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History and Future of Solar Energy

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Abstract

My paper will be about how solar energy has developed over time and what it could look like down the road. It is an alternative to fossil fuels and nuclear energy. Right now, there is a shift that is pushing people away from coal and gas and going to renewable sources such as solar, wind, and other renewables instead. It started in the U.S. when the photovoltaic effect was discovered. Which further lead to higher technology which is used today. Since then, there are now tax credits towards solar which can help a buyer be able to purchase solar and eventually save them money on their monthly electricity bills. Solar energy has significantly grown to be more popular over the past couple years.

Solar energy has become popular for its reduction in cost and and its government incentives which make it easier for people to purchase a system as said previously. Such as federal tax credits, state level rebates, and different financial mechanisms. This paper will go over the different incentives along with policies that have helped solar not only be available for businesses but for residential properties as well.

The future for solar energy is bright. The technology moving forward is only going to progress. Along with people becoming more informed on solar and what it can do for their specific unit. This happens with promoting renewable energy sources, learning more about climate change, and being satisfied with change. The government has a major role in solar energy and will come up with new incentives and policies to continue to grow the solar industry.

Technology advancement over the years has put solar where it is today. The new policies that have been made has been a huge factor as well. There is a lot of momentum behind solar energy right now and I don’t expect it to change. With this momentum it has put solar very high on the list for sustaining the environment. Being able to understand the different incentives and

the future plans solar energy has is very important for industry participants to contribute to solar as it continues to grow in the U.S.

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The sun is the most powerful energy source in the universe. The Sun enabled life to begin and supported it for 4.5 billion years. It is 865,000 wide and approximately 93 million miles away from Earth (science.nasa.gov). The core of the sun reaches temperatures of 27 million degrees Fahrenheit. At the surface it reaches 10,000 degrees Fahrenheit (nasa.gov) The Sun is comprised of hydrogen and helium gas and held together in a sphere by its own gravity. Our Sun is a star that will eventually die but not in our lifetime thankfully, it is estimated that it will last another five billion years (phys.org).

Earth lies in what is called the "Goldilocks Zone". Our planet is in just the right location to receive the energy the Sun produces. This energy is necessary to create chemical reactions. The Sun creates energy through a fusion reaction which began when a massive cloud of dust and gas collapsed together. This is known as the Nebula Theory. When this occurred, the Sun was formed and began emitting light and heat and began fusing hydrogen which created solar energy (phys.org). Nuclear fusion is what releases energy from the Sun in the form of light and heat. It is in the core of the Sun where the energy is produced when hydrogen atoms are converted into helium. The core is under extreme pressure and heat, and it is only in the core where heat is produced. The remainder of the Sun is heated by the core and this energy eventually escapes the and passes through space as sunlight. The amount of energy released by the Sun is equivalent to approximately ten megatons of TNT per second. In an average year, 342 watts of solar energy fall on every square meter of land surface on the planet. That is as much energy as 44 million large power plants producing one billion watts of electricity per year.

Why is this all important? Because without the Sun, not only would we not have life, or the light and warmth it provides, we would not have solar energy. Solar energy is not a modern invention. The solar cell as we know it today is a recent invention. However, humans have been

harnessing the Sun's energy for centuries. As far back as the seventh century B.C., man was using glass to concentrate the sun's rays to make fire. In the first century A.D., the Roman's used windows in their buildings that faced to the south to warm the interior of their bathhouses. This became so common that by the sixth century there were rules or "codes" created to ensure people had clear access to the sun. The first recorded solar device was invented in 1767 by a Swiss scientist Horace de Saussure (energy.gov). His invention was just the beginning of the modern age of harnessing the sun's energy to benefit humanity.

Humans have been aware of electricity ever since they walked the earth, but it has only been put to purposeful use for approximately 250 years. Since Ben Franklin's experiments we have studied and learned how to harness electricity and put it to use for the betterment of humanity.

Early applications of electricity included the telegraph, light bulb, and telephone. Later, appliances were powered by electricity, and people were entertained by the radio and television. Electricity made it possible to interconnect and communicate with people around the world. It had applications in the medical field that saved or improved people's lives (nasa.gov) The applications for the use of electricity continued to grow. The increased use of created industries which drove the global economy. The fossil fuel industry grew exponentially from the generation and use of electricity. Between 1900 and 2000, the amount of coal, oil, and natural gas used in generating power grew 1500% (nasa.gov). Access to electricity was considered a fundamental requirement for first world nations and key to economic growth. In developed nations, it raised the standard of living tremendously. Electricity enabled people to stay warm, or cool, keep food longer under refrigeration, and make water potable. Unfortunately, access to electricity was not

ubiquitous and took many years to reach the majority of people in the world. To this day there are people who lack access to commercial electricity.

Thomas Edison's invention of the light bulb was one of the first major uses of electricity. Light bulbs connected to small generators allowed wealthy New Yorkers to illuminate their homes in the 1880s. The light bulb was in direct competition with the gas light, and made people aware of a new energy source, electricity.

The rise of the light bulb created the need for electrical generation plants, the first of which was built in Manhattan, New York. Next was the creation of the power grid. The grid was necessary in order to make electricity economically viable. Larger generation plants were built, and more customers were sold, the two combined created more efficiencies in generation and the cost to deliver to end users, thus creating "economies of scale" (instituteforenergyresearch.org).

Politics and industry are not a new thing and were involved from the beginning of the commercial electricity industry. Whether it was corrupt politicians holding up permits to build infrastructure through extortion or demand of bribes, or local government threatening profitability by imposing arbitrary rules, early electricity companies faced many challenges as they built their networks and worked to make electricity accessible and affordable for everyone.

Fast forward to the 21st century where electricity is commoditized and rarely given much thought unless one is paying their electric bill. Electricity is an integral part of life. We need electricity to power the things we depend on. The lights, the air conditioning, the refrigerator, cell phones and computers and the networks they run on, television, tools, and increasingly automobiles, you name it, the list goes on and on. In 2022, Americans consumed over four trillion kilowatt hours of electricity. This is fourteen times the amount consumed in 1950

(eia.gov). Heating and cooling consume the most electricity in residential homes, while computers and office equipment are the biggest consumers in the commercial sector. The demand for electricity in the United States will continue growing at approximately 1% per year over the next 26 years. Global consumption is also expected to grow as access to the electric grid expands.

Electricity, when consumed, is clean and safe. However, the generation of electricity can have a negative effect on the environment. As of 2021, 61% of electricity was generated by burning fossil fuels (eia.gov). When fossil fuels are burnt, they emit harmful byproducts such as: carbon dioxide; carbon monoxide; sulfur dioxide; nitrogen dioxide; particulate matter; and mercury. Nuclear power plants produce radioactive waste. Lastly, powerplants and the distribution infrastructure have a footprint. They affect the visual landscape and may disturb the natural environment they are located in or pass through.

Climate change is driving the urgency to move to cleaner energy sources. 196 nations under the Paris Agreement agreed to reach carbon neutrality by 2050 and in order to do this a transition away from fossil fuels is required (twi-global.com). The desire to make the shift away from fossil fuels has been a popular idea for several decades, however, competing energy sources such as gas, oil and coal have been far more economical. Recently, costs for solar and wind have rapidly decreased and are now considered viable options for clean energy. There are still many challenges to transitioning away from fossil fuels and global change will require massive cooperation from everyone. While it is a popular opinion, change has been slow due to the costs of replacing systems, and reliance on fossil fuels in certain industries, and the lack of efficient storage systems. There is no question that the shift to clean, renewable energy sources will

provide many benefits for the environment and public health, it will also create jobs and create more access to energy.

This paper will focus on one clean energy alternative, solar energy. It will go over the past and future of modern solar technology and its place in the shift to clean, renewable energy. Solar energy in its many forms has been around for a long time. Unfortunately, in the past solar wasn't deemed economical for widespread development, and government policies were not in place to incentivize adoption. These things have changed and data shows that solar is rapidly growing. Since 2013, solar has experienced an average annual growth rate of 24% (seia.org). This is due to rapidly shrinking costs, increased demand, and government incentives for residential, commercial, and utility grade projects. There is still pressure on pricing due to supply chain issues, however, domestic manufacturing capacity is increasing which should lead to price stabilization (energy.gov). These are positive signs for solar which over the last four years has added more generating capacity to the grid than wind, natural gas, coal, or other forms of energy production. The policies and incentives from the government will also help with the pricing by making it easier for a buyer to purchase a system for their specific unit.

The sooner people want to learn more about solar energy and all of the benefits it can bring to a residence or a business the better off they will be in the long run. People are not used to change in today's society. Everyone wants to stick to how things have always been. Solar energy is one of those things that is definitely worth looking into. The government is basically setting it up to make it easier to purchase a system that will lower your electricity bills substantially if not completely. It is a cleaner and safer way to generate energy. With that being said, the solar energy industry is only going to keep getting better year after year. There will be new policies and incentives from the government to help make this process easier. The

technology is only going to start generating more power and most likely with less effort. All people have to do is start to learn more and more about solar energy. It has already done great things and it can only be expected that there is more to come. The future is very bright for solar.

Early Discoveries and Experiments

The first solar cell was developed in 1883 by and American inventor named Charles Fritts. This was the first successful conversion of sunlight into electricity. The following year, the first rooftop solar system was installed in New York City. But the industrial revolution was going on at this point which did not help solar at all. During this time is when the modern steam turbine was invented and it out did solar in these early times. The potential of solar energy as a major source of power was largely overlooked for many years until the dawn of the space race in the mid-20th century (revolve.org). It was not until the 1950s when solar energy was brought up again. NASA went to researches in hopes to find a trustworthy energy generating technology that was strong enough to survive the vacuum of space.

