




Advantage America:

The U.S.-China Clean Energy Technology Trade Relationship in 2011

THE PEW CHARITABLE TRUSTS

THE PEW CHARITABLE TRUSTS

The Pew Charitable Trusts applies the power of knowledge to solve today's most challenging problems. Pew employs a rigorous, analytical approach to improve public policy, inform the public, and stimulate civic life. We partner with a diverse range of donors, public and private organizations, and concerned citizens who share our commitment to fact-based solutions and goal-driven investments to improve society. For additional information on The Pew Charitable Trusts, please visit www.PewTrusts.org.

Joshua Reichert, executive vice president
Tom Wathen, deputy director, programs, environmental initiatives
Phyllis Cuttino, director, clean energy program
Jessica Frohman Lubetsky, manager
Tom Swanson, manager
Joseph Dooley, senior associate
Sarah Greene, associate
Adam Meyer, associate
Trisch Curtis, administrative assistant

For additional information on Pew's environmental initiatives, please visit www.PewEnvironment.org.
For additional information about Pew's clean energy program, please visit www.PewTrusts.org/CleanEnergy

ABOUT THE REPORT

Advantage America: The U.S.-China Clean Energy Trade Relationship was developed for public informational and educational purposes. References to specific products and projects have been included solely to advance these purposes and do not constitute endorsement, sponsorship, or recommendation by The Pew Charitable Trusts.

Underlying data for this report were compiled for Pew by Bloomberg New Energy Finance, the definitive source of insight, data and news on the transformation of the energy sector. Bloomberg New Energy Finance's global network of 200 staff members across Europe, the Americas, Asia, and Africa monitor market changes, deal flow, and financial activity, allowing transparency into the clean energy and carbon markets. A full description of the data sources and methodology employed in the development of this report can be found in the appendices.

ACKNOWLEDGMENTS

We are grateful to our research collaborators at Bloomberg New Energy Finance, led by Ethan Zindler and Nathaniel Bullard, and extend special thanks to Michael Liebreich. We would also like to thank our Pew colleagues Tracy Schario, Kymberly Escobar, Justin Kenney, Ed Paisley, Leah Weiser, Carol Hutchinson, Liz Visser, and Jerry Tyson. We thank Alziro Braga with InArt Design Works for graphic assistance and David Harwood of Good Works Group for his help in preparing this report.

Cover Photo Credits (from left to right, top to bottom): Shutterstock.com/© Paul Matthew Photography – iStockphoto.com/© tunart – iStockphoto.com – Shutterstock.com/© donvictorio – Shutterstock.com/© sbko – Shutterstock.com/© Stefano Ginella

Table of contents

TABLE OF FIGURES

Foreword

By Michael Liebreich, CEO, Bloomberg New Energy Finance

The United States and China are inextricably linked as global trade partners, with more than half a trillion dollars in goods passing between them in 2011.

Bloomberg New Energy Finance is proud to partner with The Pew Charitable Trusts to produce this report on U.S.-China clean energy trade. This research is an important effort to better understand the realities and opportunities of the complex exchanges of wind, solar, and energy smart technologies equipment and services between the world's two largest economies.

The United States and China are inextricably linked as global trade partners, with more than half a trillion dollars in goods passing between them in 2011, the last year for which complete data are available. The two countries are the largest and second-largest global electricity markets and greenhouse gas emitters and the leading recipients of clean energy investment; nearly two of every five dollars invested in clean energy worldwide since 2004 has gone to one country or the other. They also are the two most significant parties in a vocal (and sometimes strident) debate about future national competitive advantage and about the fairness of each country's trade practices in supporting its clean energy firms.

The conventional wisdom on clean energy trade is a microcosm of assumptions about U.S. and Chinese competitiveness. The United States is viewed primarily as

a services economy and an insatiable importer, while China is the workshop to the world: "China makes, the world takes," as author James Fallows once put it. This report challenges those assumptions, and its findings compel us to reimagine the conventional wisdom.

