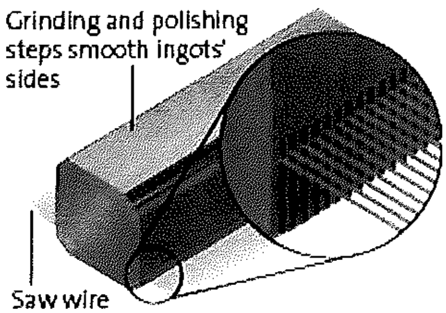


Czochralski process whole ingot (left), and brick and chords after sawing (right), crown and tail (upper right) (SVM)

For multi-crystalline cells (called multi PV) polysilicon is melted in rectangular quartz molds, then allowed to cool slowly into a rectangular ingot of multi-crystalline silicon. which is trimmed to remove unusable portions, then sliced into bricks.

10. Wafer sawing

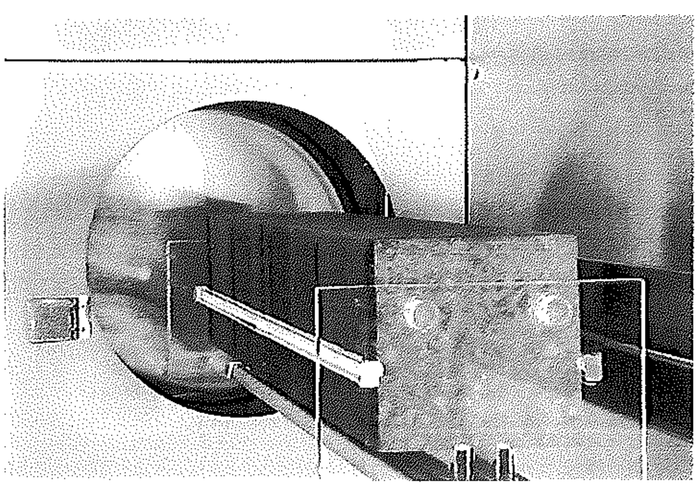
Then, like a loaf of bread, the silicon "bricks" are sliced with wire saws into thin wafers, which will later be processed into cells.



About half of the "brick" is lost as "sawdust" in the wafer slicing process, and this can't be recovered. So, after all of the energy and materials that have gone into making each "brick", much of the incoming polysilicon does not ever become finished wafers. Some of the heads, tails, chords, and trimmings can be etched (to remove contamination) and remelted **using additional energy** if the purity of the scrap is sufficient to justify the expense, otherwise they are discarded as waste.

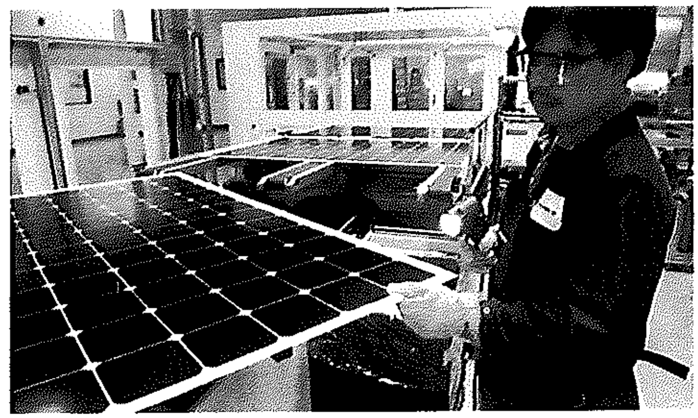
11. Cell and module production.

Once the wafers are sliced, they are made into "cells" by adding layers of other materials and components in a series of additional production steps.



Diffusion Furnace in the PV-TEC at Fraunhofer ISE
Loading of the diffusion tubes with [illegible] silicon wafers. The wafers [illegible] into the (up to) 1000 [illegible] quartz tubes. (Fraunhofer ISE)

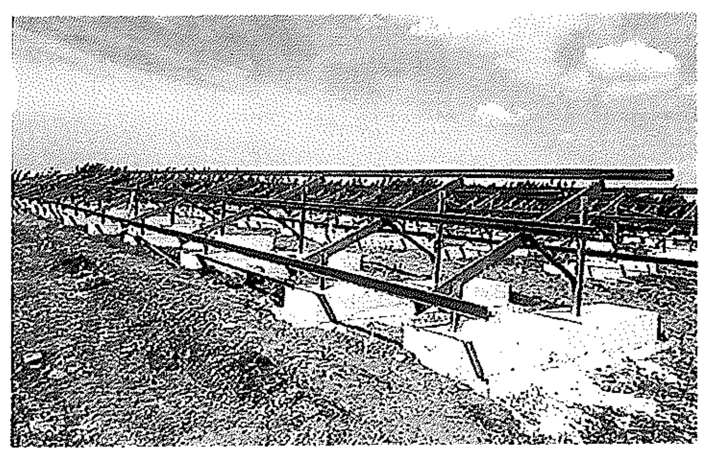
Then the cells are assembled into modules. Beside silicon wafers, most solar PV modules also require many other energy-intensive materials - aluminum (for the frame), silver, copper, glass, plastic, highly toxic rare earth metals, acids, and dozens of other chemicals for processing the polysilicon into cells and modules. A lot of electricity is needed to power the cell production and module assembly, **a supply of natural gas** is used to provide heat in the process.