With this, the researchers learned something new. The discovery of using silicon instead of selenium in solar cells was a significant breakthrough that contributed to improving solar cell efficiency (revolve.org). This was quickly adopted by the space program and by 1972 almost every United States satellite was running on solar energy. This was also when oil prices were through the roof. Which helped the start of renewable energies being used instead. But, once again the urgency for solar started to become weaker in the 1980s and 1990s. It wasn't until the 21st century when people decided to start taking solar energy seriously. This was because of the rise of awareness of climate change and low-cost sources of energy. The signing of the Kyoto Protocol in 1997 marked a turning point in global efforts to address climate change and promote renewable energy sources like solar power (revolve.org). The demand for solar cells continued to

grow around the world. With that there were bigger facilities being built. This made the price of solar cells to drop drastically. Solar cells have been compared to computer chips because of the fall in price due to the manufacturing economies.

Establishment of the National Renewable Energy Laboratory (NREL)

The National Renewable Energy Laboratory (NREL) was initially established as the Solar Energy Research Institute (SERI) in July 1977. Its primary focus was on advancing research and development in solar energy technologies. In September 1991, it was designated as a national laboratory of the U.S. Department of Energy (DOE), broadening its mandate to include various renewable energy sources beyond just solar (nrel.gov). Here is a small timeline of important events that lead to the establishment. This started back in 1973 when tensions were high from helping Israel. The price of oil per barrel was high which later led to Saudi Arabia to stop all oil exports to the United States. President Gerald Ford established the Energy Research and Development Administration (ERDA) in 1974. ERDA was created to coordinate federal energy research and development activities, including those related to solar energy (nrel.gov). Establishing SERI was the United States first time gaining control of the energy problems with a center of innovation to make renewable energy technology instead of with policies.

Moving on to March of 1976, the ERDA requested a proposal for organizations that are interested in operating SERI. The Midwest Research Institute (MRI) collaborated with Colorado Governor Richard Lamm and the state legislature to submit a plan to the Energy Research and Development Administration (ERDA) to establish the Solar Energy Research Institute (SERI). This proposal included a plan to designate site atop South Table Mountain in Golden, Colorado, as the future home of SERI (nrel.gov). The ERDA selected the Rocky Flats Plant test site for research done by the federal wind program. In March of 1977, ERDA selected MRI to operate in

Golden, Colorado. On July 5, 1977, the Solar Energy Research Institute (SERI), the first federal facility dedicated to developing solar power, officially opened its doors. Paul Rappaport, a researcher from Princeton was appointed as the director of SERI (nrel.gov). The next month President Carter made the U.S. Department of Energy which replaced the ERDA. Later that year, SERI began research for the federal wind program. Fast forward to 2010, NREL opened two parts of its Research Support Facility. The National Bioenergy Center set a goal for NREL back in 2000. Which was to create affordable cellulosic ethanol with two separate platforms. Those platforms being biochemical and thermochemical. This goal was accomplished in 2012. NREL then completed construction on multiple different facilities on its South Table Mountain campus. These facilities include, Integrated Biorefinery Research Facility (IBRF). This LEED Gold-certified facility focuses on research related to the conversion of biomass into biofuels and other bio-based products (nrel.gov). The Vehicle testing and integration Facility (VTIF). This facility is dedicated to testing and integrating advanced vehicle technologies, including electric and hybrid vehicles, to support research in transportation electrification (nrel.gov). Another is the NREL Café. A LEED Platinum-rated facility that played as a model for sustainable cafeterias. It demonstrates sustainable practices in food service, energy efficiency, and waste reduction (nrel.gov). NREL Parking Garage. This five-level parking structure is designed to be highly energy-efficient, surpassing standard building codes by 90%. It features a significant solar PV array on the roof, providing renewable energy for employees and electric vehicle charging stations (nrel.gov). And the Energy Systems Integration Facility. This facility focuses on research and development in the integration of renewable energy systems into the electricity grid. It was recognized as the Laboratory of the Year by R&D Magazine in 2014 for its innovative research capabilities (nrel.gov).

2020 was a huge year for solar energy. NREL (National Renewable Energy Laboratory) has been at the forefront of solar energy research for years. Achieving two world records for highest solar conversion efficiency and the record under one-sun illumination with their six-junction solar cell demonstrates significant progress in advancing solar technology (nrel.gov). The Advanced Research on Integrated Energy Systems program launched to give a real-time testing for equipment that connects with the electrical grid. This year, Jennifer Granholm who is the Secretary of Energy, came back to the Flatirons Campus to announce the Net Zero Labs initiative. This tasked NREL and three other national labs by eliminating all greenhouse gas emissions to get carbon neutrality (nrel.gov).

Evolution of Solar Policy and Regulations

There have been many different approaches to energy policies. One being adopting the Federal energy legislation which increases the use of renewable energy through mandates and tax incentives. Along with Federal environment policies that affect renewable energy use. These have been passed by Congress in the last couple of years with a huge effect on development of renewable energy. State legislation has indeed played a crucial role in stimulating the demand for renewable energy by implementing policies and programs to promote its adoption. Agriculture legislation has also been leveraged to support renewable energy initiatives. Additionally, at the federal level, landmark policies like the National Energy Act of 1978 and the Public Utility Regulatory Policies Act of 1978 (PURPA) have been instrumental in shaping the renewable energy landscape in the United States. PURPA was a significant piece of legislation aimed at promoting energy conservation and increasing the deployment of renewable energy resources in the United States. (Duffield, Collins, 2006). A goal for that PURPA had was to foster the

development of biopower by requiring utilities to purchase electricity generated from small power plants that use renewable energy sources.

There are also different renewable energy programs from the state. These programs are designed to help or encourage the growth in the use of renewable energy. States do this by using tax credits, production incentives, and renewable energy mandates. Renewable Portfolio Standards (RPS) are policies implemented by many states across the United States to promote the development and deployment of renewable energy resources. Under an RPS, utilities are mandated to generate or procure a specific percentage or amount of their electricity from renewable sources such as solar, wind, biomass, geothermal, and hydroelectric power (North Carolina Solar Center, 2005). Minnesota is the most aggressive state in promoting renewable fuels. This also makes there be consumption mandates for ethanol and biodiesel.

Environmental policies will stimulate the demand for renewable energy. Policymakers recognize the significant opportunity to reduce pollutants and greenhouse gas (GHG) emissions by transitioning from fossil energy to renewable energy sources and bioproducts derived from agriculture Some prime examples of this are ethanol and biodiesels. Ethanol, a type of renewable biofuel commonly produced from crops such as corn, sugarcane, or cellulosic feedstocks, indeed offers several environmental benefits when used as a fuel additive or substitute in transportation (Environmental Protection Agency, 2002). Along with that, biodiesels have a lot of desirable environmental properties. They are nontoxic, the exhausts emit less toxic air emissions, carbon dioxide, and particulate matter than petroleum diesel. It is also biodegradable.

Milestones in Solar Technology Advancements

From 1954 to 1996, the United States lead the solar charge. This rapidly changed in 1997 where Japan had the most solar capacity installed until 2004. Germany then took the lead in 2005 to 2014. The next year China took over as the leader of solar energy output and still is to this day. Here is a small timeline of the history of solar output through the years.

- "1977: The world production of photovoltaic cells exceeded 500 kW.
- 1982: Worldwide photovoltaic production exceeds 9.3 megawatts.
- 1983: Worldwide photovoltaic production exceeds 21.3 megawatts, with sales of more than $250 million.
- 1999: Cumulative worldwide installed photovoltaic capacity reaches 1000 megawatts" (astdtsolar.com).

"As of 2020, the world now has 583.5 GW of operational solar" (astdsolar.com). With the growth of solar came the start of installing power plants. These plants are huge installations of solar panels in cleared out land to try and generate as much power as possible. Power from these plants can be used on a city-wide scale and can also be used to power entire theme parks. Disneyworld is one example of that.

Rise of Photovoltaic Installations

The global PV base grew significantly again in 2022 reaching 1 185 gigawatts of cumulative capacity. Not just in the United States but around the world. Multiple countries have made policies to help speed up PV in line with Europe along with national energy sovereignty decisions in 2022.

China is still leading the way, by adding 106 GW of 44% of new capacity to reach 414,5 GW of cumulative capacity, over double than Europe (iec.ch). On the other hand, Europe

dominates because of their percentage that comes from solar. One of the only systems to be contracted in 2022 was the American market. The IEA puts this result on the influence of trade issues and grid connection. India for example is one of the emerging countries with amazing growth rates. By installing 18,1 GW. These being mostly in centralized systems which helps the penetration rate a lot.

The International Electrotechnical Commission (IEC) plays a critical role in developing international standards for photovoltaic (PV) systems, which are essential for ensuring the safety, reliability, and interoperability of solar energy technologies. The IEC contributes to standardizing PV systems with development of international standards, technical specifications for rural electrification, recognition by international organizations, and having a basis for testing and certification (iec.ch). There are two IEC Conformity Assessment Systems that are in charge of the PV systems, parts, and installations. The IECEE which is the IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components, has a program that gives access to qualified testing laboratories for the certification of PV components and modules with relevance to the IEC Standards (iec.ch). The IECRE is the IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications (iec.ch). The strategy behind that is to make a consistent electricity generation and supply. It's an internationally accepted CA system for all power plants that are creating, converting or storing solar PV and wind or different types of marine energy.

Impact of Federal and State-Level Incentives

Most rebates or tax credits and renewable energy certificates for new solar customers do not directly impact the solar ITC. But they can lower the credit amount if the total cost of the inst6allation is lower. The utility rebates are subtracted from the cost of the system before the tax

credit is calculated into it. Along with that, the payments received for renewable energy certificates can be considered as taxable income. Which could potentially increase the federal tax liability. As far as the state government rebates go, they generally will not reduce the federal tax credit “State tax credits for solar installation typically don’t affect federal costs directly. Still, claiming state tax credit might raise reported income on federal taxes due to reduced state income tax deductions, which can affect federal tax liability” (forbes.com).