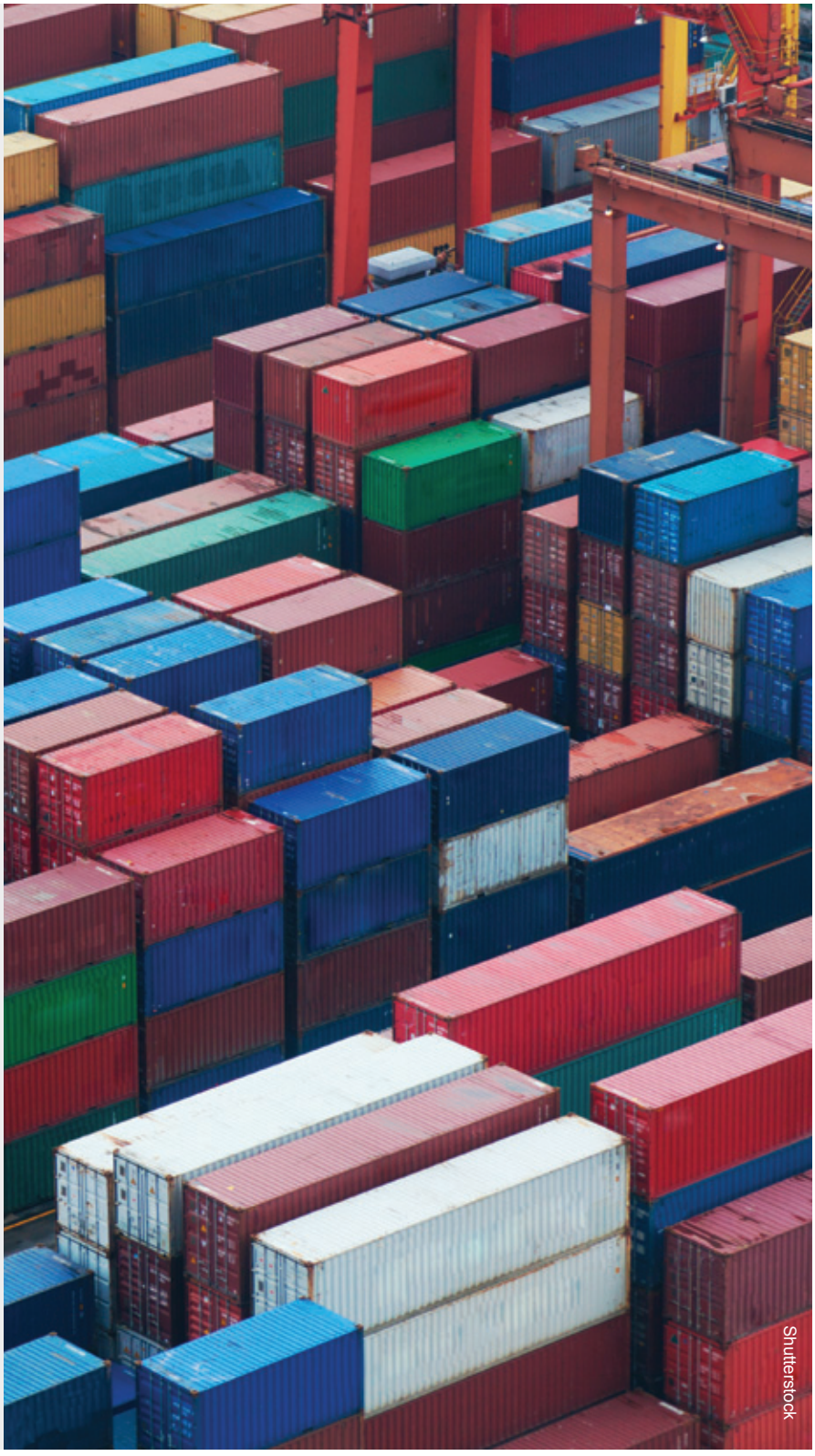
China is certainly a workshop in certain areas of clean energy, in particular solar photovoltaic cells and modules. But when we fully and carefully account for trade in clean energy technologies between countries, we find that it was the United States, not China, that was a net exporter in 2011. China's dominance in complete solar modules obscures its meaningful imports of higher-margin capital equipment, specialty materials, and polysilicon.

Although China is an enormous wind energy market, it is not yet a major exporter of homegrown wind turbines, and it remains a major importer of

controls, bearings, and materials for manufacturing wind turbine blades. In energy smart technologies such as advanced batteries, smart meters, and light-emitting diodes, or LEDs, China remains a substantial importer of manufacturing equipment in particular.

The U.S.-China clean energy relationship, in other words, challenges us to analyze today's global trade not as an exchange of goods but rather an exchange of value added. The Organization for Economic Co-operation and Development has just published its first database of "Trade in Value Added Indicators" to track this complexity of trade between nations. At first glance, the United States and China seem to be in competition on solar energy, with each country dominating different subsectors. In reality, however, they are not so much competing as they are interdependent.

In short, the U.S.-China clean energy trade's ties are every bit as nuanced and complex as those in other industries. They stand to become even more so in coming months as the two nations quarrel over issues of intellectual property rights, dumping of goods onto international markets, and tariffs. I hope that this paper offers facts and insights that prove useful to policymakers in contemplating these issues, not just as they apply to the United States and China but also to other nations.



Shutterstock

Executive summary

More than half a trillion dollars' worth of goods and services are traded by the world's two leading economies, the United States and China. In 2011, the last year for which complete data were available for the purposes of this report, China exported $4 worth of goods and services for every $1 exported by the United States. Current trade flows reflect the reality that China is a low-cost producer and the United States a high-volume consumer of finished products. But underlying these truths is a trading relationship that is more nuanced, in which the United States has key strengths that often go unrecognized.

Clean energy is a recent contributor to the overall U.S.-China trade relationship as renewable and advanced energy systems have emerged as a global priority for economic progress, energy security, and environmental protection. It is well known that the United States and China are leaders in the global clean energy sector. But beyond overall investment and deployment data, there is a poor understanding of how the two clean energy superpowers interact in the sector.

