

**QUEST CLUB
JANUARY 30, 2026**

**SOLAR FARMS
BENEFITS AND
BURDENS**

C. F. HAIGH, ED.D.

Slide 1 (Opening Slide)

THE SUN

The Mesopotamians called it Shamesh, the Persians called it Mithra, the Egyptians called it Ra, the Greeks called it Helios, the Romans called it Sol, and the Nordic tribes called it Sunne. We call it just plain Sun.

The Romans named the days of the week after the gods of the Sun, Moon, and the five known planets, with the most important day being the one that worshiped the Sun – Sunday. Constantine made it a holiday on March 7, 321.

Many early civilizations constructed monuments to celebrate the sun or track the seasons, Stonehenge being a great example. And we still use the Latin basis when we speak of the Solstice or Solar. We not only track the days of week with the sun, but also the days in a month, the days in a year, and of course our own age. And if you are 50 years old, you have counted at least 18,250 solar days. And obviously all of life produced on this planet, including our own, would not exist if it were not for the Sun.

In essence, the sun is a pretty big deal. So how did this happen?

Slide 2 (Sun Dissection)

HOW OUR SUN WAS CREATED

Stars are created from giant molecular clouds that exist in vast cold regions of interstellar space. Gravity causes these clouds to become dense clumps that pull in more and more material over a period of several million years. As this gas and dust gather, the inner core becomes increasingly dense and hot. In response to this heat and pressure, hydrogen nuclei fuse to form helium, a process releasing energy primarily as high-energy gamma-ray photons and neutrinos, as described by Einstein's famous equation: $E = mc^2$

Essentially, our sun is a colossal nuclear reactor in space continually fusing hydrogen atoms into helium. This process releases a staggering 174,000 terawatt hours of energy per day towards the Earth. To put this into perspective, the earth's total global electricity consumption barely surpasses 24,000 terawatt hours per year. Harnessing even a fraction of the sunlight that touches the earth in one day could not only satisfy the current annual global electricity demand but also provide a surplus capable of supporting additional needs.

So, who discovered solar energy and harnessed this power?

Slide 3 (Edmond Becquerel and Charles Fritts)

THE INVENTORS

The use of the sun for a source of energy can be traced as far back as the 7th century BC when a magnifying glass was used to concentrate the sun's rays to make a fire starter. But the more recent technical efforts to capture the sun's energy began with Edmond Becquerel. In 1839, when he was 19 years old, he noticed an electric current was generated between two elements when they were exposed to sunlight. This became known as the photovoltaic effect. Although Becquerel's work was purely experimental, it marked the origin of solar energy.

The next milestone came nearly 50 years later. In 1883, American inventor Charles Fritts created the first solar cell. His device, made by coating selenium with a thin layer of gold, converted sunlight into electricity, although it was only 1% efficient.

Twenty-two years later Albert Einstein published a paper explaining the photovoltaic effect. Einstein's research clarified how light interacts with certain materials to release electrons, a process critical to the functioning of solar cells. This work earned him the Nobel Prize in Physics in 1921.

In 1954 Bell Laboratories created the first silicon solar cell using a selenium-based design, and in 1958, NASA used these solar cells to power the Vanguard 1 satellite, which remains the oldest human-made object still in orbit.

In 1994 NREL, the National Laboratory of the Rockies, developed a solar cell with 30% efficiency using Gallium Indium Phosphide and Gallium Arsenide. And by the 2020s the commercial adoption of Perovskite and bifacial solar cells, promised higher efficiency with lower manufacturing costs.

So how do solar cells work?

Slide 4 (The Photovoltaic Effect)

HOW DO SOLAR CELLS WORK

They work via the photovoltaic effect. This process involves four steps.

Step 1: Photons are absorbed. Sunlight, made of tiny energy packets of photons, strikes the Photovoltaic Cell (PV cell).

Step 2: Electrons become excited. The PV cell contains semiconductor layers (Positive-type and Negative-type silicon) that form a P-N junction, creating an internal electric field. When a photon hits, it transfers its energy to an electron in a silicon atom, knocking it loose.