Along with solar ITC at the federal level, some states offer incentives for new solar purchases. Each state has specific details that go into their incentives. Certain states offer additional tax credits to go toward system purchases. These incentives work similarly to the solar ITC except for the tax credit gets deducted from any state taxes that are owed. The amount of tax credit is different depending on the state. State government rebates work a little bit differently. These are typically a set amount of money that is given to those who purchase a system or other solar technology such as solar water heaters or solar batteries. These are usually available regardless depending on whether the homeowner owes any federal taxes or not. There is also a Solar Renewable Energy Certificate (SREC) that is a part of the EPA Green Power Partnership which is a state-level solar incentive. “SREC markets operate on renewable energy certificates the symbolize the rights to non-power aspects of renewable electricity generation. These SRECs represent each megawatt-hour generated from solar systems” (forbs.com). States with SREC markets give homeowners and businesses with solar systems a chance to lower their energy costs by selling associated SRECs to utility companies. The monetary value of an SREC is determined by supply and demand. A lot of the demand comes from electricity suppliers that are needing to comply with their state’s Renewable Portfolio Standard (RPS) or needing to pay a compliance premium.

"Along with rebates and tax incentives at the federal and state level, there are several other potential avenues to save on the cost of installing solar panels" (forbes.com). There are also local utility companies that offer rebates for installing PV systems. These are not included in income taxes. The rebate amount is taken away from the total system cost before calculating the solar tax credit. Subsidized loans are also offered. They are offered by the state entities or local businesses and they can help in financing the purchases of solar systems. Installers of these systems can also help the buyers by informing them of local solar programs such as these subsidized loan options. Lastly there are tax exemptions. These property tax exemptions allow homeowners or business owners to take away the increased value from a solar system when they assess the property tax. Property taxes are locally collected. Because of that, some states allow local taxing authorities to offer this solar-related tax incentive. The bottom line is, "With tax credits and other benefits at federal, state and local levels, it's a great time to go solar. While solar energy systems can be pricey upfront, the relief from these incentives and long-term ROI of solar panels can make them a wise investment" (forbs.com).

Technology Innovations Driving Growth

Recently there have been five new innovations to solar and the Photovoltaic Technology. Here is a brief summary of each of these innovations and what they do. Starting with the Perovskite solar cells.

1. Perovskite Solar Cells

   "Perovskite solar cells are a breakthrough innovation. These cells offer a cheaper and more efficient alternative to traditional silicon cells, dramatically increasing the accessibility and efficiency of solar power" (tamesol.com).

2. Transparent Solar Cells

   These solar panels have a special innovation particularly for BIPV. These panels can be put into windows or glass surfaces which opens up a lot more opportunities for solar harvesting in buildings without changing the aesthetics.

3. Floating Solar Farms

   This is a novel concept where the solar panels would be installed on bodies of water. By doing this it will save land space but will also benefit the panel efficiency because of the cooling effect that water has.

4. Solar Skins

   This innovative technology allows it to be possible to customize the appearance of the solar panels which will make them blend in with its surroundings. This is appealing for residential and commercial buildings to keep the aesthetic that is wanted.

5. AI-Optimized Energy Systems

   This is a cutting-edge innovation. “AI algorithms can predict energy production and consumption, enabling smarter energy management and integration with the grid” (tamesol.com).

Case Studies of Successful Solar Projects

A great example of this would be Kit Carson Electric Cooperative. They achieved a huge environmental milestone. This being that customers in their service area which would be around Taos and Santa Fe, New Mexico, will now have 100% of their daytime electric use. This all being provided by solar. Delivering 100% daytime solar power to members through locally built

and maintained solar arrays, coupled with battery storage, is a significant achievement that demonstrates a commitment to both clean energy and cost savings. By meeting member demand for clean power while simultaneously reducing costs, your organization is not only responding to the preferences of your members but also contributing to broader climate change action initiatives in your state (cleantechnica.com). KCEC celebrated this milestone at the opening of the new Taos Mesa Solar Array. With the switch flipped on that project, the fossil fuels that were left over from daytime power use in that service area ended. Installing 43,680 solar panels across approximately 170 acres is a substantial investment in renewable energy infrastructure. This scale of solar deployment significantly boosts the cooperative's solar power capacity, bringing it to a total of 41 megawatts (cleantechnica.com). This is just one example of showing what solar can do for a community or an area. More of this can be expected in the near future.

Capacity Deployment and Market Trends

In each quarter, the National Renewable Energy Laboratory (NREL) does a Quarterly Solar Industry Update. This is a presentation of the technical trends in the solar industry. These presentations focus on the supply and demand, system price and module, investment trends and business models, along with updates on the United States government programs that support the solar industry (energy.gov).

Here are some important updates from the fall quarterly update from 2023. The first half of 2023 there was a huge increase in photovoltaic installations. Mainly in China and Germany but also in the United States. But the installations started to shrink in Australia and India. “The U.S. Energy Information Administration (EIA) projects the percentage of U.S. electric capacity additions from solar will grow from 45% in 2022 (17 gigawatts alternating current [GWac]) to 56% in 2023 (31 GWac) and 62% (41 GWac) in 2024” (energy.gov). The United States had their

biggest H1 ever in 2023 installing 11.2 GWac. Increasing 44% year after year. Along with installing around 7.7 GW-hours of energy storage onto the electric grid which was upward of 32% which is 8% year after year because of the growth in all of the sectors. On the import side of things, the United States imported 25.1 GWdc of PV in H1 of 2023 which was well over double from 2022. Most of these panels that were imported were taken away from Section 201 duties which made them too likely be bifacial. There was a significant amount if thin-film modules that were also imported. 1.5 GWdc of cells got imported in H1 of 2023 that was up 28% year to year. As of right now the United States is not on track to reach the 5 GE quota exemption limit for Section 201 tariffs (energy.gov).

Cost Reduction and Economic Viability

"The cost of solar has consistently dropped over the years, making it increasingly competitive with traditional energy sources. As economies of scale and technological advancements continue, solar farms will become even more economically viable, attracting further investments and driving down costs" (linkedin.com). There are several cost benefits that come with using solar. Starting with reduced electric bills. Absolutely, installing efficient solar panels can have a transformative impact on your electricity bills. Reduced dependency on traditional power sources, lower or eliminated electricity bills, long term savings, financial incentives, and environmental benefits are ways that help with that (energy5.com).

Not only will buyers save money on future electricity bills but it also could increase the value of your property. Which is the next benefit. The installation of solar panels can increase the value of residential properties, making them more attractive to potential buyers (energy5.com). The third benefit is one that has been talked about before which is the tax incentives and rebates that solar panel buyers are able to receive. Government incentives play a crucial role in

promoting the adoption of renewable energy sources like solar panels (energy5.com). Not only are there ways to reduce the cost of the systems for buyers, but by purchasing solar it can save homeowners money in the long run all while potentially making them more money by raising the property value.

The ROI on solar panels is incredible as well. There is a quick payback period where buyers can expect to recover their initial investment in five to seven years. This also depending on energy consumption, location, and the incentives that are available. The long-term savings period is after the payback is complete. Now buyers can enjoy the savings that are made from the solar panels. Solar panels have a lifespan of over 25 years. This meaning the savings over that time can be substantial. Buyers can also make profit from excess energy. Depending on the region, homeowners can sell the extra energy that was generated back to the grid. This system allows owners of solar panels to make income which also increases the ROI on their investment.

Key Players in Solar

There are multiple solar industries across the nation. Some bigger than others while some are more successful. Here are the top five solar companies that are leading in this industry. Starting with Tesla, Inc. While being known mostly for their vehicles, tesla has made a big impact in this industry. Tesla's acquisition of SolarCity was a pivotal move that bolstered its position in the renewable energy market. By integrating solar energy solutions with its existing suite of products like electric vehicles and energy storage, Tesla has created a more holistic approach to sustainable energy. The sleek design of Tesla's solar panels and the efficiency of their energy storage solutions like the Powerwall appeal to consumers who prioritize both aesthetics and performance in their renewable energy choices (green.org). Another front runner is SunPower Corporation. SunPower Corporation indeed stands out as a leader in the solar

industry, particularly known for its high-efficiency solar panels. Their Maxeon solar cells have been at the forefront of pushing the boundaries of solar technology, achieving some of the highest efficiency rates available. This level of efficiency makes SunPower panels an attractive option for both residential and commercial installations, as they can generate more power from limited space compared to traditional solar panels. (green.org). The next company has made a name for themselves because of their thin-film solar technology. This company being First Solar Inc. First Solar is a prominent player in the solar industry, renowned for its thin-film solar technology. This technology has demonstrated high efficiency and cost-effectiveness, particularly suitable for utility-scale solar projects. By specializing in large-scale installations, First Solar has established itself as a major contributor to the expansion of solar energy on a global scale. (green.org). Next is Canadian Solar Inc. who is a global player in this industry. They not only include solar but modules, inverters, and energy storage solutions. They have built their reputation around the world based on quality and reliability. They are not only involved in manufacturing solar products but they are a significant player in the development and operation of solar projects. Doing this has helped expand solar energy around the world (green.org). Lastly is JinkoSolar Holding Co. JinkoSolar Holding Co. has emerged as a significant player in the global solar industry, recognized for its high-quality and cost-effective solar panels. The company's rapid rise to prominence is a testament to its commitment to innovation and customer satisfaction. (green.org). The landscape for renewable energy is growing, and solar is at the front of it. Along with numerous others in the solar industry, are pivotal in driving the transition towards a cleaner and more sustainable energy future. As the demand for clean energy escalates, their contributions in developing high-quality, cost-effective, and innovative solar technologies are crucial in making solar power a mainstream and indispensable source of electricity.

Environmental and Social Impact of Solar Energy

Solar energy is a renewable source of power. Its role is to reduce the greenhouse gas emissions and mitigate climate change. This protects humans, wildlife, and ecosystems. "Solar energy can also improve air quality, reduce water use from energy production, and provide ecosystem services for host communities through carbon sequestration, pollination, and ground and stormwater management" (energy.gov). The site of the system needs to be decided on based on the effect it will have on the local wildlife, their habitat, along with the soil and water sources. DOE's Solar Futures Study has presented many scenarios for solar energy deployment that could eventually help the United States have a carbon free grid by 2035. "According to the study, solar energy development could require as much as 5.7 million acres of land, which is about 0.3% of the contiguous U.S., by 2035. As deployment of solar energy projects continues to increase, having a better understanding of how solar energy infrastructure can impact wildlife and the surrounding environment will help in developing strategies and technologies that can avoid or minimize adverse impacts and maximize benefits" (energy.gov).