Clean energy has become a recent contributor to the overall U.S.-China trade relationship as renewable and advanced energy systems have emerged as a global priority, for economic progress, energy security and environmental protection. It is well known that the United States and China are leaders in the global clean energy sector.

Misunderstanding of clean energy trade realities is fed by broad-based turmoil in the marketplace resulting from intense international competitive pressures, rapid price declines, and policy uncertainty in U.S. and European markets. High-profile clean energy trade cases involving Chinese exports of photovoltaic (solar) cells and modules[1] and wind turbine towers to the United States also amplify confusion about the nature of this trade between the two countries.

This report seeks to shed light on that relationship. Although the U.S.-China relationship in clean energy trade is still a relatively small portion of the total exchange of goods and services between them, it nevertheless is extensive. This report examines U.S.-China clean energy trade overall and the relative strengths and weaknesses of each country in the solar photovoltaic, wind, and energy smart-technology sectors.

U.S.-China trade in solar photovoltaics

In the solar photovoltaic subsector, we examined trade in polysilicon, wafers, cells, and modules, as well as other aspects of the solar value chain related to essential materials, inverters, and capital

1 Photovoltaic cells are the generating units of solar modules. Photovoltaic cells create electricity when exposed to sunlight; a series of cells, when assembled into a frame, are known as a module. "Module" and "panel" are interchangeable words for the basic unit of photovoltaic power generation.

equipment that are required in the solar energy production process.
Solar energy product exports are the largest component of U.S.-China clean energy trade for both countries. Combined, firms based in the two nations traded more than $6.5 billion worth of products and services in 2011.

Finished solar modules account for 95 percent of the solar products exported by China to the United States. China also exports $151 million worth of solar cells to the United States. Both of these products reflect China's strengths in mass assembly and high-volume manufacturing.

But China's strength in production of solar modules is matched on the U.S. side by leadership in high-tech goods and services. The trading strength of the United States in this sector derives from competitive advantages in producing high-value inputs (polysilicon and wafers, both for making photovoltaic cells), materials used in making photovoltaic modules, and the capital equipment and systems necessary in solar factories.

All told, firms based in the United States traded more than $3.7 billion worth of goods and services with Chinese interests in the solar photovoltaic subsector, while Chinese companies exported $2.8 billion worth of products to the United States. On a net basis, the United States enjoyed a $913 million surplus in the solar sector.

U.S.-China trade in wind technologies

The wind component is the smallest of the three U.S.-China clean energy trade sectors examined in this report. Overall, more than $923 million worth of wind energy goods and services was exchanged between the two countries in 2011.

As with solar, the U.S. wind industry excels in relatively high-margin specialty materials such as fiberglass produced by large firms and sensitive electronic and other controls systems, with U.S. exports to China totaling $534.9 million. China's largest trade contributors are wind turbine towers (a trade driven almost entirely by logistical concerns rather than pure cost advantages) and turbine rotors manufactured under a U.S.-China joint venture. China's wind energy exports to the United States total $388.7 million.

Overall, U.S. wind energy firms have a net trade surplus of just over $146 million.

U.S.-China trade in energy smart technologies

Energy smart technologies include a suite of technologies, services, and products that help improve energy performance and efficiency, store energy, and reduce carbon emissions. For this report, U.S.-China trade was tracked in four leading energy smart technologies: smart meters; light-emitting diodes, or LEDs; advanced lithium-ion batteries; and electric vehicles.

Trade in energy smart technology constitutes the second-largest component in U.S.-China trade flows. Overall, more than $1.1 billion worth of equipment is traded.

China leads in smart metering and lithium-ion batteries, with trade to the United States valued at more than $120 million. In addition, China exports $133 million worth of LED products, primarily fixtures, to the United States. Although each country exports chips, modules, and fixtures to the other, U.S. firms exported more than $800 million worth of LED capital equipment to China while importing none. The United States also traded $29 million worth of lithium-ion batteries in 2011.

In total, the United States had a net trade surplus of $571 million in the energy smart technology sector in 2011.

Conclusions

Our analysis of U.S.-China clean energy trade highlights six trends that underscore the complexity and interconnectedness of

trade relations in this sector between the largest and second-largest economies in the world. Specifically:

- **Clean energy markets are global.** Trade flows between the United States and China demonstrate the global nature of clean energy markets and the opportunity they present for businesses. All told, the United States and China exchanged more than $8.5 billion worth of clean energy goods and services in 2011.

- **The United States has a $1.63 billion clean energy trade surplus with China.** Considering all aspects of the value chain, U.S. exports and trade to China actually exceeded Chinese exports to the United States by $1.63 billion in 2011.

- **U.S. firms have an advantage resulting from national leadership in innovation and entrepreneurship.** U.S. companies excel in production and sale of complex, high-margin, and performance-critical goods. These include capital equipment for manufacturing solar panels and LEDs, specialty chemicals, and materials needed for production of solar and wind products, as well as controls for energy systems.