Step 3: The electric charge is separated. The internal electric field at the P-N junction forces the freed electrons to move to the N-type layer, resulting in "holes" on the P-type layer, preventing them from recombining.

Step 4: The electric current is generated. Metal contacts on the cell's top and bottom collect these separated electrons and holes. When an external wire connects the contacts, the electrons flow back to fill the holes, creating a DC electrical current. Then an inverter converts this DC power to AC to enter our electric grid.

The key components are therefore: The semiconductor – usually silicon. The P-N junction. And then the Photovoltaic Effect.

Slide 5 (Types of Solar Cells)

TYPES OF SOLAR CELLS

There are more than two dozen types of solar cells, many developed in just the last few years. They vary in size, cost, efficiency, voltage, flexibility, and chemical makeup. They are unique because they serve different purposes and because this is a new and evolving field of science. I'll mention just four.

Crystalline silicon is by far the most common type of solar cell with a current market share of over 90%. There are two types of silicon cells. The first is Mono-crystalline which is made from a single, pure silicon crystal. It has a high efficiency, between 15% and 22%, is a uniform dark color, and performs better in hot environments. The second is Poly-crystalline which is made from multiple silicon fragments. This variation has a speckled blue appearance, lower cost, and slightly lower efficiency than mono.

The third type of solar cell is a Thin-Film cell. These are flexible and versatile and come in three versions. Amorphous Silicon, Cadmium Telluride, and Copper Indium Gallium Selenide.

The fourth type are the more advanced and emerging solar cells. These are sometimes called Passivated Emitter Rear Cells or PERC for short. Another example is Perovskite. This is the fastest growing type and promises high efficiency at a low cost. They can absorb a wide spectrum of sunlight, including both visible and near-infrared wavelengths, making them exceptionally good at converting sunlight into electricity.

Slide 6 (Creating an Industry Standard)

WHO CREATED THE INDUSTRY STANDARD

No single person created the size and technical standards of solar cells. Instead, it was a culmination of seventy years of scientific breakthroughs, industrial innovation, and collective efforts. Organizations like the SEIA, the Solar Energy Industries Association, worked within the U.S. to develop market-friendly codes and product standards, and the IEC, the International Electrotechnical Commission, published crucial international performance and safety standards across the growing global solar market. These other organizations helped modify and create the technical standards we see today. The standard size is currently 152 mm square or 6" by 6".

While it's been the standard for more than a decade, new technologies are producing bigger cells of 182 mm squared and 210 mm squared. These produce a higher power output with fewer cells.

For each cell type, size, and power configuration, there is a technical formula that can match solar panel needs to power requirements. Large DIY construction supply stores like Lowes, provide solar panels and sales personnel who can guide you through installation space, power requirements, panel efficiency, and geographical constraints. Obviously, there are a wide range of different solar panel sizes on a fluid and dynamic market.

Slide 7 (The Manufacture and Marketing of Solar Cells)

MANUFACTURING AND MARKETING

China produces over 80% of the world's solar cells and panels. In comparison, Europe and North America each produce around 3%, with India, Japan and South Korea becoming competitive. Although China has an overwhelming presence in the market, I have listed several US companies that are quickly gaining a market share. First Solar, founded in 1990, was the first US company to produce solar cells and is just 3 hours east of us in Perrysville, Ohio.

While many companies assemble modules in the U.S., the bottleneck has traditionally been upstream with the production of Polysilicon and Perovskite wafers. The new facilities from companies like ES Foundry are crucial for building a complete domestic solar supply chain, reducing reliance on imports for high-quality solar cells.

Traditional solar panels on American rooftops and farm fields aren't exactly subtle or pleasing to the eye. They've been an eyesore for neighbors at times, and surely a pain for homeowner associations to deal with, but the benefits to the environment are substantial. So, where's the balance? Today, companies are striving towards better looking and advanced solar technology. This type of discreet solar cell is currently being integrated into existing roof tiles or ceramic and glass facades of buildings and will similarly be incorporated into agriculture and farm fields.