There is research done by SETO on solar, the environment, and the wildlife that lives there. The Solar Energy Technologies Office (SETO) plays a vital role in advancing solar energy research, development, and deployment in the United States. Through its funding programs and technical assistance initiatives, SETO fosters collaboration among diverse stakeholders and promotes the adoption of solar energy in an environmentally responsible manner (energy.gov). The research on wildlife and the environment includes a focus on environmental justice principles and equity. They understand the improving the conservation outcomes will help the wildlife can live a safe and healthy life. By maximizing the ecosystem

services, it can benefit the livelihood of most communities. These research projects happen often and stakeholders are there to give research objectives with communities values and needs being important. Also implementing practices to have differences between the teams, and having conversations to try and push participation from technology students. As well as students in engineering, science, and mathematics.

Federal Tax Credits and Incentives

With purchasing a solar panel system there are different tax credits and incentives that are available for the buyer. “A tax credit is a dollar-for-dollar reduction in the amount of income tax you would otherwise owe” (energy.gov). There is a tax credit called the federal residential solar energy credit. This can be acquired on federal income taxes for a percentage of the cost on a system that a buyer purchases. These installations must be finished during the tax year. The extension and adjustment of the Investment Tax Credit (ITC) for solar photovoltaic (PV) systems provide important incentives for renewable energy adoption over the coming years. The breakdown of these changes are from installations starting in 2020 and expiring in 2035 (energy.gov). There is also no limit to the amount that can be claimed. Here are some credentials that can make a buyer eligible for the federal solar tax credit along with the expenses that are included.

- If the solar PV system is owned outright, whether it was purchased with cash or by financing, and are not leasing the system or entering into a power purchase agreement (PPA) with a solar company, you are eligible to claim the Investment Tax Credit (ITC) directly (coda.io).

    - If you purchased an interest in an off-site community solar project and the electricity generated is credited against your home's electricity consumption, you may be eligible to claim the Investment Tax Credit (ITC) under certain circumstances (coda.io).

- The Investment Tax Credit (ITC) for solar photovoltaic (PV) systems can only be claimed for the "original installation" of the solar equipment. This means that the tax credit is available for new solar PV systems or systems that are being used for the first time (coda.io).
- Solar PV panels or PV cells used to power an attic fan, but not the fan itself, are eligible for the federal Investment Tax Credit (ITC) in the United States (coda.io).
- Contractor labor costs for onsite preparation, assembly, or original installation of solar energy systems, including permitting fees, inspection costs, and developer fees, are generally considered eligible expenses for the federal Investment Tax Credit (ITC) in the United States (coda.io).
- Balance-of-system (BOS) equipment, including wiring, inverters, and mounting equipment, is typically eligible for the federal Investment Tax Credit (ITC) in the United States when installed as part of a solar energy system (coda.io).
- Energy storage devices with a capacity rating of 3 kilowatt-hours (kWh) or greater are eligible for the federal Investment Tax Credit (ITC) if installed as part of a solar energy system after December 31, 2022 (coda.io).
- Sales taxes on eligible expenses related to the installation of solar energy systems are generally considered eligible for the federal Investment Tax Credit (ITC) in the United States (coda.io).

However, other incentives that a buyer receives can affect the federal tax credit such as the rebate from electric utility to install the solar system, payment fir renewable energy certificates, and from state government. The state tax credit usually do not reduce the federal tax credits. When you receive a state tax credit for installing solar panels or for any other qualifying expense, it can affect your federal income taxes in a couple of ways (energy.gov).

State-Level Rebates and Programs

There are different rebates and programs for each state. Here is a table comparing Illinois incentives for solar panels.

“Illinois solar incentives

Illinois incentive	Description	Eligibility	Estimated value*
Residential clean energy credit	This federal tax credit reimburses you for 30% of the cost of a solar system.	All Illinois residents	About $7,200, based on the national average cost of an 8 kW solar array.
Solar property tax adjustment	When you have a solar system installed, you can ask the tax assessor to calculate the property's value as the lesser of whether it had the solar system or a conventional heating and cooling system.	All Illinois residents	About $497 a year, but the figure will vary based on home price, solar installation and local taxes.
Commonwealth Edison Co. (ComEd)	The utility company offers a rebate to its customers for installing solar	ComEd customers	Up to $300 per kilowatt capacity for an eligible

Distributed Generation Rebate	panels and another rebate for installing an energy storage device.		solar system and up to $300 per kilowatt for an eligible energy storage device.
Ameren Illinois Smart Inverter Rebate	The utility company offers a rebate to its customers for installing a smart inverter.	Ameren Illinois customers	Up to $300 per kilowatt capacity
Illinois Shines	This statewide program provides upfront funding for 15 years' worth of solar renewable energy credits (see below).	All Illinois residents	Varies
Illinois Solar for All	This statewide program covers all of the upfront costs of a solar system for residents who earn less than 80% of the area median income.	Income-eligible Illinois residents	Varies
Net metering	Net metering allows you to sell excess solar power back to the utility. Illinois utility companies are required to provide credits on your bill at the full retail rate.	ComEd, Ameren and MidAmerican utility customers	Varies
Solar renewable energy credits, or SRECs	Illinois residents who install solar panels earn one credit for every 1,000 kilowatt- hours produced by	All Illinois residents who own solar panels	Varies

	their solar panels, and can then sell those credits.		
Chicago's Green Building Permit Program	This citywide program expedites the permit process and lowers the costs associated with installing solar panels.	Chicago residents	$100 per permit
City of Naperville Electric Utility solar installation rebates	Utility customers can receive up to $1,750 in rebates for installing solar panels or a solar water heating system.	City of Naperville Electric Utility customers	$1,750
Solar group buy programs	These programs provide education and group discounts on solar panels.	Residents of Urbana-Champaign and the metro Chicago area	Varies”

Adapted from: cnet.com

Evaluation of the Effectiveness of Existing Policies

Solar energy policies are needed because of the urgent challenge of reducing greenhouse gas emissions and decrease climate change. Solar energy offers numerous environmental and economic benefits, including reducing reliance on fossil fuels and curbing harmful emissions that contribute to climate change and air pollution. Policymakers play a crucial role in accelerating the transition to solar energy by implementing incentives, regulations, and supportive policies

(energy5.com). When evaluating the effectiveness, it is important to make these factors a top priority.

- "Cost-effectiveness and Affordability
- Regulatory Framework and Simplified Processes
- Net Metering and Feed-in Tariffs
- Job Creation and Economic Growth
- Grid Integration and Storage Solutions"

  (energy5.com)

Case Studies on the Influence of Incentives on Solar Adoption

There are several case studies on solar adoption across the world. One being the Australian Capital Territory. This is where the countries capital is. They are recognized for being the first city outside of Europe to have 100 percent renewable electricity. Which serves as an example for other territories and states in Australia to consider other mechanisms that can grow the amount of renewable energy in this sector (renewablesroadmap.iclei.org). Pingtung County, Chinese Taipei is another example of a case study. The commitment of the Pingtung County Government to boost green power development and enhance sustainability since Typhoon Morakotin in 2009 reflects a commendable dedication to environmental resilience and renewable energy. By prioritizing renewable energy initiatives, Pingtung County sets an example for sustainable development within Chinese Taipei (renewablesroadmap.iclei.org). They have a goal for the citizens to have 100% green-powered electricity to begin the first step in their transition. Setting up solar photovoltaics (PV) zones in subsidence areas as a strategy for achieving sustainable land use and green energy targets is a innovative approach. Subsidence areas, often

characterized by land sinking due to groundwater extraction or natural geological processes, can present challenges for conventional land use. By repurposing these areas for solar PV installations, Pingtung County demonstrates a creative solution that maximizes the utility of otherwise compromised land (renewablesroadmap.iclei.org). The city of Vancouver is another great case study. Vancouver's commitment to becoming carbon neutral and achieving 100 percent renewable energy status by 2050 is a laudable goal that demonstrates proactive leadership in combating climate change. Focusing efforts on the buildings sector, which accounts for a significant portion of the city's greenhouse gas emissions, reflects a strategic approach to reducing carbon footprints and promoting sustainable urban development (renewablesroadmap.iclei.org). There are many more case studies that show the progress solar has made and how it is being pushed for not just in the United States but across the world as well.

Economic Challenges

Solar energy's popularity has grown excessively in the United States. But the popularity and growth is not equally shared across the nation. From research that has been done it shows that Black-and Hispanic-majorities have less rooftop systems than no-majority or white-majorities (nrel.gov). To help with this, the National renewable Energy Laboratory has made eight teams across the United States to join the third round of the Solar Energy Innovation Network. These teams work together to understand what keeps some communities from adopting solar than others. The NREL provides information to the teams to come up with solutions to fix these problems in certain communities (nrel.gov).

"The Round 3 team projects fall broadly into two cohorts—equitable residential solar and equitable commercial-scale solar—both of which share common challenges and goals"

(nrel.gov).

Technological Hurdles

"These issues include problems connecting solar to electrical grids, equipment shortages, supply chain delays, a lack of land for commercial solar arrays, and a lack of qualified contractors and laborers to meet installation demands" (pvcase.com). Manufacturers, governments, and scientists in the industry are looking for ways to take care of these hurdles and continue to grow the solar power development. One problem that has been pointed out is that most of the sunlight that is hitting the solar panels is getting lost in the conversion process. The light is either getting reflected or turned into heat instead of being converted into electricity (pvcase.com). "Recombination is another factor limiting PV efficiency. It happens when charge-

carrying electrons encounter defects in the PV material or merge with charge carriers known as "holes," which do not have electrons. During recombination, the energy turns into light photons or heat instead of producing energy. Currently, most panels have efficiencies of 17-20%" (pvcase.com).