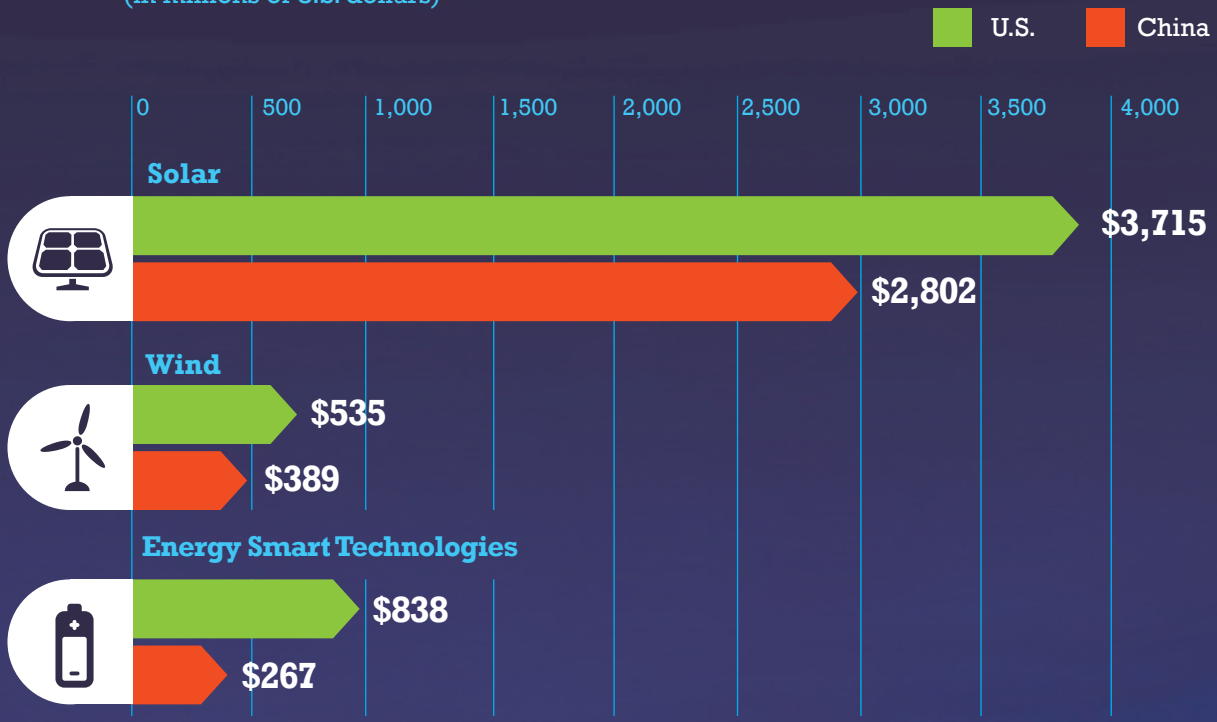
- **U.S. companies are more active overseas than are their Chinese counterparts.** Chinese firms have only small assembly operations in the United States for clean energy equipment. The U.S. clean energy trade picture significantly improves when the global footprint of U.S. firms that manufacture products overseas is taken into account.

- **China's strength is more narrowly based on assembly and high-volume manufacturing.** The data show that Chinese firms are relied on for large-scale manufacturing and high-volume assembly of finished products such as solar modules and LED fixtures, whereas the United States' strength lies in a wide variety of high-technology products across clean energy sectors. Domestic clean energy targets for solar and wind power in China have provided ready and proximate markets for rapidly expanding its manufacturing capacity and allowed Chinese firms to gain a competitive advantage in the global marketplace.

- **Uncertainties surrounding U.S. clean energy policies are likely to have the greatest impact on domestic manufacturing in the clean energy industry.** In the United States, clean energy policy is in a state of flux. Much of the demand associated with state-based renewable energy goals and standards has been met. Several key federal initiatives have expired or will soon expire, such as the Advanced Energy Manufacturing Tax Credit, the Department of Energy's Loan Guarantee program for renewable energy deployment, and the Department of Treasury's clean energy grants initiative. In addition, the Production Tax Credit and Investment Tax Credit face an uncertain future in ongoing tax and budget policy discussions. Policy choices, not China's exports, will determine the direction of the U.S. clean energy industry in the months and years ahead.


Shutterstock

FIGURE 1: Total U.S.-China Clean Energy Trade Flows
(in millions of U.S. dollars)