Solar module inspection on the assembly line. (Solar World)

12. Other materials and steps

Once the modules are made, the whole PV system usually needs steel or aluminum framing, concrete, and some empty land (or a rooftop) to position it securely toward the sun, a lot of wiring to connect (through DC/AC inverters and transformers) to the existing power grid, or directly to battery banks,



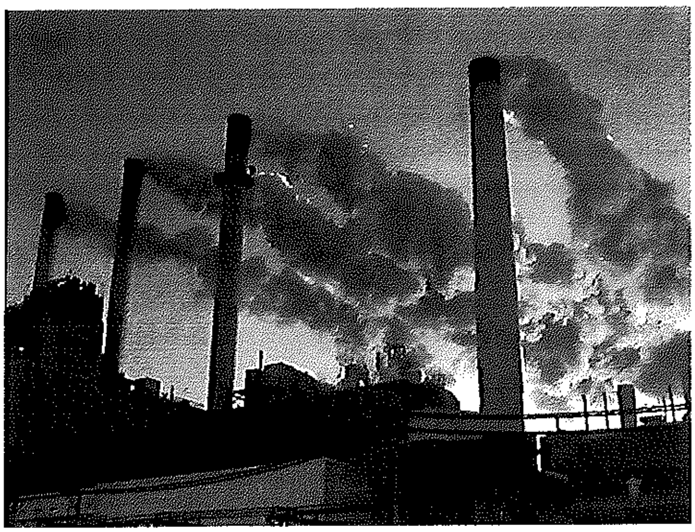
PV support structure and concrete foundation (Hill & Smith)

Of course, it takes **a lot of energy and resources** to make steel, aluminum, concrete, inverters, copper wiring, and all of these other materials. In many cases, the "balance of system" components in a PV installation can require as much (or more) "up-front" resources and energy to make as the modules. **[21]**

In addition, the amount of fossil fuels and non-renewable resources needed to construct and maintain new PV production infrastructure (smelters, polysilicon refineries, etc.) is considerable, but has been excluded from all "life cycle analysis" (LCA) of solar PV production by definition. [38]

13. Transportation

Throughout the solar PV manufacturing process all of the materials and products must be shipped **to and from more than a dozen countries** around the world in large barges, container ships, trains, or trucks - **all powered by non-renewable oil. [36]**



14. Power

Worldwide, only a few silicon smelters, like those in Norway, are powered primarily by hydro-electricity. Elsewhere, the current majority of smelters, polysilicon refineries, ingot growers, cell and module factories are running on grids **powered mostly by fossil fuels and uranium.** At present, more than 50% of all solar silicon is made in China, where the industrial grid is powered largely by fossil fuels, primarily low-grade coal. Depending on the "energy mix" available, the quantity of coal, coke, or gas that is being burned to deliver power 24/7 to the PV factories may be far greater than the amount needed as the carbon source for smelting silicon. To provide a realistic assessment of the total environmental impact of PV manufacturing, this **must be added to the "fossil fuel bill"** for solar PV production - along with the "embodied energy" of PV factories. [11][12][21]

15. Conclusions

Every step in the production of solar photovoltaic (PV) power systems requires a perpetual input of fossil fuels - as carbon reductants for smelting metals from ore, for process heat and power, international transport, and deployment. Silicon smelters, polysilicon refineries, and crystal growers around the world all depend on uninterrupted, 24/7 power that comes mostly from coal and uranium. **The only "renewable" materials consumed in PV production are obtained by deforestation** - for wood chips, and by burning vast areas of tropical rainforest for charcoal used as a source of carbon for silicon smelters. So far, both **media and journal claims** that solar PV can somehow "replace fossil fuels" **have not addressed the non-renewable reality of global supply chains** necessary for mining, manufacturing, and distribution of PV power systems. Based on current world production levels of solar PV, an attempt to replace conventional electricity production with solar PV would require a **dramatic increase in the amount of coal and petcoke needed for silicon smelting**, along with the **increased cutting of vast areas of forest** for charcoal and wood chips.

Readers are encouraged to **examine all of the references below**, to become aware of other aspects with solar pv manufacturing and deployment that are beyond the scope of this paper.

References

[1] Thorsil (2015) "Metallurgical Grade Silicon Plant - Helguvík, Reykjanes municipality (Reykjanesbær), Reykjanes peninsula, Iceland Environmental Impact Assessment (EIA) Capacity: 110,000 tons" https://www.giek.no/getfile.php/133565/web/Dokumenter/Prosjekter%20under%20vurdering/EIA-Thorsil_Lingua-2-%20konsekvensutredning.pdf (1) "Thorsil's initial assessment report was based on using...**Coal from El Cerrajon in Columbia**...for an annual production...of 110,000 tpy [of mg-Si]...**would correspond to 605,000 tpy of carbon dioxide...The Environment Agency feels that...such exhaust would significantly increase Iceland's overall emissions"**

[2] Efla (2013) "Environmental Impact Assessment of a SILICON METAL PLANT AT BAKKI IN HÚSAVÍK"https://www.agaportal.de/_Resources/Persistent/856d55b1a3c1948e5f856f800195760741faa93b/eia_island_silizium.pdf (2) "The main raw materials used for the production of Silicon Metal are quartzite... **coals (mainly from [Cerrejón] Columbia, Venezuela, and USA)**, charcoal, wood chips"