Some solutions to fix these hurdles come from new technologies. One being multi-junction PV cells. These cells increase the efficiency to more than 45% (pvcase.com). Before this technology can be accessible, different factors such as manufacturing costs and material availability need to looked in to (pvcase.com). "Another solution is bifacial solar panels, which have cells on their underside to catch light reflected off the ground, roof, or other reflective surfaces. If combined with sun-tracking panels that adjust to maximize solar contact throughout the day, bifacial panels are 30-40% more efficient than their one-sided counterparts" (pvcase.com). The solar industry is always looking for solutions to the problems there are to continue to grow its popularity and demand across the nation.

Regulatory and Policy Challenges

Policies and incentives from the government have progressed over the years which have helped grow the demand for clean energy. These policies help grow the renewable energy industry and push people to adopt solar, reduce greenhouse gasses, and promote the manufacturing of solar panels.

"Solar industry and regulations include:

- Federal solar tax incentives
- State solar rebates
- Net metering laws

- Renewable energy property tax exemptions
- Solar sales tax exemptions
- Clean energy grants
- Renewable portfolio standards
- Solar tariffs on imported solar cells and modules

(greenlancer.com)

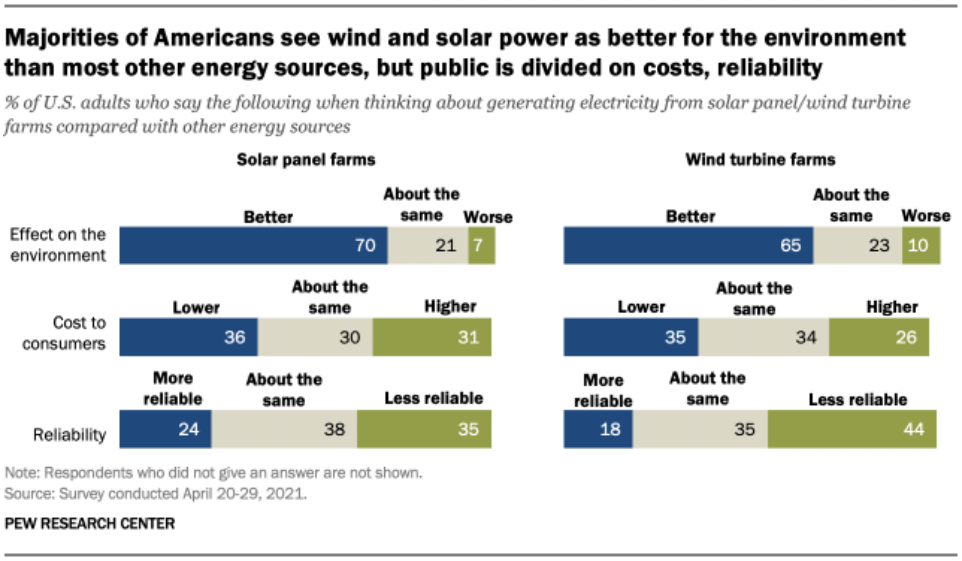
The regulatory environment can be different depending on the state or town, or the company. This causes challenges for the businesses and homeowners that are wanting to purchase a solar panel system. The policies can also be complex making it harder to understand. Such as some states have different policies and incentives than others. “Frequent solar policy changes and variations in clean energy incentives can create uncertainty for potential solar customers. These changes may disrupt project planning, increase administrative costs, and affect the overall cost-effectiveness of solar installations. Additionally, the complexity of regulations may deter potential customers and increase the time and effort required for compliance” (greenlancer.com).

Public Perception and Awareness

Most American citizens support the expansion and growth of solar and wind energy. But Republicans and Democrats have different views on it. “Among Republicans and Republican-leaning independents, support for increasing reliance on solar power is down from 84% last year to 73% today, while support for more wind power dropped from 75% in 2020 to 62% today. Around nine-in-ten Democrats and Democratic-leaning independents continue to support expanding solar (93%) and wind power (91%)” (pewresearch.org). Now the gaps on growing wind and solar energy are the highest they have ever been since 2016 (pewresearch.org). “Most Americans view solar and wind power as good for the environment. Seven-in-ten adults think

generating electricity from solar panel farms is better for the environment than most other energy sources, and 65% say the environmental effect of wind turbine farms is better than that of most other sources" (pewresearch.org).

Democrats are more likely to say that renewable energy is better for the environment than Republicans. The public is more indecisive about the price of these renewable energy sources. "About two-in-ten U.S. adults (18%), for instance, think generating electricity from wind turbine farms is more reliable than other energy sources, while a much larger share (44%) think wind power is less reliable. Roughly one-third (35%) view the reliability of wind power as about the same as other energy sources" (pewresearch.org). When it comes to the cost of these sources, 35% of people say the price of renewable energy sources is lower than other energy sources. With that, 34% say the price is around the same and 26% say it's more expensive (pewresearch.org). Below is an image showing the opinions of U.S. adults on getting energy from solar or wind compared to other sources.



(pewresearch.org)

Emerging Solar Technologies

The solar industry is constantly trying to come up with new and more advanced technologies to keep solar powered energy on the rise. Such as the solar skins that was said earlier. They are always trying to find new ways to use solar and new technologies to make it even better. Here are three other examples of some emerging technologies in solar.

1. Solar Powered Lightning

   "Street lighting has undergone significant technical developments with advancements in solar and LED technology. Solar street lamps absorb sunlight during the day to keep streets illuminated and safe at night. Scientists are working hard to develop smart systems and improve solar power LED energy efficiency, as the technology will result in considerable savings of at least twenty-five years" (proesolar.com).

2. Photovoltaic Noise Barriers

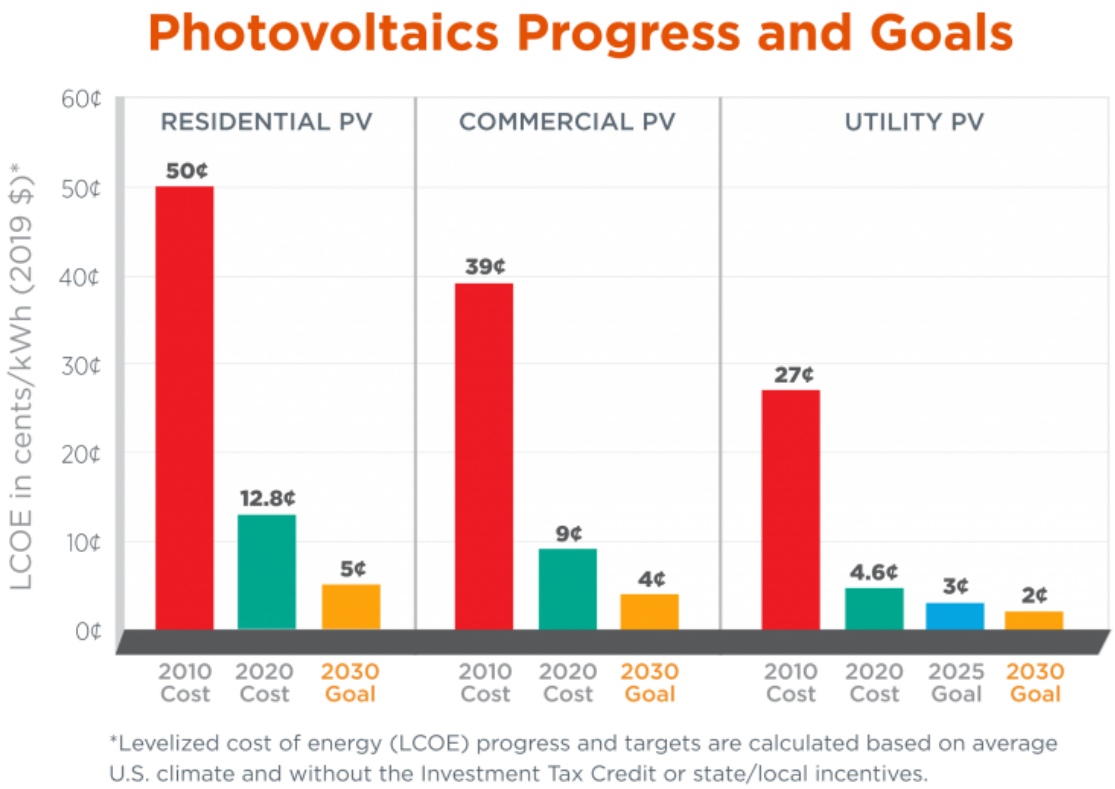
   "Photovoltaic systems use emerging solar technologies such as noise barriers to convert sunlight into electricity. Unlike older silicon solar panels, photovoltaic noise barriers shield the receivers from noise pollution. Installing these solar panels over the roof reduces your home's noise levels" (proesolar.com)

3. Solar Fabrics

   "Scientists have been researching how to embed solar cells into clothing. Solar fabrics are small and breathable, so they're perfect for tracking fitness levels or keeping your phone's battery charged. The US Army is developing solar-powered robotic tents with the help of solar cell manufacturers" (proesolar.com).