Shutterstock

Introduction

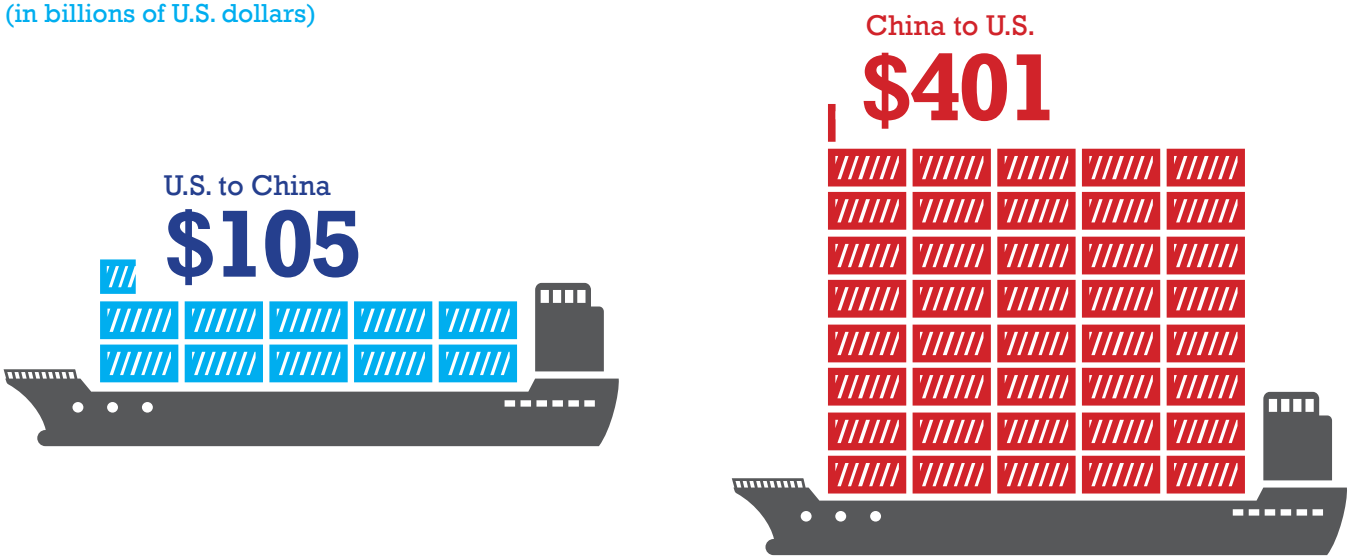
China and the United States are each other's largest trading partner. In 2011, the last year for which complete annual data are available, total trade in goods and services between the world's largest and second-largest economies exceeded half a trillion dollars. The United States exported $105 billion in goods and services to China, which exported four times as much—$401 billion—to the United States.[2] The trade relationship spans a variety of goods and services, from soybeans to aircraft, chemicals to electronics, plastics to wind turbines, and machinery to solar panels. (See Figure 2.)

Current trade flows reflect the reality that China is a low-cost producer and the United States a high-volume consumer of finished products. But underlying these truths is a trading relationship that is more nuanced, in which the United States has key strengths that too often go unrecognized.

Clean energy is a recent contributor to the overall U.S.-China trade relationship as renewable and advanced energy systems have emerged as a global priority for economic progress, energy security, and environmental protection. Inventors

FIGURE 2: U.S.-China Overall Trade in Goods and Services

(in billions of U.S. dollars)



2 U.S. Department of Commerce, Bureau of Economic Analysis, *U.S. International Trade in Goods and Services, Annual Revision for 2011*, June 8, 2012. http://bea.gov/newsreleases/international/trade/2012/trad1312.htm

3 Pew Charitable Trusts, *Who's Winning the Clean Energy Race? 2011 Edition*, page 2. http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/FINAL_forweb_WhoIsWinningTheCleanEnergyRace-REPORT-2012.pdf

and investors, companies, and countries are exploring ways to take the lead in an industry that grew by more than 600 percent from 2004 to 2011.[3] With demand and deployment increasing in most regions of the world, it is a strategic national and business priority to gain a competitive foothold in the promising clean energy sector.

It is well known that the United States and China are leaders in the clean energy sector. They attracted more than 39 percent of worldwide clean energy investments in 2011.[4] They ranked first and second in terms of annual investment and were first and second in terms of total installed renewable energy generating capacity as of 2011.[5] But beyond this well-established data, there is little understanding as to how the clean energy superpowers interact in the sector.

Misconceptions about clean energy trade realities are fed by broad-based turmoil in the marketplace resulting from intense international competitive pressures, rapid price declines, and clean energy policy uncertainty in the U.S. and European markets. These factors make it difficult for manufacturers in the United States, China, and elsewhere to survive in what has become a low-margin environment. Some high-profile U.S. bankruptcies prompted suggestions that China is becoming the dominant force in the sector, although this speculation ignores the breadth of products traded as well as the reality that many Chinese firms are also struggling.

High-profile clean energy trade cases involving the export of photovoltaic (solar) cells and modules[6] and wind turbine towers from China to the United States also amplify confusion about the nature of clean energy trade between the two countries. In the past 18 months, various legal actions have been filed in the United States and China, and at the World Trade Organization involving clean energy trade. The U.S. Department of Commerce has leveled anti-dumping and countervailing duties on Chinese solar panels ranging from 15 percent to 34 percent; a similar tariff against Chinese-made wind turbine towers is pending. For its part, China is probing U.S. polysilicon producers for potential dumping in the Chinese market.

Understanding the nature of the trade flows between the two countries helps to illuminate the complexities of this bilateral relationship and the realities of international economic interdependence.

The high-profile nature of these wind and solar cases has obscured the complexities of clean energy trade between the United States and China. This report seeks to shed light on the relationship between the countries in a new and expanding sector of global commerce.

U.S.-China clean energy trade is a relatively small portion of the total cross-border exchange of goods and services, yet the relationship already is extensive. Understanding the nature of the trade flows between the two countries helps to illuminate the complexities of this relationship as well as the realities of international economic interdependence.