[3] "New York State Department of Environmental Conservation - Facility DEC ID: 9291100078 PERMIT Under the Environmental Conservation Law (ECL) Permit Issued To: GLOBE METALLURGICAL INC" http://www.dec.ny.gov/dardata/boss/afs/permits/929110007800009_r3.pdf **(3) "Globe Metallurgical produces high purity silicon metal...The facility is a major source of emissions of sulfur dioxide, carbon monoxide, hydrogen chloride and nitrogen oxides...** "The submerged electric arc process is a reduction smelting operation...**Reactants consisting of coal, charcoal, petroleum coke, or other forms of coke, wood chips, and quartz are mixed and added at the top of each furnace... At high temperatures in the reaction zone, the carbon sources react with silicon dioxide and oxygen to form carbon monoxide and reduce the ore to the base metal silicon."**

[4] "The Use and Market for WOOD in the ELECTROMETALLURGICAL Industry" https://www.fs.usda.gov/treesearch/pubs/23800 (4) [woodchips are used in smelters]...**to provide a large surface area for chemical reaction to take place more completely and at improved rates...To maintain a porous charge, thereby promoting gentle and uniform - instead of violent - gas venting**...To help regulate smelting temperatures...To keep the furnace burning smoothly on top...To reduce conductivity...To promote deep electrode penetration...To prevent bridging, crusting, and agglomeration of the mix...To reduce dust, metal vapor, and heat loss; and as a result to improve working conditions near the furnace.

[5] Healy, N., Stephens, J. C., & Malin, S. A. (2019). "Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains." *Energy Research & Social Science*, *48*, 219-234. (link) (5)**"Cerrejón is one of the world's largest open-pit coal mines [supplying silicon manufacturers]**...energy extraction often entails the physical displacement of populations or the "slow violence" of landscape destruction, water contamination and livelihood disruption"

[6] What Terrible Injustices Are Hiding Behind American Energy Habits? By Itai Vardi • Friday, November 16, 2018 (link) (6) **"There is a clear 'consumer blindness' and citizens and residents are often unaware of where the fuel they consume is coming from** and what injustices were inflicted on communities within those sites of fossil fuel extraction," said Healy. "Exposing these **injustices of energy 'sacrifice zones' — like [the Cerrejón open-pit coal mine] in La Guajira, Colombia** ...— could be critical for future energy policy decision-making."

[7] 2017/06/18/why-this-part-of-coal-country-loves-solar-power-215272 (7)**"the seam in Whitley County [Kentucky] is an even more valuable variety of metallurgic coal known as "blue gem."..."You need the blue gem to make the solar panels, and that's what people don't know,"** Moses told me, articulating a simple truth: **"Without Coal Valley, there's no Silicon Valley"**

[8] **https://www.prnewswire.com/news-releases/new-colombia-resources-inc-discovers-huge-new-metallurgical-coal-seam-at-their-property-in-colombia-as-the-company-prepares-to-begin-production-while-coal-prices-continue-to-soar-600823111.html** (8) "Colombian coal accounts for close to 75% of coal imports to the U.S... New Colombia Resources' Blue Gem coal is only found on the KY-TN border and central Colombia and is used to produce specialty metals **such as Silicon to make solar panels**, electric car batteries, and many more next generation products"

[9] https://carnegietsinghua.org/2015/05/31/managing-china-s-petcoke-problem-pub-60023 **(9) "Figure 5. [graph] Chinese Petcoke Consumption by Sector (2013 silicon=6%) (2014 silicon=7%)** A significant share of the petcoke used in China [which was made in U.S. refineries] is imported from the United States, ..."According to the U.S. Energy Information Administration (EIA), **U.S.** petcoke exports to China... a staggering 7 million metric tons in 2013...accounting for nearly 75 percent of Chinese petcoke.

[10] Petroleum Coke: The Coal Hiding in the Tar Sands (10) "Because it is considered a refinery byproduct, **petcoke emissions are not included in most assessments of the climate impact of tar sands**"...

[11] https://www.sightline.org/2018/06/25/small-town-silicon-smelter-plan-tees-up-big-questions/ (11) "**these furnaces would have a voracious appetite for electricity: around 105 megawatts on a continuous basis, roughly the equivalent of 68,000 homes...the facility would demand more power than the dam could provide**....Producing one ton of silicon metal requires about six tons of raw materials...Nearby sawmills would send seven or eight trucks per day to deliver wood chips, which are integral to the smelting process...."**The smelting process requires a rare type of metallurgic coal known as "blue gem," ... Operations at the smelter would demand approximately 48,000 metric tons of coal per year—roughly 40 rail cars each month.**"

[12] https://siteselection.com/theEnergyReport/2009/apr/Wacker-Chemie/ (12) "A nuclear plant is 1200 megawatts. **Fully built out, [Wacker Polysilicon] could be a third of a nuclear plant [400 MW]**...Not everybody out there can handle that size of a load. We're selling the fact that we [TVA] have the reliability, and we have a very diverse portfolio across **coal, nuclear and hydro.**"

[13] Jungbluth, N., M. Stucki, R. Frischknecht, S. Büsser, and ESU-services Ltd. & Swiss Centre for Life Cycle Inventories. (2009) "Part XII photovoltaics." *Swiss Centre for Life Cycle Inventories* (link) (13) "An issue of concern... **is the use of charcoal in this [photovoltaic silicon] process that originates from Asia or South America and might have been produced from clear cutting rainforest wood**"

[14] Eikeland, Inger Johanne, B. Monsen, and Ingunn S. Modahl.(2001) "Reducing CO2 emissions in Norwegian ferroalloy production." *Greenhouse Gases in the Metallurgical Industries: Policies, Abatement and Treatment, (Met. Soc. CIM), Toronto* 325 . (link) (14) **Most of the charcoal used...[for silicon production]...is imported from Asia and South America.** The crude, traditional methods of charcoal making, which are still widely used in these continents, are inefficient and strongly pollute the environment."