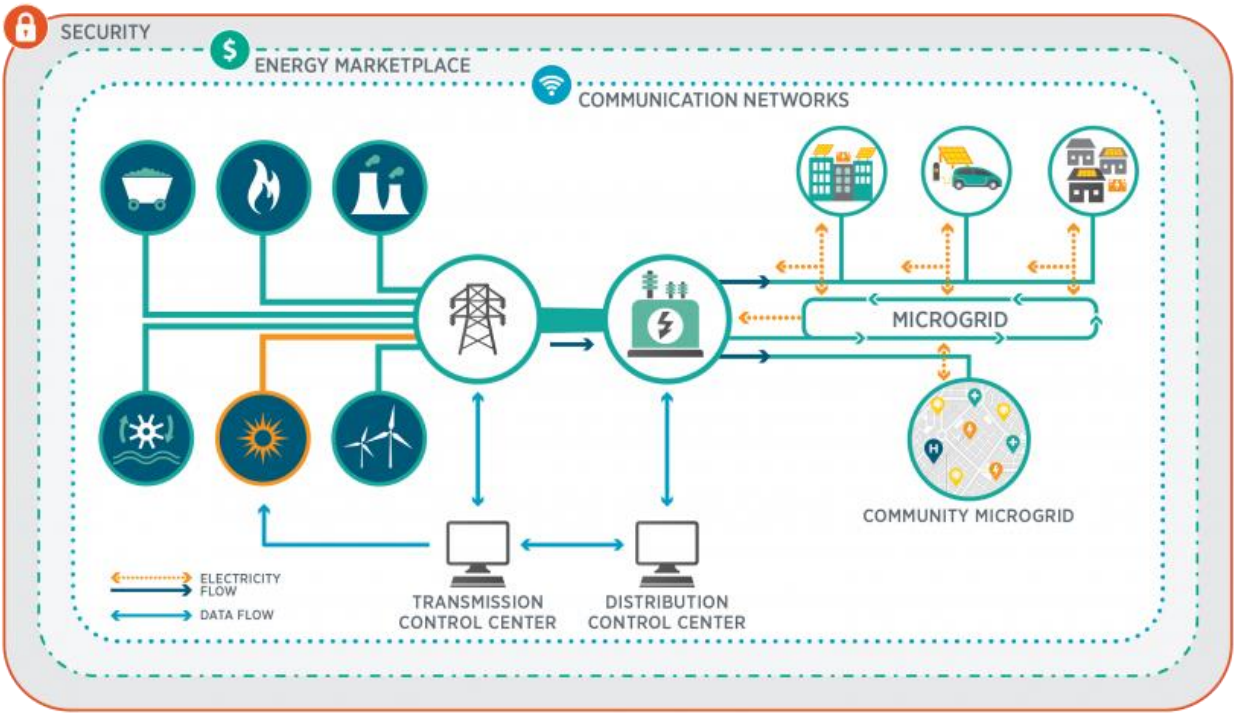
Research and Development Initiatives

There are seven main categories that The U.S. Department of Solar Energy Technologies Office funds. These being photovoltaics, concentrating solar-thermal power, systems integration, soft costs, manufacturing, competitiveness, access to solar, and the solar workforce development (energy.gov). With this research they try to make solar more affordable all while improving the performance as well. Here is some more in-depth research on each of these categories. Starting with photovoltaics. Also known as solar panels, photovoltaics generate power from the sun and turn it into electricity. They believe by lowering the cost of these systems will make the efficiency and reliability better. They are also working towards goals of lowering the price of kilowatt per hour. Here is a chart to show the recent progress working towards their goal.



(energy.gov).

"Systems integration research in the U.S. Department of Energy Solar Energy Technologies Office (SETO) supports technologies and solutions that enable solar grid integration while ensuring the reliability, resilience, and security of the electric power system" (energy.gov). This research looks at issues in areas such as technical, protection, energy storage, and cybersecurity as well as other issues. Below is an image of the role of solar energy.



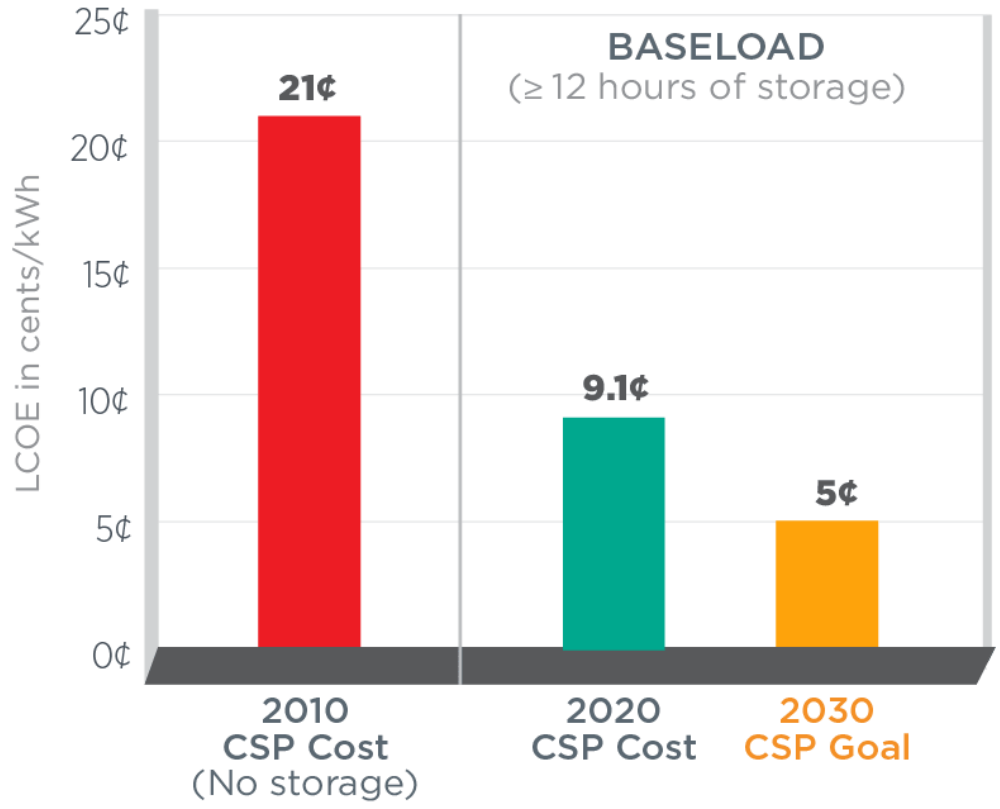
(energy.gov).

Soft cost research works with problems dealing with lowering non-hardware costs on solar systems. Siting, design, permitting, installation, interconnection, and financing being examples of these. Also including sales costs and other expenses that come with buying a system. The reduction of soft costs is crucial for making solar energy more accessible and affordable for homeowners. While hardware costs have been declining steadily, soft costs such as permitting, installation, financing, and customer acquisition remain significant barriers to wider adoption. The fact that soft costs for residential solar energy systems have already

decreased by around 50 percent between 2010 and 2020 is encouraging progress. However, further reductions of 60-70 percent are necessary to meet SETO's (Solar Energy Technologies Office) cost targets and make unsubsidized residential solar a competitive option nationwide (energy.gov).

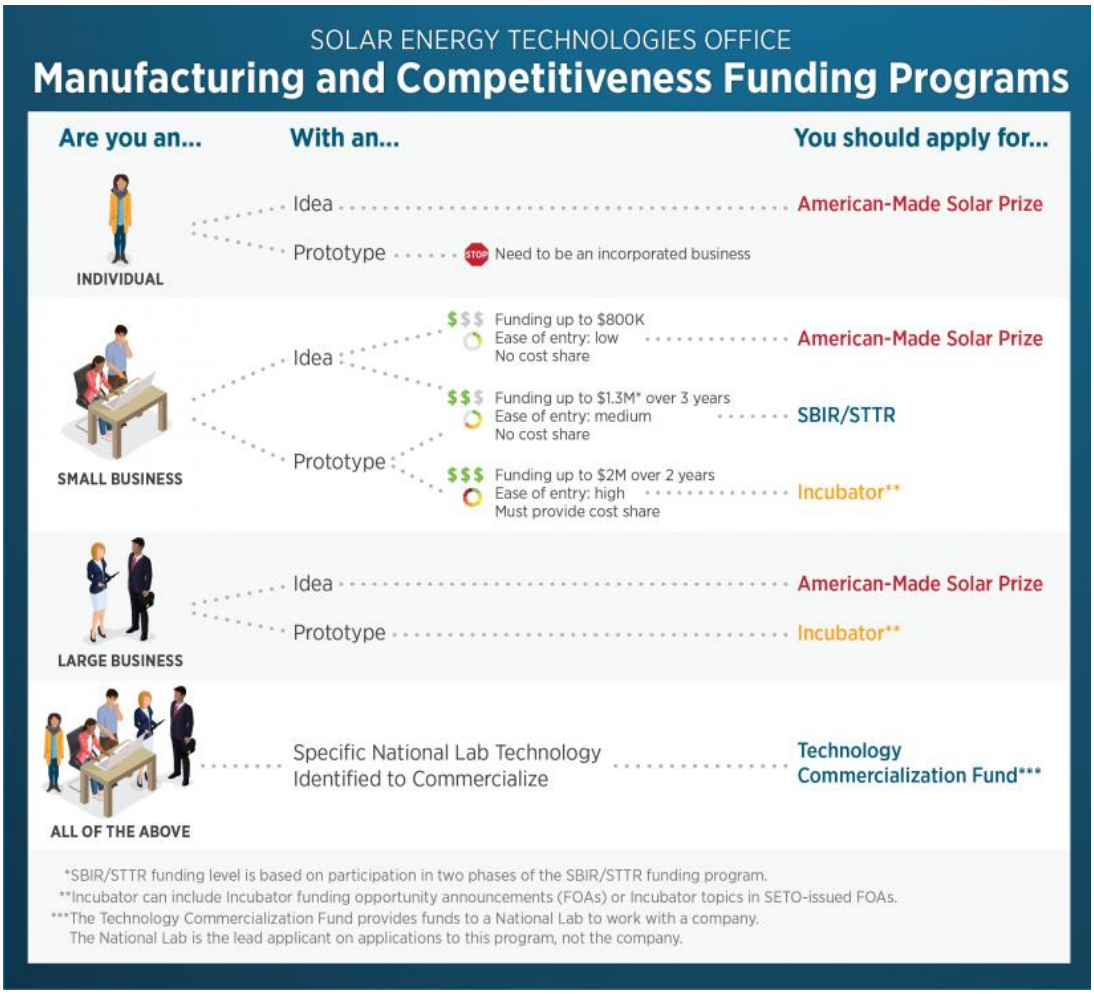
With the cost of solar systems decreasing over the years it has made it a lot easier for residential buyers afford them. Along with rooftop systems being cheaper. There are over two million solar energy systems working across the United States as of 2019 (energy.gov). The accessibility of solar electricity remains a challenge for many households in the United States, particularly for those facing barriers such as affordability, financing limitations, and physical constraints (energy.gov).