The Pew Charitable Trusts initiated this report to compile the hard data needed to craft a more accurate understanding of trade between the United States and China. The data have been collected and reviewed by Pew's research partner, Bloomberg New Energy Finance, a leading market research firm focused on renewable energy. The total trade numbers presented in the report represent the value of goods and services exported between the two countries, as well as the value of goods and services sold by U.S. companies operating overseas to China and vice versa. (See the methodology section in the appendix for further explanation.)

Our goal was to explore the scale and scope of U.S.-China clean energy trade alongside the relative strengths and weaknesses of each country in key subsectors. For this purpose, we surveyed data related to trade in goods and services in the solar photovoltaic, wind, and energy smart-technology sectors. The remainder of this report presents the findings of this research and resulting conclusions.

4 Ibid., page 15.

5 Ibid., page 16.

6 A photovoltaic cell is the generating unit of a solar module. Photovoltaic cells create electricity when exposed to sunlight; a series of cells, when assembled into a frame, is known as a module. "Module" and "panel" are interchangeable words for the basic unit of photovoltaic power generation.

U.S.-China trade in solar energy products

Solar energy incorporates a number of technologies that capture the sun's energy. Photovoltaic, or PV, modules (also called solar panels or PV panels) use crystalline cells or thin layers of semiconductors to generate electricity via the photoelectric effect. Solar thermal electrical technologies capture the sun's energy as heat, which is then used to drive a turbine in the same fashion as a fossil-fuel-fired or nuclear power plant. Because there is little trade in solar thermal electrical technologies between the United States and China, this analysis focuses on solar photovoltaic modules and their components.

PV modules come in two varieties: crystalline silicon, which uses the same semiconductor layer contained in computer chips, and "thin film," or the microscopic layer of semiconductors deposited on a glass or metal surface. Thin film PV accounts for less than one-fifth of global solar production; the leading manufacturer, First Solar Inc., is a U.S. firm that commenced meaningful activity in China only in 2012. China exports little thin film to the United States.

The key components of a solar panel are:

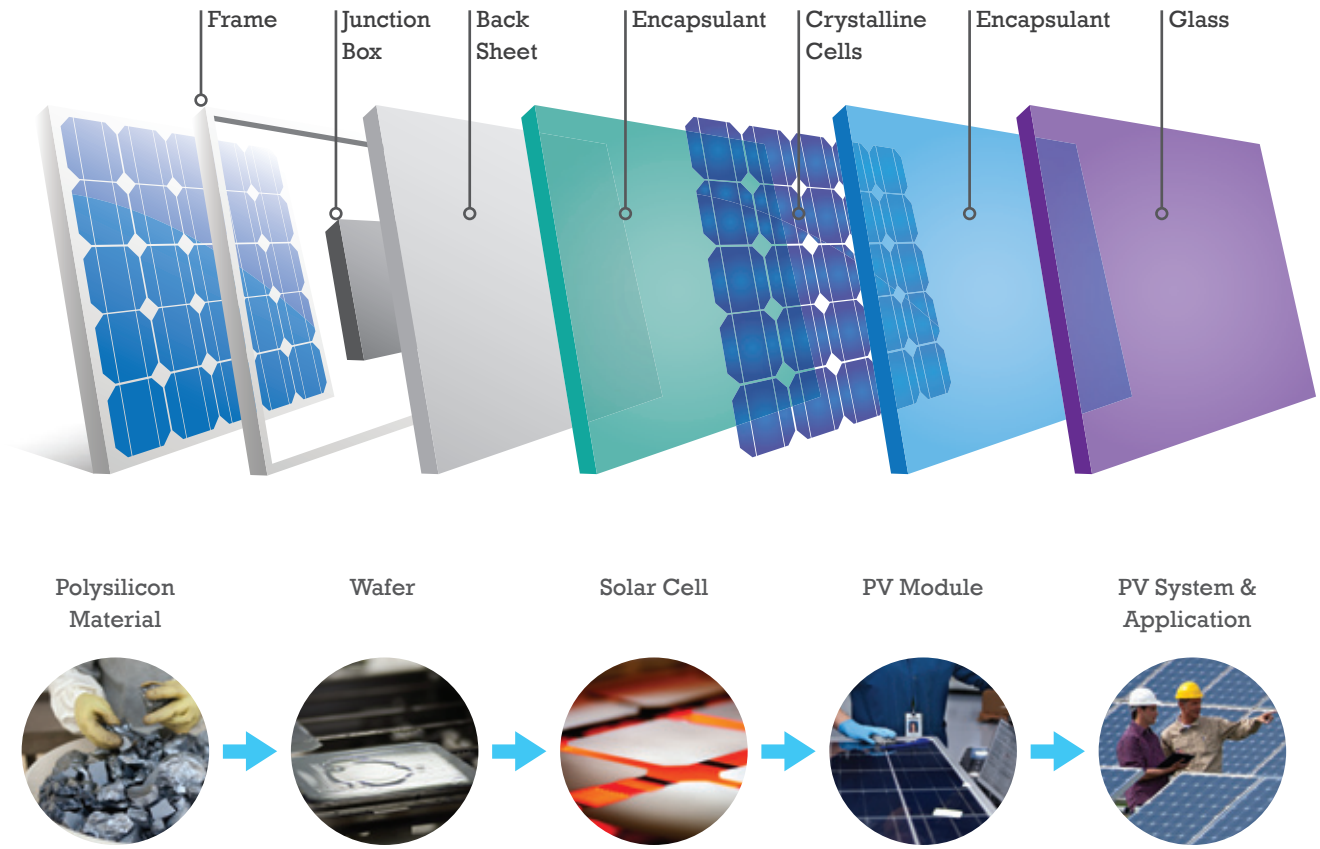
- **Polysilicon**, the crystalline metal that is the basis for PV panel semiconductors.
- **Wafers**, the finely cut slivers of silicon.
- **Cells**, the chemically prepared and electrically connected wafers that become the fundamental unit of generating solar energy.
- **Modules**, the collection of cells joined in a panel that can be mounted on homes, built into commercial buildings, or installed in fields as part of a solar power plant.