[15] Nisgoski, Silvana & Muniz, Graciela & Morrone, Simone & Schardosin, Felipe & França, Ramiro. (2015). NIR and anatomy of wood and charcoal from Moraceae and Euphorbiaceae species. Revista Ciência da Madeira - RCM. 6. 183-190. 10.12953/2177-6830/rcm.v6n3p183-190. (link) (15) "**charcoal supply is still present in illegal cutting of native forests, which represented 30-35% of total output [in Brazil]**... charcoal consumption represents the deforestation of approximately 1.6 million hectares or 16.000 km² of the Cerrado Biome"

[16] 2017/10/burning-down-the-house-myanmars-destructive-charcoal-trade/ (16) "**Dehong's silicon industry ... "has caused a serious damage to forest resources,**" and estimated that "119,700 tons of charcoal were consumed in the production of industrial silicon in Dehong prefecture **in 2014... 31 square miles—"of forests were cut down. (...) In 2016, the [silicon] industry consumed nearly twice that amount** (216,273 tons of charcoal)

[17] BP Statistical Review of World Energy, 67th Edition, June 2018 (17) "despite the huge policy push encouraging a switch away from coal and the rapid expansion of renewable energy in recent years, **there has been no improvement in the mix of fuels feeding the global power sector over the past 20 years. Astonishingly, the share of coal in 2017 was exactly the same as in 1998. The share of non-fossil fuels was actually lower**, as growth in renewables has failed to compensate for the decline in nuclear energy."

[18] De Castro, Carlos, Margarita Mediavilla, Luis Javier Miguel, and Fernando Frechoso. "Global solar electric potential: A review of their technical and sustainable limits." *Renewable and Sustainable Energy Reviews* 28 (2013): 824-835. (link) (18) "**based on real examples...our results show that present and foreseeable future density power of solar infrastructures are much less (4–10 times) than most published studies...** an overview of the land and materials needed for large scale implementation show that many of the estimations found in the literature are hardly compatible with the rest of human activities."

[19] Koomey, J. G., Calwell, C., Laitner, S., Thornton, J., Brown, R. E., Eto, J. H., ... & Cullicott, C. (2002). Sorry, wrong number: The use and misuse of numerical facts in analysis and media reporting of energy issues. *Annual review of energy and the environment*, 27(1), 119-158. (link) (19) "Unfortunately, numbers that prove decisive in policy debates are not always carefully developed, credibly documented, or correct...**A common mistake in the media has been to apply this statistic (1000 homes per MW) to intermittent renewable power sources**...Intermittent renewables generally produce far fewer kilowatt-hours per MW than conventional power

plants...**this widely used equivalence between homes and MW should generally not be applied to intermittent renewables such as...PVs."**

[20] Shaner, Matthew R., Steven J. Davis, Nathan S. Lewis, and Ken Caldeira. (2018) "Geophysical constraints on the reliability of solar and wind power in the United States." *Energy & Environmental Science* 11, no. 4 (2018): 914-925 (link) **(20) "Achieving 99.97% reliability with a system consisting solely of solar and wind generation... would require** a storage capacity equivalent to several weeks of average demand...**Three weeks of storage (227 TW h) [which] results in ~6500 years of the annual Tesla Gigafactory production capacity** or a **~900x increase** in the pumped hydro capacity of the U.S."

[21] Carbajales-Dale, Michael, Charles J. Barnhart, and Sally M. Benson.(2014) "Can we afford storage? A dynamic net energy analysis of renewable electricity generation supported by energy storage." *Energy & Environmental Science* 7, no. 5 (2014): 1538-1544. (link) (21) **"PV technologies (CIGS and sc-Si)**...cannot 'afford' any storage while still supplying an energy surplus to society... **since they are already operating at a deficit**...These technologies require large, 'up-front' energetic investments...A fractional [energy] re-investment of greater than 100% ... means that **the industry consumes more electricity than it produces** on an annual basis, i.e. running an energy deficit"

[22] Milligan, M., Ela, E., Hein, J., Schneider, T., Brinkman, G., & Denholm, P. (2012). *Renewable Electricity Futures Study. Volume 4: Bulk Electric Power Systems: Operations and Transmission Planning* (No. NREL/TP-6A20-52409-4). National Renewable Energy Lab.(NREL), Golden, CO (United States). (link) (22) "although **RE Futures** describes the system characteristics needed to accommodate high levels of renewable generation, it **does not address the institutional, market, and regulatory changes that may be needed to facilitate such a transformation**...[and] **a full cost-benefit analysis was not conducted** to comprehensively evaluate the relative impacts of renewable and non-renewable electricity generation options.