Concentrating solar-thermal power are used to make electricity taking the energy from the sun and using it for power. But can also be used to generate heat to different applications.



(energy.gov).

Manufacturing and competitiveness research helps solar developers to bring their technologies and bring them into the market and commercialize it. To find new ways to get their product out there. “Research and development in solar manufacturing and competitiveness helps to build a strong clean energy manufacturing sector and supply chain that produce cost-competitive clean energy products and keep pace with the rising domestic and global demand for affordable solar energy” (energy.gov). This also helps small businesses come up with new ideas to help the solar industry. SETO’s funding for this category goes over multiple different technologies such as, photovoltaics, concentrating power, power electronics, and deals with non-hardware costs (energy.gov).

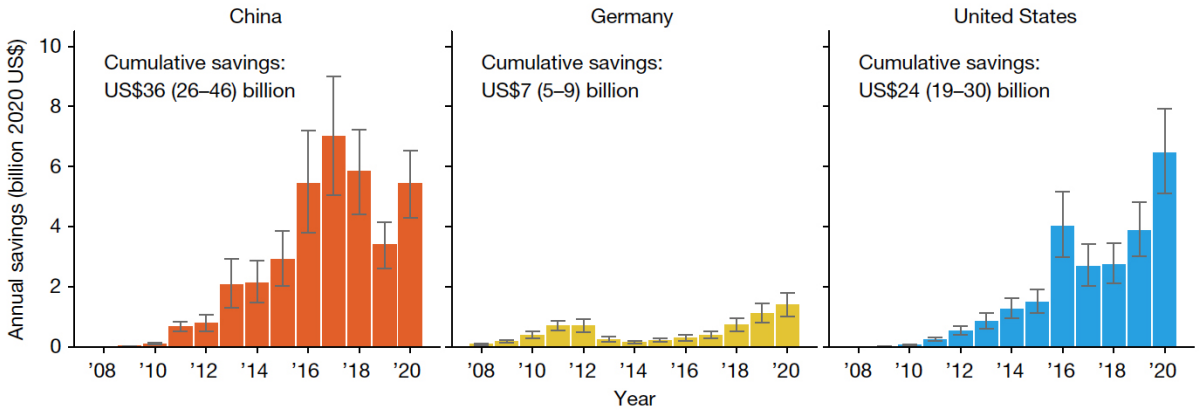


(energy.gov).

Lastly the solar workforce development deals with repairs and to keep these systems up and running. There are online or in person training sessions, along with internships and apprenticeships. They offer all the things a person could possibly need to be able to learn about solar energy and know what to do in certain situations. “Additionally, SETO solicits stakeholder feedback and analyzes industry growth and workforce trends in order to make informed decisions related to the solar workforce” (energy.gov).

International Collaborations and Partnerships

To lower carbon emissions that are promoting climate change the world needs to put out renewable energy at an absurd speed. The solar option plays a key role on having a low-carbon energy future if production prices continue to decrease. There is a new study by a team of scientists on this matter. Findings show that the supply chain of solar photovoltaics saved countries $67 billion in solar module costs. It also found that if strong policies that limit the flow of goods could lead to the cost of solar panels being a lot higher in the coming years (news.stonybrook.edu). This helps to keep track of savings for the industry. These findings also come at a time when other countries are introducing policies that would make renewable energy national and will also benefit local manufacturers.



(news.stonybrook.edu)

"Our research shows international collaboration is key to address global climate change. Nationalistic policies hurt every country and risk missing pressing climate targets. International climate policy benefits from a globalized low-carbon value chain, however, it is important to introduce complementary policies to mitigate welfare distribution effects and potential impacts on technological crowding-out" (news.stonybrook.edu). They predict according to their findings that solar module prices would be around 20 to 25 percent higher in each country in 2030 (news.stonybrook.edu).

The study shows installed capacities from the past as well as input materials and prices for modules in the United States, China, and Germany. Which is three of the largest solar deploying countries. The research highlights the interconnected nature of the global solar industry and the significant economic benefits that result from a collaborative, open-trade approach. Moving forward, policymakers and industry stakeholders should continue to prioritize policies that foster innovation, competition, and sustainable growth in the solar sector (news.stonybrook.edu).

There are also global partner programs that are used to grow the use of renewable energy and energy efficiency in ways to increase economic and sustainable development and energy resilience and security (nrel.gov). One being the Global Climate Action Partnership. "The Global Climate Action Partnership (formerly the Low Emission Development Strategies Global Partnership) is a worldwide network that accelerates ambitious climate goals and advances implementation in Africa, Asia and the Pacific, and Latin America and the Caribbean" (nrel.gov). This network collects information from 120 countries and over 450 institutions to push collaboration and focusing on achieving a low-emission and net-zero economies. Another

one is The Global Power System Transformation Consortium. “ The Consortium brings together key power system operators, research and educational institutions, governments, businesses, and stakeholders from around the world to accelerate clean energy transitions by providing coordinated and holistic end-to-end support and knowledge infusion to power system operators across five pillars of focus: system operator research and peer learning, system operator technical support, workforce development, localized technology adoption support, and open-source data and tools” (nrel.gov).

Overview of Federal Policies Supporting Solar Energy

Local governments have many resources to promote the growth of solar energy. The decisions made at the federal and state level set the scene for local decisions to be made to help encourage solar energy in their communities. At the federal level, there are several programs and policies that support and promote solar energy. Some policies helping with the costs that come with purchasing solar. While others provide data that help local governments make their own solar energy programs. Here is a list of the most important federal programs, agencies, and initiatives.

- The Federal Investment Tax Credit (ITC) is a significant incentive in the United States that encourages the deployment of solar energy systems across residential, commercial, and utility-scale sectors (solsmart.org).
- The Modified Accelerated Cost Recovery System (MACRS) is a depreciation method used for tax purposes in the United States that allows solar project owners to recover the capital costs of their solar energy systems over a specified period of time (solsmart.org).

- The Public Utility Regulatory Policies Act (PURPA) is a federal law enacted in 1978 in the United States to promote greater energy efficiency, encourage the conservation of natural resources, and diversify the country's energy supply (solsmart.org).
- The Federal Energy Regulatory Commission (FERC) is an independent regulatory agency within the United States government that is responsible for regulating the interstate transmission of electricity, natural gas, and oil (solsmart.org).
- The Solar Energy Technologies Office (SETO) is a division within the U.S. Department of Energy (DOE) that is responsible for overseeing solar-related programs and activities aimed at advancing solar energy research, development, demonstration, and deployment (solsmart.org).
- The U.S. Energy Information Administration (EIA) is an independent statistical and analytical agency within the U.S. Department of Energy (DOE) that is responsible for collecting, analyzing, and disseminating comprehensive data and information on U.S. energy markets (solsmart.org).

Analysis of Proposed and Existing Legislation

The U.S Department of Energy released the Solar Futures Study talking about the role solar energy will play in decreasing the carbonation on the power grid. The findings of the study underscore the significant potential of solar energy to transform the nation's electricity sector, drive decarbonization efforts, create jobs, and maintain affordable electricity prices (energy.gov). This study calls for a massive deployment of clean energy sources. This is underscoring the Biden Administration’s efforts to take care of the climate crisis and to increase access throughout the country to renewable power sources. The study's findings highlight the transformative

potential of solar energy as a clean, abundant, and cost-effective source of power for the United States (finansavisen.no). The study lays out a plan to achieve goals they have set. Here is a list of the study's key findings.

- Achieving a clean and sustainable energy grid requires a concerted effort to deploy a diverse mix of renewable energy sources at a massive scale. The targets outlined in the study emphasize the importance of accelerating the deployment of solar energy, along with other clean energy technologies, to meet the country's carbon reduction goals (electricenergyonline.com).
- The transition to a decarbonized power sector presents significant opportunities for job creation across various sectors of the economy. The study's modeling highlights the potential for millions of jobs to be created as the U.S. shifts towards clean energy technologies, with solar energy playing a particularly prominent role (electricenergyonline.com).
- The integration of advanced technologies and infrastructure upgrades is crucial for maximizing the potential of renewable energy sources like solar and wind and achieving a more flexible, resilient, and efficient electricity grid (electricenergyonline.com).
- The transition to a renewable-based grid offers substantial health and cost savings, primarily through the reduction of carbon emissions and improvements in air quality. These can be achieved by health benefits, cost savings, and price stability (electricenergyonline.com).
- Supportive decarbonization policies and continued technological advancements are essential for further reducing the cost of solar energy and enabling widespread deployment (electricenergyonline.com).

Assessment of the Government's Impact on the Industry

The government has a significant impact on the solar industry due to the policies they have released. It has increased the awareness of solar and helped with the growth of solar adoption as well. These policies can encourage investment and growth as well as discourage it. The solar energy laws from the government can come in forms such as subsidies, mandates, and tax breaks. One policy in particular has had the biggest influence on increasing the use of solar energy. This policy being the Renewable Portfolio Standards. "RPS mandates that utilities produce a predetermined portion of their electricity from renewable resources, including solar power. These rules may provide a secure market for solar energy, boosting investment and growth" (VR, Akshay, 2023). As said before these policies can lower the cost of purchasing solar energy making them more accessible to residential properties and businesses. This also increases the demand and uptake.

Although, there are policies that restrict the use of solar energy. Including those that have high permission costs might influence people not to invest in solar energy. Financial advantages can also be taken away due to utility laws that restrict certain things such as net metering or the opportunity to sell the surplus energy that is generated by the solar panels back to the grid (VR, Akshay, 2023).

Future Policy Directions

The state that solar energy policies are in are made up of different existing policies at both the national and international level. These policies make the solar adoption process a lot easier for buyers by offering support financially, speeding up permitting processes, and setting targets or goals for energy targets. But, the impact of these policies are different in some

countries or states. Such as the growth and popularity of adopting solar energy is greater in some areas than others. Some of the main issues with this are the high costs and limited infrastructure. Finding out the strengths and weaknesses of current policies is very important to improve these policies or possibly make new ones in the future.