The U.S.-China solar trade also includes:

- **Solar materials** are specialty chemicals, plastics, and metals used to make solar panels.
- **Inverters** are electrical devices used to make solar electricity ready for use in the utility grid.
- **Capital equipment** is the specialized robotics and semiconductor production machinery used to make polysilicon, wafers, cells, and modules.

(See Figure 3 for an illustration of the various components of a solar panel.)

FIGURE 3: Solar module components and assembly



Photos credit: SolarWorld/Fred Joe

Polysilicon and wafers

Polysilicon is the fundamental material in photovoltaic cells. Silicon is one of the most abundant minerals on earth, found in the form of silicon dioxide, or sand. But refining it to the high purity required for use in semiconductors—at least 99.9999 percent pure—is an energy-intensive, highly specialized process. Construction of polysilicon production plants is not undertaken lightly because the facilities require long lead times, from initial planning to final commissioning.

The leading polysilicon companies around the world are generally large firms specializing in chemicals and metals. In the United States, these include Hemlock Semiconductor Group (a Dow Corning joint venture with Japanese companies Shin-Etsu Handotai and Mitsubishi Materials Corp.), MEMC Electronic Materials Inc., and the U.S. division of REC Group, a Norwegian entity. These companies were the world's third-, fifth-, and seventh-largest polysilicon producers in 2011, respectively.

U.S. companies' share of polysilicon exported to China in 2011 totaled $684 million. China has its own major producers, such as GCL-Poly Energy Holdings Ltd., but those firms do not export to the United States and instead serve primarily local and other international markets.

The United States is a major wafer exporter as well. MEMC Electronic Materials exported $289 million worth of polysilicon and wafers to China in 2011. Chinese firms do not export wafers to the United States.

Photovoltaic cells

Photovoltaic cells, or solar cells, are the heart of the solar power generation system. Cells are made by chemically preparing the surface of silicon wafers so that they create a stream of electrons when exposed to the sun. Cells are then wired together and enclosed in a durable outer fitting to become solar panels.

In less than a decade, China emerged as home to the bulk of the world's cell manufacturing capacity; the five largest manufacturers are Chinese. Cells are linked together in solar panels (commonly referred to as modules) at assembly factories but can also be sold separately for assembly by contractors or for use in other applications, such as building-integrated tiles.

With the world's largest manufacturers located in China, it is not surprising that trade in PV cells strongly favors Chinese interests. In 2011, Chinese companies exported $151 million worth of PV cells to the United States, while the United States exported only $14 million worth of cells to China. The United States has a small number of cell manufacturing firms, but most U.S. companies specialize in assembling premade cells or in operating integrated facilities that produce cells and modules.

Photovoltaic modules

PV modules are the final product of the PV manufacturing supply chain and are the primary source of solar power generation around the world. As with solar cells, China is the world's biggest producer of PV modules, and although an increasingly large domestic market is emerging, it is by far the world's largest exporter.

The five largest solar cell manufacturers in the world are Chinese.

U.S. firms are world leaders in specialized solar materials used to make PV panels.

Based on production, Suntech Power Holdings Co. Ltd., in China's Jiangsu province, was the world's largest PV module manufacturer in 2011, Chinese firms Trina Solar Ltd., Yingli Solar, and Canadian Solar Inc. were third, fourth, and fifth, respectively.[7] The U.S. company First Solar, which makes thin film panels, was the second-largest producer slightly behind Suntech.

Chinese PV module exports to the United States constitute the single largest component of clean energy products traded between the two countries. In 2011, Chinese firms exported $2.65 billion of PV modules to the United States. In contrast, U.S. firms exported only $12 million worth of modules to China.