[23] Lithium Ion batteries for Stationary Energy Storage - The Office of Electricity Delivery and Energy Reliability, Pacific Northwest National Laboratory **(23)** "Despite their success in mobile applications, **Li-ion technologies have not demonstrated sufficient grid-scale energy storage feasibility "**

[24] Lessons Learned Report - Electrical Energy Storage DOCUMENT NUMBER CLNR-L163 AUTHORS John Baker, James Cross, EA Technology Ltd, Ian Lloyd, Northern Powergrid PUBLISHED 08 December 2014 **(24) "The round trip efficiencies for the [Li-ion] EES systems have been calculated [in actual use]... between 41% and 69% where parasitic loads are included"**

[25] https://energy.stanford.edu/news/calculating-energetic-cost-grid-scale-storage **(25) "using the kind of lead-acid batteries available today to provide storage for the worldwide power grid is impractical."**

[26] Luque, A., & Hegedus, S. (Eds.). (2011). *Handbook of photovoltaic science and engineering.* John Wiley & Sons. (link) **(26) "Photovoltaics is polluting just like all high-technology or high-energy industries only with different toxic emissions** ... Manufacturing of PV modules on a large scale requires the handling of large quantities of hazardous or potentially hazardous materials (e.g. heavy metals, reactive chemical solutions, toxic gases"

[27] https://www.researchgate.net/publication/311440469_CO2_Emissions_from_the_Production_of_Ferrosilicon_and_Silicon_metal_in_Norway (27) "These emission factors only include CO2 emitted from fossil raw materials in the reduction process. **CO2 from biological, renewable sources is not included (according to joint agreement). Neither is CO2 emitted from electric power production or during transportation of raw materials."**

[28] Cleaning Up Clean Energy - https://web.stanford.edu/group/sjir/pdf/Solar_11.2.pdf **(28) "the (PV) industry has largely overlooked investigative reports revealing current problems with production waste,** particularly pertaining to Chinese manufacturing. Until these concerns receive more attention, **promises of panel recycling will quell any public anxiety, preventing the creation of necessary safeguards** to stop rogue firms from unsafe manufacturing practices"

[29] https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/#256668c121cc **(29) "We estimate there are 100,000 pounds of cadmium contained in the 1.8 million panels,"** Sean Fogarty of the group told me.

"Leaching from broken panels damaged during natural events – hail storms, tornadoes, hurricanes, earthquakes, etc. – and at decommissioning is a big concern."

[30] https://www.scmp.com/news/china/society/article/2104162/chinas-ageing-solar-panels-are-going-be-big-environmental-problem (30) Lu Fang, secretary general of the photovoltaics decision in the China Renewable Energy Society, wrote...**By 2050 these waste panels would add up to 20 million tonnes, or 2,000 times the weight of the Eiffel Tower**...Tian Min, general manager of Nanjing Fangrun Materials, a recycling company in Jiangsu province that collects retired solar panels, said **the solar power industry was a ticking time bomb."It will explode with full force in two or three decades and wreck the environment, if the estimate is correct,"**

[31] https://www.solarpowerworldonline.com/2018/04/its-time-to-plan-for-solar-panel-recycling-in-the-united-states/ (31) "We've conducted some toxicity testing on modules, and we have seen results showing that **the presence of lead is higher than the threshold allowed by the TCLP (toxicity characteristic leaching procedure)**...There is a potential for leaching of toxic materials such as lead in landfill environments. **If modules are intact, it's a low risk, but as soon as they're broken or crushed, then the potential for leaching is increased."**

[32] https://www.welt.de/wirtschaft/article176294243/Studie-Umweltrisiken-durch-Schadstoffe-in-Solarmodulen.html (32) "Based on installed power and performance weight, we can estimate that **by the year 2016, photovoltaics has spread about 11,000 tonnes of lead and about 800 tonnes of Cd (cadmium),**" the study said"

[33] https://www.solarpowerinternational.com/wp-content/uploads/2016/09/N253_9-14-1530.pdf (33) "disposal in "regular landfills [is] not recommended **in case modules break and toxic materials leach into the soil"** and so "disposal is potentially a major issue."

[34] Tao, Coby S., Jiechao Jiang, and Meng Tao. "Natural resource limitations to terawatt-scale solar cells." *Solar Energy Materials and Solar Cells* 95, no. 12 (2011): 3176-3180. https://doi.org/10.1016/j.solmat.2011.06.013 **"Material scarcity prevents most current solar cell technologies from reaching terawatt scales.** (...) Scarce materials in solar cells include indium, gallium, tellurium, ruthenium, and silver. - Natural resource limitations to terawatt-scale solar cells."

[35] Metal-demand-for-renewable-electricity-generation-in-the-netherlands **"The current global supply of several critical metals is insufficient to transition to a renewable energy system.** ...production of wind turbines and photovoltaic (PV) solar panels already requires a significant share of the annual global production of some critical metals... Furthermore, mining is often associated with significant environmental and social costs"

[36] INCREASES IN EFFICIENCY HAVE NOT REDUCED ABSOLUTE CO2 EMISSIONS FROM SHIPS **"Although the CO2 intensity of many major ship classes decreased (i.e., they became more efficient) from 2013 to 2015, total CO2 emissions from ships increased.** For example, although the CO2 intensity of general cargo ships (measured as emissions per unit of transport supply) decreased by 5%, CO2 emissions increased by 9% **Thus, increases in distance traveled due to a greater demand for shipping more than offset gains in operational efficiency during the period studied"**

[37] Kato, K., Murata, A., & Sakuta, K. (1998). Energy pay-back time and life-cycle CO2 emission of residential PV power system with silicon PV module. *Progress in Photovoltaics: Research and Applications*, *6*(2), 105-115.