Slide 8 (Solar Cell Efficiency Formula)

THE EFFICIENCY FORMULA

Over the last decade the cost of solar panels has dropped while their efficiency and power output have improved. Efficiency refers to how well a solar panel converts sunlight to energy and the power output refers to the amount of wattage it produces. Although the panel's efficiency will remain the same under any condition, the power is always dependent on ideal geographic and weather conditions.

This solar panel efficiency formula calculates the percentage of sunlight converted to electricity. Essentially, you divide the electrical power produced by the total solar power hitting the panel, then multiply that by 100 to get a percentage.

Research done in 1961 by William Shockley and Hans Queisser (KVY-SER) defined the maximum theoretical efficiency for converting sunlight into electricity. The Shockley-Queisser limit, called SQ limit, explained why solar panels can't reach 100% efficiency. Their formula set the peak theoretical efficiency for a single-junction silicon cell at 33.7%.

However, emerging technologies like multi-function cells, nanostructures, and concentrator photovoltaics, have exceeded the SQ limit by using multiple bandgaps or concentrating sunlight, but these often involve more complex designs or conditions.

Slide 9 (Acronyms and Watts)

ACRONYMS AND WATTS

Like the military, acronyms for solar energy are frequently tossed around by the industry. In case you are checking them out at Lowe's or Menard's, here are just a few.

1. BMS – Battery Management System
2. CSE – Commercial Solar Energy
3. ESS – Energy Storage System which is also called a Battery Backup System
4. PPA – Power Purchase Agreement
5. PVC – Photovoltaic Cell
6. SPPA – Solar Power Purchase Agreements

Also important are an understanding of kWh, how much you use, how much our community needs for comfort and industrial growth, and how much our nation relies on for people, defense, and industrial growth. The U.S. uses around 4 trillion kilowatt-hours of electricity annually, which translates to roughly 466 gigawatts of continuous power demand or about 12,400 kWh per person per year. Our consumption of energy is second only to China.

Overall Fossil Fuels deliver about 60% of these energy needs, Nuclear about 19%, and Renewables (wind, water, and solar) about 21%. In essence, the U.S. consumes a staggering amount of energy, primarily measured in large units like terawatt-hours (TWh) or quadrillion BTUs, reflecting our status as a leading global energy consumer.

Slide 10 (Energy Influencers)

WHO INFLUENCES OUR ENERGY POLICY

This chart shows some of key influencers guiding our nation's energy policy. The oil and gas industry has had an outsized role in influencing public opinion and supporting politicians who support their interests. During the energy crisis of the 1970s, when major politicians, like President Carter, supported solar panels and renewable energy, the fossil fuel industry supported their opponents. Today, there are over 1500 lobbyists in Washington who are employees of the gas and oil industry.

Energy producing companies have also been an undercurrent in shaping our foreign policies. Our increasing reliance on gas and oil continue to influence our relations with oil producing nations around the world. Large oil reserves have made some nations extremely wealthy and this wealth, and the power to control it, have spawned conflicts and wars. A recent example is Venezuela. It has the world's largest proven oil reserves, estimated at over 300 billion barrels, but production and extraction have been hampered by outdated infrastructure, lack of investment, and sanctions. As a consequence, it has become a magnet for nations who want to control and benefit from these resources.

Subsidies, which I did not include on this chart, are an even greater influence. Today, according to the International Monetary fund, fossil fuel subsidies in the United States total over \$750 billion. This includes \$3 billion in explicit subsidies and \$754 billion in implicit subsidies, which are costs like negative health impacts, climate challenges, and environmental degradation that are borne by society at large, rather than producers.

In comparison, renewable energy subsidies were only \$31.4 billion but at one time were projected to exceed over \$400 billion in the next decade. These projections were in part due to the Inflation Reduction Act (IRA) which was signed into law by President Joe Biden in August of 2022. The IRA remains the most significant climate legislation in U.S. history.