Emerging policy directions and advancements in solar energy policy and advocacy hold great promise for expanding access to solar energy and driving increased investment in renewable energy infrastructure (green.org). Along with this, there is talk of potential of some policies being changed. Some changes being the price of carbon and shifting towards decentralized energy systems. These changes and the direction of policies are all to continue to grow and support solar energy. Support from the public influence these policy decisions. With the help of campaigns to raise awareness, stakeholder engagement, and education, these advocates can push positive change and help make sure these policies will work toward the goals that have been set to have a sustainable future. Campaigns that promote lobbying for favorable legislation or net metering have led to great outcomes that have sped up the process of transitioning to solar energy (green.org).

As more advancements are being made to lower the costs and improve efficiency, solar is headed in the right direction to become a main energy source. Advancements and innovations in solar energy integration with energy storage systems, smart grids, and electric vehicle infrastructure hold tremendous promise for the future of renewable energy. However, several challenges must be carefully addressed to ensure the successful transition to a solar-powered future (green.org). Understanding the backgrounds, current state, and potential direction of solar energy policies brings in important information on the challenges and opportunities that are to

come. Bringing all of this to mind will help continue to grow and work towards a future where solar powered energy will be the best choice for everyone (green.org).

Highlighting Successful Solar Energy Projects

There are tons of successful solar projects across the United States and the world. Here is a list of the 14 most impressive projects in the world.

- " Benban Solar Park, Benban, Egypt
- Longyangxia Dam Solar Park, China
- Cochin International Airport, India
- Cherrnobyl Solar Plant
- Sungrow Solar Farm, Huainan, China
- Solar Star, California
- Solar Panel Bike Path, Krommenie, Netherlands
- Solar "Tindo" Bus, Adelaide, Australia
- Canal Solar Power Project, Gujarat, India
- The World's First Photovoltaic Road, Jinan, China
- Tokelau Renewable Energy Project, Tokelau
- Vanguard 1
- Solar Impulse
- Arco Solar, California"

(popularmechanics.com)

Lessons Learned from Case Studies

Country X's success story in solar energy policy and advocacy demonstrates the effectiveness of a comprehensive approach to promoting solar energy adoption. By

implementing a range of supportive policies and initiatives, Country X has created an enabling environment for the growth of the solar energy sector (green.org). This success of this policy can be awarded to the lengthened work between government agencies, stakeholders, and advocate groups. The result of this was a significant increase in capacity of solar energy for Country X. Which lowered the demand for fossil fuels making the environment cleaner. Challenges that were faced in implementing policy was the importance of effective advocacy efforts. Advocacy groups play a big role in advancing solar adoption by making people more aware, bringing in more public support, and trying to influence policymakers. These groups leverage various strategies to promote the economic and environmental benefits of solar energy and overcome barriers to its widespread adoption (green.org).

Model Initiatives for Future Developments

The future for solar energy is looking very promising. More growth and innovation is to come from the industry. Here are some developments that are likely to come in the future of solar energy.

- Increasing Adoption: The future of solar energy adoption looks promising as countries worldwide set ambitious goals for deploying solar energy. With the continual decrease in the price of solar technology and increasing awareness of its environmental benefits, solar energy is becoming an increasingly attractive option for individuals and businesses seeking clean, renewable energy sources (thesolarlabs.com).
- Innovations in Technology: Innovations in the solar industry are vital for driving continued growth and improving the efficiency and versatility of solar technology. Some of the most promising developments in solar technology include nanomaterials for cells,

transparent solar panels, and artificial intelligence for solar system optimization (thesolarlabs.com).

- Growing Role in the Transportation Sector: Solar is expected to play a big role in transportation with the development of solar powered vehicles powered by solar panels (thesolarlabs.com).
- Increased Storage Capacity: Solar energy is an intermittent source of energy. Which is one of the biggest challenges because of the varying of production due to the time of day or weather conditions. The development of solar thermal storage and advanced batteries helps fix this problem by being able to store left over solar and use it when it needs to be (arka360.com).
- Policy and Regulatory Support:The shift towards solar energy is gaining momentum globally as governments and policymakers recognize its significance in addressing climate change, reducing dependence on fossil fuels, and promoting sustainable (thesolarlabs.com).

Along with that, there are several trends that are shaping the solar energy industry.

- The Fall of Costs for Solar Panels: The declining cost of solar panels has been a game changer in making solar energy more competitive with traditional energy sources like coal, natural gas, and nuclear power.
- Increased Efficiency of Solar Panels: Advancements in solar panel efficiency are indeed a significant driver in the continued cost effectiveness of solar energy systems. Improved efficiency means that for a given surface area of solar panels, more electricity can be generated, leading to higher energy yields and reduced overall system costs (thesolarlabs.com).

- The Growth of Utility Scale Solar Projects: Large-scale solar projects, often referred to as solar farms or solar parks, play a crucial role in the transition to renewable energy. These projects typically consist of arrays of solar panels spread across vast areas of land, collectively generating significant amounts of electricity (thesolarlabs.com).
- Increasing Adoption by Businesses and Institutions: Businesses and institutions are increasingly turning to solar energy as a cost-effective and environmentally friendly solution to reduce both energy expenses and carbon emissions (thesolarlabs.com).
- The Growth of the Rooftop Solar Market: The residential solar market has been experiencing significant growth in recent years, driven by several factors including decreasing installation costs, technological advancements, and increasing awareness of the benefits of solar energy (thesolarlabs.com).

Recommendations for Policymakers, Stakeholders, and Researchers

As said before, a big challenge the solar energy industry faces is the overall cost for a solar panel system. A couple recommendations have been made to make it easier for lower income households to go solar. Low-income households face obstacles that many others do not. With the decline in cost of a solar system, it has already presented opportunities to save money. And no one needs to save money more than lower income households. Who already spend a higher portion of their money on energy. Here are some recommendations that should be considered when approaching these households. Starting with leveraging the state energy policy to support low-income deployment. Existing renewable energy policies can serve as a foundation for supporting low-income solar initiatives. These policies can be adapted by (RPSs) also known as Renewable Portfolio Standards, financial incentives, community solar, and net metering

(pdfcoffee.com). Another would be to adapt housing and anti-poverty programs to include low-income solar. There are multiple federal and state programs that try to reduce poverty and promote economic development. Which are two things solar can help. “Energy assistance programs, like the Low-Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP), can be adapted (and in some cases *are* being adapted) to include solar power as approved cost-effective measures” (govtech.com).

Setting up a financial vehicle can also help. There are a lot of different financial strategies that can enable access to solar. Establishing a lead agency with expertise in project finance can help coordinate these efforts, navigate legal and regulatory complexities, and ensure that resources are allocated effectively to maximize the impact of low-income solar initiatives. This agency can serve as a central point of contact for stakeholders, provide technical assistance, and oversee the implementation and evaluation of programs to support low-income solar adoption. (pdfcoffee.com). Lastly thy can ensure programs provide tangible benefits to low-income consumers. It may seem obvious that low-income customers would benefit from low-income solar programs. But in the scheme of things, it is not that easy. Low-income solar programs need to be carefully designed to ensure they provide tangible financial benefits to the low-income customers they aim to serve. Installing solar on a multifamily apartment building, for instance, might not directly translate to savings for tenants if the building owner or landlord retains control over the electricity bill. (pdfcoffee.com). Even though there is an opportunity to promote low-income solar, the idea that solar is only for those of a higher-income is being broken down by real world deployment across the income level (govtech.com).

Conclusion

The history of solar energy traces back thousands of years, with civilizations like the Romans utilizing passive solar techniques for heating and lighting. However, it was not until the 19th century that the photovoltaic effect was discovered laying the foundation for modern solar technology.

In just the past 100 years or so, inventions have improved our lives more than our ancestors could imagine. The light bulb brought us out of the dark. The telegraph and later the telephone allowed us to communicate instantly over long distances. Appliances that helped keep food longer and to cook, others that kept us warm and assisted with cleaning all changed our daily lives for the better. Television, medical technology, cellular phones and computers, the list goes on and on. These inventions and technologies all have one thing in common. They all require electricity to operate. The modern era of productivity and technology has driven an exponential and continuing growth in demand for electricity. Because of this and its abundance and low cost, fossil fuel use grew 1500% in just 100 years. Due to climate change, there is a new urgency to move to cleaner energy sources to replace our reliance on fossil fuels to produce electricity.

The 20th century witnessed significant advancements, including the development of the first practical photovoltaic cell, and the commercialization of solar panels in the 1970s. Since then, solar energy has experienced exponential growth, driven by factors such as government incentives, technological improvements, and increasing environmental concerns.

The adoption of solar energy has had positive national and global effects. Countries around the world have recognized the importance of transitioning to renewable energy sources to reduce dependence on fossil fuels and battle climate change. Reducing fossil fuel use and transitioning to solar power has led to a reduction in greenhouse gas emissions, improved air

quality and energy security. Additionally, the solar industry has become a major economic driver, creating jobs, attracting investments, and stimulating innovation. Globally, the advancement of solar energy has contributed to efforts to limit global warming.

Advancements in solar technology has driven the growth of the solar industry. Over the years, researchers and engineers have taken huge steps in improving the efficiency and affordability of solar panels. These breakthroughs have made solar more reliable and grid-compatible. The future of solar energy is very promising, with continued innovation and investment in order to further improve efficiency and cost-effectiveness. Additionally, the integration of solar energy into technologies like electric vehicles is creating possibilities for a more interconnected and sustainable energy environment.

In conclusion, solar energy has evolved from use during ancient times to become a major component of the transition away from fossil fuels. Its history is an excellent example of human's ability to develop innovations, and to work together to take action and find solutions to the problems we face. By harnessing the everlasting sun, solar energy technology will allow humankind to have a cleaner, more sustainable supply of electricity long into the future.

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