[38] Fthenakis, V., Kim, H., Frischknecht, R., Raugei, M., Sinha, P., & Stucki, M. (2011). Life cycle inventories and life cycle assessment of photovoltaic systems. *International Energy Agency (IEA) PVPS Task*, *12*. http://www.clca.columbia.edu/Task12_LCI_LCA_10_21_Final_Report.pdf

Energy + Environment
Legislature

Grain Belt Express takes first resistant Missouri landowner to court

Progress on the $2 billion transmission line is accelerating as 65% of the route in Missouri and Kansas has been acquired voluntarily

By: Lukas Vanacker - December 21, 2021 12:00 pm

Evergy's Flat Ridge Wind Farm in Kansas (photo submitted).

A $2 billion wind energy project spanning the length of northern Missouri is for the first time asking a judge to force a resistant landowner to sell the company an easement on their land.

Grain Belt Express, a proposed high-voltage transmission line that would carry 4,000 megawatts of renewable energy from Western Kansas to Indiana, has faced fierce criticism from some Missouri landowners and elected officials.

In September, it filed a petition for condemnation against a farmer from Gower named Bradley Horn. A hearing in the case was originally scheduled last week in the Circuit Court of Buchanan County but was delayed until Feb. 2.

The company is arguing that Horn "did not accept the written offer for the property interests," and later "negotiations were unsuccessful." It marks the first time Grain Belt Express has taken a resistant landowner to court.

The judge can appoint three disinterested residents of the county, who have to assess the just compensation for Horn.

Horn's attorneys declined to comment.

Payments

When the Grain Belt Express got its approval from the Missouri Public Service Commission in 2019, the decision was criticized by some because it granted the private company the right to obtain easements through eminent domain.

Yet the company has always insisted it would only use that procedure as a last resort to acquire 1,700 parcels of land in Kansas and Missouri.

According to Patrick Whitty, vice president of the project's parent company, Invenergy Transmission, Grain Belt Express has "now completed right-of-way acquisition through voluntary easement agreements for approximately 65% of the route in Missouri and Kansas, compared to only one third completed at the start of

the year."

At the beginning of this year, the company had made payments of $4.9 million to landowners in Missouri combined. As it stands today, that figure is $8.5 million.

Grain Belt Express offers landowners compensation of 110% of the market value of land, plus $18,000 per tower structure. That offer was recently increased, Whitty said, to reflect "rising farmland values." For example, one farmer from Madison in northeast Missouri was offered $98,000 to allow two tower structures on nine acres of cropland.

Donna and Kenneth Inglis, a retired couple from Huntsville, were happy to close a deal with Grain Belt Express a year ago.

"I strongly support the project because I strongly believe in green energy," Donna Inglis said. "If our ancestors wouldn't have accepted rural electricity, we would still be working with kerosine lamps."

Inglis didn't want to disclose the details of the financial offer, but she said "it's a lot of money."

However, while some landowners are more than willing to grant the company access to their land, others continue to resist the transmission structures, which are 40 feet by 40 feet wide and between 130 to 160 feet tall.

"Some people have been farming here for more than 100 years," says Marilyn O'Bannon, western district commissioner in Monroe County. "Their land is their heritage. And now, they want to build something through the middle of our land, next to an existing electricity line. We can't farm efficiently around obstacles. And show me where the value for our state is."

O'Bannon's family owns land on the future transmission line. Whereas Inglis praises the professionalism of Grain Belt Express agents, O'Bannon says there has been a lack of transparency.

"The potential dangers and unknowns as well as lack of project details are overwhelming," O'Bannon said. "Landowners are left in the dark as long as possible. I can't describe the emotional impact."

Risks

The road ahead to complete the Grain Belt Express project remains long and bumpy.

In the summer of 2020, Invenergy announced the transmission line would deliver more energy to Missouri than originally anticipated, doubling its investment in the state to $1 billion.

The Public Service Commission still has to approve the extended plan. And after years of litigation and regulatory proceedings involving the project, that could once again stir up opposition to the transmission line.