But most of these programs, and their accompanying subsidies and tax breaks, were dismantled when the One Big Beautiful Bill was signed into law last July. While it effectively ended most consumer-facing incentives, it preserved or expanded specific business-focused credits favored by the current administration.

Slide 11 (Burdens)

THE BURDENS

On this chart I have identified seven major objections to solar farms. Some are based on cultural ideals and visions but others are fact based and financially sound. And these can be viewed differently based on geographic locations, climate changes, and personal opinions.

First is Visual & Cultural Objections with four factors. Aesthetics is first. This is where solar panels are perceived as 'eyesores' that clash with natural or rural scenery. The average traveler on a country road would rather see rows of corn and beans than rows of solar panels. Solar panels aren't leafy crops and they sometimes respond with a glare instead of an oink. Another factor is Rural Identity. This is an understandable fear that large solar arrays will fundamentally change the character of our rural community. We, as city slickers, unconsciously identify something as rural when we see a farmhouse, a silo, some outbuildings, a small windmill and some horses or cows in the distance. It's a scenario that reminds me of Bob Sievers, WOWO, and the 'little red barn, on farm, down in Indiana.' A third factor is Property Values. This is where adjoining neighbors and farms will fear their properties will decrease in value. This is especially important to multi-generational farms that have been in the family for more than a century.

The fourth factor are political viewpoints. Politics plays an enormous role in the laws we follow and played a part the recent decision by the Allen County Plan Commission. New rules went into effect last October establishing 1,000-foot setbacks on property lines, height limitations, regulations on commercial-scale developments, and waivers that needed to be reviewed on an individual basis.

These political restrictions were seen by some farmers, as well as many public officials, as an impingement on the rights of the individual property owner. Historically farmers have always had the right to profit from their land as they see fit, to grow the crops or raise the livestock they wish. But just like HOAs can dictate property usage, our plan commission felt obligated to control the rural aspects of our area. This reminds me of a story from my past.

The Second set of objections are about Land Use and the Environment. These include three factors. First is a Loss of Agricultural Land, where productive farmland is taken out of the food cycle. When done frequently and on a large scale this can create a food-chain insecurity. A second factor is Habitat Disruption. This is where wildlife habitats are lost and there is an interference with animal migration and native vegetation. Hunting for wild game and soil recycling and regeneration can also be impacted. Third are Construction Issues which can also impact the environment. This is where soil compaction during construction, changing erosion patterns, increased runoff, and potential water contamination can permanently change the landscape, affecting rainfall patterns and drainage, and risking leakage of toxic metals like cadmium or lead into the soil and groundwater.

The Third area involves and Social Objections. These include two factors. First is Economic Uncertainty. For example, contractual agreements between a landowner and a utility company may involve multiple layers of agreements and multiple legal entities. These complex relations can make it difficult to resolve conflicts and unanticipated ownership changes over the next twenty-five to thirty years. And second, there are Infrastructure concerns especially with rural electrical co-ops like REMC. Remote areas frequently lack updated transformers and transmission lines, and the electrical grid can be easily disrupted.

The Fourth area covers concerns about Water Contamination and the Recycling of solar cells. Water wells are the main source for water in the rural community and runoff from solar panels has understandably been a concern for farmers. There are also uncertainties about the end-of-life management, recycling, and the costs for removing or replacing panels and possibly restoring the land. This finiteness results in significant waste management challenges that are used to extract small quantities of valuable metals from the panels and often require the use of hazardous chemicals.

The Fifth area involves Intermittency and Storage problems. One factor is the fluctuation of cloud cover, rain, and time of day. And naturally, there is a mismatch between solar energy's peak production times – somewhere late morning – and peak consumption demands in the

evening. A second factor is Storage Bottlenecks where current battery technologies, particularly lithium-ion, face high costs and limited lifespans. A third factor is Efficiency, which I mentioned earlier. This is where silicon cell panels convert only 21% of sunlight to electricity and Perovskite cells convert 35%. These efficiency numbers remain lower than oil, natural gas, and coal.