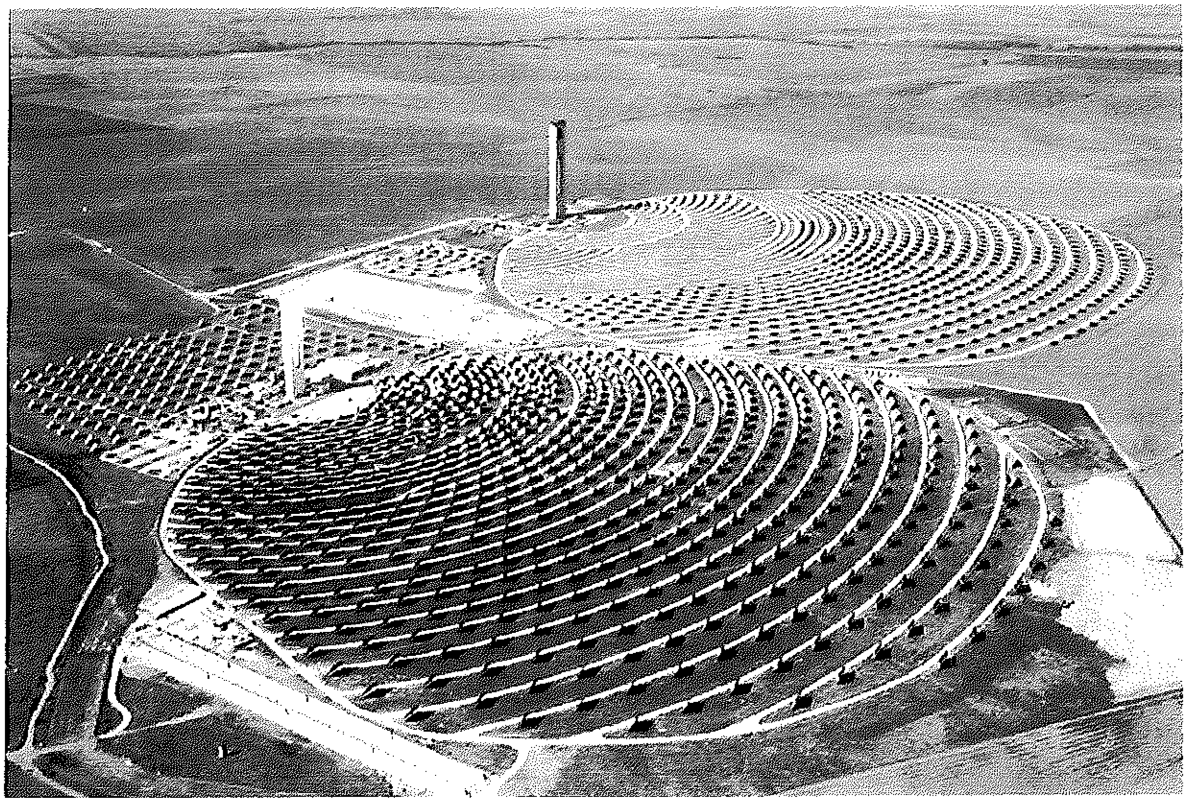
It could also fuel continued efforts by Grain Belt Express critics to push Missouri lawmakers to pass legislation undermining the project.

Earlier this year, a bill requiring that Grain Belt Express gets resolutions of support from county commissions in each of the counties in the project's path cleared the Missouri House but died in the Senate.

This story has been updated since it originally published.

Analysis: 41 Inconvenient Truths on the "New Energy Economy"

Heartland Author August 19, 2022 2



By Mark P. Mills

A week doesn't pass without a mayor, governor, policymaker or pundit joining the rush to demand, or predict, an energy future that is entirely based on wind/solar and batteries, freed from the "burden" of the hydrocarbons that have fueled societies for centuries. Regardless of one's opinion about whether, or why, an energy "transformation" is called for, the physics and economics of energy combined with scale realities make it clear that there is no possibility of anything resembling a radically "new energy economy" in the foreseeable future. Bill Gates has said that when it comes to understanding energy realities "we need to bring math to the problem."

He's right. So, in my recent Manhattan Institute report, "The New Energy Economy: An Exercise in Magical Thinking," I did just that.

Herein, then, is a summary of some of the bottom-line realities from the underlying math. (See the full report for explanations, documentation, and citations.)

Realities About the Scale of Energy Demand

1. Hydrocarbons supply over 80 percent of world energy: If all that were in the form of oil, the barrels would line up from Washington, D.C., to Los Angeles, and that entire line would grow by the height of the Washington Monument every week.

2. The small two-percentage-point decline in the hydrocarbon share of world energy use entailed over $2 trillion in cumulative global spending on alternatives over that period; solar and wind today supply less than two percent of the global energy.

3. When the world's four billion poor people increase energy use to just one-third of Europe's per capita level, global demand rises by an amount equal to twice America's total consumption.

4. A 100x growth in the number of electric vehicles to 400 million on the roads by 2040 would displace five percent of global oil demand.

5. Renewable energy would have to expand 90-fold to replace global hydrocarbons in two decades. It took a half-century for global petroleum production to expand "only" ten-fold.

6. Replacing U.S. hydrocarbon-based electric generation over the next 30 years would require a construction program building out the grid at a rate 14-fold greater than any time in history.

7. Eliminating hydrocarbons to make U.S. electricity (impossible soon, infeasible for decades) would leave untouched 70 percent of U.S. hydrocarbons use—America uses 16 percent of world energy.

8. Efficiency increases energy demand by making products & services cheaper: since 1990, global energy efficiency improved 33 percent, the economy grew 80 percent and global energy use is up 40 percent.

9. Efficiency increases energy demand: Since 1995, aviation fuel use/passenger-mile is down 70 percent, air traffic rose more than 10-fold, and global aviation fuel use rose over 50 percent.

10. Efficiency increases energy demand: since 1995, energy used per byte is down about 10,000-fold, but global data traffic rose about a million-fold; global electricity used for computing soared.

11. Since 1995, total world energy use rose by 50 percent, an amount equal to adding two entire United States' worth of demand.

12. For security and reliability, an average of two months of national demand for hydrocarbons are in storage at any time. Today, barely two *hours* of national electricity demand can be stored in all utility-scale batteries plus all batteries in one million electric cars in America.

13. Batteries produced annually by the Tesla Gigafactory (world's biggest battery factory) can store three *minutes* worth of annual U.S. electric demand.

14. To make enough batteries to store two day's worth of U.S. electricity demand would require 1,000 years of production by the Gigafactory (world's biggest battery factory).

15. Every $1 billion in aircraft produced leads to some $5 billion in aviation fuel consumed over two decades to operate them. Global spending on new jets is more than $50 billion a year—and rising.

16. Every $1 billion spent on data centers leads to $7 billion in electricity consumed over two decades. Global spending on data centers is more than $100 billion a year—and rising.

Realities about Energy Economics

17. Over a 30-year period, $1 million worth of utility-scale solar or wind produces 40 million and 55 million kWh respectively: $1 million worth of shale well produces enough natural gas to generate 300 million kWh over 30 years.

18. It costs about the same to build one shale well or two wind turbines: the latter, combined, produces 0.7 barrels of oil (equivalent energy) per hour, the shale rig averages 10 barrels of oil per hour.

19. It costs less than $0.50 to store a barrel of oil, or its equivalent in natural gas, but it costs $200 to store the equivalent energy of a barrel of oil in batteries.

20. Cost models for wind and solar assume, respectively, 41 percent and 29 percent capacity factors (i.e., how often they produce electricity). Real-world data reveal as much as ten percentage points less for both. That translates into $3 million less energy produced than assumed over a 20-year life of a 2-MW $3 million wind turbine.

21. In order to compensate for episodic wind/solar output, U.S. utilities are using oil- and gas-burning reciprocating engines (big cruise-ship-like diesels); three times as many have been added to the grid since 2000 as in the 50 years prior to that.

22. Wind-farm capacity factors have improved at about 0.7 percent per year; this small gain comes mainly from reducing the number of turbines per acre leading to a 50 percent increase in average land used to produce a wind-kilowatt-hour.

23. Over 90 percent of America's electricity, and 99 percent of the power used in transportation, comes from sources that can easily supply energy to the economy any time the market demands it.

24. Wind and solar machines produce energy an average of 25 percent–30 percent of the time, and only when nature permits. Conventional power plants can operate nearly continuously and are available when needed.

25. The shale revolution collapsed the prices of natural gas & coal, the two fuels that produce 70 percent of U.S. electricity. But electric rates haven't gone down, rising instead 20 percent since 2008. Direct and indirect subsidies for solar and wind consumed those savings.

Energy Physics... Inconvenient Realities

26. Politicians and pundits like to invoke "moonshot" language. But transforming the energy economy is not like putting a few people on the moon a few times. It is like putting all of humanity on the moon—permanently.

27. The common cliché: an energy tech disruption will echo the digital tech disruption. But *information*-producing machines and *energy*-producing machines involve profoundly different physics; the cliché is sillier than comparing apples to bowling balls.

28. If solar power scaled like computer-tech, a single postage-stamp-size solar array would power the Empire State Building. That only happens in comic books.

29. If batteries scaled like digital tech, a battery the size of a book, costing three cents, could power a jetliner to Asia. That only happens in comic books.

30. If combustion engines scaled like computers, a car engine would shrink to the size of an ant and produce a thousand-fold more horsepower; actual ant-sized engines produce 100,000 times less power.

31. No digital-like 10x gains exist for solar tech. Physics limit for solar cells (the Shockley-Queisser limit) is a max conversion of about 33 percent of photons into electrons; commercial cells today are at 26 percent.

32. No digital-like 10x gains exist for wind tech. Physics limit for wind turbines (the Betz limit) is a max capture of 60 percent of energy in moving air; commercial turbines achieve 45 percent.

33. No digital-like 10x gains exist for batteries: maximum theoretical energy in a pound of oil is 1,500 percent greater than max theoretical energy in the best pound of battery chemicals.

34. About 60 pounds of batteries are needed to store the energy equivalent of one pound of hydrocarbons.

35. At least 100 pounds of materials are mined, moved and processed for every pound of battery fabricated.

36. Storing the energy equivalent of one barrel of oil, which weighs 300 pounds, requires 20,000 pounds of Tesla batteries ($200,000 worth).

37. Carrying the energy equivalent of the aviation fuel used by an aircraft flying to Asia would require $60 million worth of Tesla-type batteries weighing five times more than that aircraft.

38. It takes the energy equivalent of 100 barrels of oil to fabricate a quantity of batteries that can store the energy equivalent of a single barrel of oil.

39. A battery-centric grid and car world means mining gigatons more of the earth to access lithium, copper, nickel, graphite, rare earths, cobalt, etc.—and using millions of tons of oil and coal both in mining and to fabricate metals and concrete.

40. China dominates global battery production with its grid 70 percent coal-fueled: EVs using Chinese batteries will create *more* carbon-dioxide than saved by replacing oil-burning engines.

41. One would no more use helicopters for regular trans-Atlantic travel—doable with elaborately expensive logistics—than employ a nuclear reactor to power a train or photovoltaic systems to power a nation.

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