The Sixth area are Supply Chain and Materials. These include two factors. First is Material Scarcity where the production of high-efficiency thin-film and tandem cells rely on rare earth materials. Geopolitical dynamics come into play as China controls approximately 97% of the global market for these minerals. And second, there are International Political and Regulatory Shifts that dictate what and how much can be purchased from non-prohibited foreign sources.

And seven, a final negative, there are significant Up-Front Costs that require \$20,000 to \$40,000 for an average sized home and between \$200,000 and \$600,000 per acre for solar farms. Higher solar costs usually reflect more expensive components. Many solar farms are passive and are funded and installed by utility companies that lease the land, but some owners, particularly large-scale ranchers, prefer to install their own solar grids.

Slide 12 (Return on Investment)

ROI OR RETURN-ON-INVESTMENT

While initial set-up costs for solar can seem prohibitive, the investment rewards can be highly beneficial. Current revenue estimates suggest a solar farm, where all up-front expenses are paid by the owner, can return between \$22,000 to \$45,000 per acre annually. And on passive low-risk farms, where the land is leased to a power company, payback can be between \$500 to \$2000 per acre. In other words, your income from owning a 100-acre solar farm could be as high as \$4.5 million dollars per year, and from leasing, as much as \$200,000 per year. In comparison, 100 acres of corn, where you purchase the seed, fertilize, and plant and harvest the crop, will bring in, for Indiana farmers, as much as \$34,000 per acre. Soybeans maybe \$60,000. Wheat can vary, but most recently it has been a break-even crop.

Another ROI issue are Indiana's electricity costs. These are currently around 15-16 cents per kilowatt-hour for residential users, with average monthly bills often falling in the \$140-\$260 range. Recent costs have risen due to increased demand and fuel prices. And unfortunately, these numbers place Indiana as one of the two most expensive energy markets in the Midwest.

Financial Institutions are aware of all these costs and solar investments and offer 'Green Loans' where the loan is repaid from the revenue generated by the solar farm rather than from the borrower's general assets.

Since the early 2000s, solar energy has become more affordable and is now roughly 75% cheaper than it was in 2014. It has become the fastest-growing source of electricity, with generation capacity roughly doubling every three years. Solar and wind energy are now projected to become the largest source of electricity globally over the next few months. In fact,

last year over 90% of all new electricity capacity added worldwide, came from renewable sources.

Slide 13 (Benefits)

THE BENEFITS

I have grouped these into seven areas.

The first area involves Ecology and Climate Change issues. Here there are four factors. First, solar energy is renewable. We can harness the power of the sun every day without depleting it, ensuring a consistent energy supply that doesn't compromise future generations' ability to fulfill their own energy needs. Second, solar energy is clean. It's a green source of energy and avoids the environmental damage associated with mining or drilling for fossil fuels. It produces electricity without releasing harmful greenhouse gases into the atmosphere and reduces our carbon footprint.

As a result, solar power can and will mitigate climate change and reduce air pollution, contributing to a healthier atmosphere and environment. Fourth, solar energy, like the sun, is a silent, noise-free energy source that can be utilized in remote locations where plants and animals are not impacted by unnatural and disruptive sounds.

The second area involves Economic and Financial Benefits. One factor is a reduction of personal energy bills. Because a significant portion of our electricity is generated from coal and natural gas, this rate largely reflects the cost of fossil fuel-based energy in our state. As I have mentioned earlier, for users of solar energy, this cost becomes a credit after seven years.

A second factor is that farmers no longer have the expense of tilling, planting, cultivating, fertilizing, and reaping crops. And solar panels produce significantly more energy per acre than traditional farming. For example, 1 acre of solar panels produce 200 times more energy than an acre of corn used for ethanol.

A third factor is that homes and especially farms with solar panels often sell for more. But this can be dependent on the age and efficiency of the panels. As more homebuyers prioritize sustainable energy solutions, homes with installed solar energy systems become more appealing.

The third area involves Energy Independence. This is first apparent on a personal level. Homeowners with solar panels are less reliant on the large electrical grids and less affected by geopolitical conditions and fluctuations in energy prices. Essentially, solar panels give you control over your own electricity production, especially in locations that have unstable electricity prices. The only challenge then becomes storage and efficiency.

A second factor is that the energy independence of our nation is critically important during geopolitical conflicts. Although we are producing and refining more oil, we are and have been, responsive to the interests of the fossil fuel industry for over 100 years. Any country with ample solar resources can reduce their dependence on fossil fuels and enhance their energy independence and security.

The fourth area is Maintenance and Labor. Solar energy has few or no moving parts that can wear out and requires minimal upkeep beyond occasional cleaning and routine inspections. Both installation and maintenance can be handled by your solar provider if you opt for a solar lease or power purchase agreement (PPA).

A second factor is that the solar energy industry is also a significant job creator. From manufacturing to installation, maintenance, and support, the industry creates numerous jobs across a wide spectrum of skill levels. As the industry continues to grow, so does its contribution to the economy through job creation.

A sixth area is Agrivoltaics or simply Solar Grazing. Solar farms can integrate solar energy generation with growing crops. Crops create benefits like reduced water use, cooler panels, and diversified income, though careful planning is needed for optimal sunlight and adequate spacing for equipment and animals.

Livestock create second dual use benefit. They can keep grass and weeds down, reducing or eliminating expensive mowing, chemical use, and labor. Also, panels provide shade, protecting animals from intense sun and potentially reducing water needs. Livestock that are commonly raised on solar farms include sheep, goats, and of course, free-range chickens.

Finding the right balance between panel placement and crop and livestock needs is key, with some crop, like leafy greens and berries, thriving in partial shade. Another dual use is planting native flowers, like clover, that support bees and butterflies.

And finally, solar energy is constantly evolving, with Emerging Technology continually improving the efficiency and cost-effectiveness of solar panels. We have witnessed computers, cell phones, and televisions vastly improve during our lifetime. Commercial solar panel technology is currently in the early stages of development with the endpoint product and full benefits still decades away.

Slide 14 (Conclusion)

CONCLUSION

When it comes to deciding if solar farms are right for our area, benefits and burdens become the key. Solar power can significantly reduce our electricity bills, boost property value on both homes and farms, and help protect the environment by cutting down on carbon emissions.

However, the high upfront costs, dependence on sunlight at our Fort Wayne latitude, the costs of energy storage, and public acceptance continue to be limiting factors.

The average Indiana farm size is 270-279 acres, with Allen County averaging around 220 acres. Assuming a local farm is a perfect square, a 220-acre lot with a 1,000-foot setback would leave roughly 44.4 acres of usable space. Although this is a smaller plot of land and will likely need a remote access for maintenance, it can yield between 17,600 and 20,000 mega-watt hours of electricity per year powering roughly 1700 homes annually. If it is an active farm, developed and operated by the owner, it would produce a profit of \$1.32 million per year. If passive, it still would earn more than \$50,000 annually.

For many local landowners and businesses, the financial savings, energy independence, and long-term environmental impact of solar power make it an appealing option. As solar technology advances and costs continue to fall, the advantages are increasingly outweighing the drawbacks, making it a practical and sustainable energy choice for more people. But like a lot of new ideas and technology, the appeal and acceptance of solar panels may take several generations. We have all witnessed some sort of cultural change during our lifetimes, and many of us have resisted. I have an example to share: Style changes for women's dresses.

Also, many diverse cultures exist within Allen County, and many have embraced solar energy. The Amish, for example, a conservative Christian group noted for not driving automobiles, have been installing solar panels on many of their buildings and homes. There are also several local suppliers of solar panels in our county, including box stores like Lowe's, Menard's, and Home Depot, and also several commercial installers, who are eager to suit your interests.

While solar energy does come with its set of challenges, I believe the Benefits significantly outweigh the Burdens. We know the sun's energy is unending, free, plentiful, renewable, and environmentally friendly. We also know that it's foreseeable future as a power resource is unlimited and can lead to significant climate healing and cost savings over time. And finally, I personally find great comfort in the independence that solar energy provides, and in the feeling that I am at peace with nature and not a burden to our future.