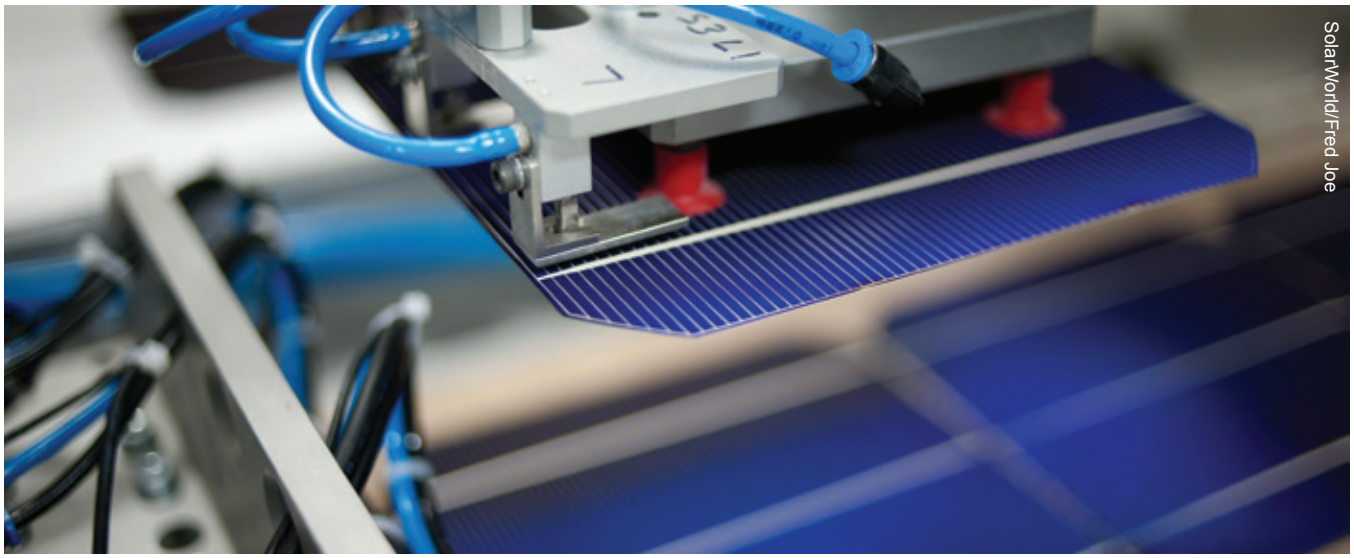
Solar materials

Finished solar panels rely upon more than photovoltaic cells and the metals and glass used to contain them. They also require specialized materials in their assembly, many of which must meet unique and rigorous operational performance standards. These materials include foam back sheets, on which PV cells rest; plastic encapsulants, which are used to seal the covering glass onto modules; and specialty metal compounds used to raise cell efficiency.

FIGURE 4: Applied Materials' Pegaso system for crystalline silicon PV cell production

Source: Applied Materials

7 Canadian Solar's headquarters are Ontario but it was founded in China and does the bulk of its manufacturing in there.


SolarWorld/Fred Joe

Some of the largest U.S. chemicals companies are world leaders in production of solar materials and are leading exporters as well. Delaware-based E.I. du Pont de Nemours and Co. (DuPont) and the Minnesota-based 3M Company are the world's foremost producers of solar materials.

U.S. firms sold more than $500 million worth of solar materials to Chinese interests in 2011. A number of major U.S. chemicals firms have established large manufacturing capabilities in coastal provinces in China. Chinese firms did not export statistically meaningful amounts of solar materials to the United States in 2011.

Photovoltaic inverters

Photovoltaic inverters are used to convert the direct current produced by solar panels into the alternating current required by the electrical grid. AC-DC inverters allow solar panels to be linked into residential, commercial, industrial, or wholesale electrical systems. Inverters are essential equipment—all systems have them—and are produced by a mix of specialized firms as well as large global power systems and industrial equipment companies such as French-based Schneider Electric, Swiss-based ABB Group, and U.S. companies General Electric and Emerson Electric.

U.S. manufacturers exported $9.6 million worth of inverters to China in 2011, according to trade data, and none were imported into the United States from China.

Capital equipment

Solar capital equipment is used to make polysilicon and wafers. These machines include furnaces and wire saws, deposition chambers and coating machines for applying chemicals to solar cells, robotics for assembling cells and modules, "clean rooms" to maintain contaminant-free work spaces for assembling solar panels, and service agreements to maintain these delicate and extremely valuable systems. (See

The United States and China traded more than $2 billion worth of capital equipment used in solar manufacturing processes, with all of the trade flowing from U.S. to Chinese interests.

Figure 4 for an illustration of an entire factory floor at California-based Applied Materials Inc.)

Capital equipment is not something manufacturers should economize on, because it must be made to precise specifications. Reliability, throughput, and quality control are critical to the production of marketable products. Any savings that might be obtained through acquisition of less expensive equipment can easily be negated by losses resulting from manufacturing equipment downtime or sale of inferior products.

Trade in capital equipment used in solar manufacturing processes constitutes a significant component of the U.S.-China trade relationship in the clean energy sector, with all of the trade flowing from the United States. In 2011, U.S. capital equipment companies, including Applied Materials and New Hampshire-based GT Advanced Technologies Inc., exported $2.2 billion worth of equipment to China.

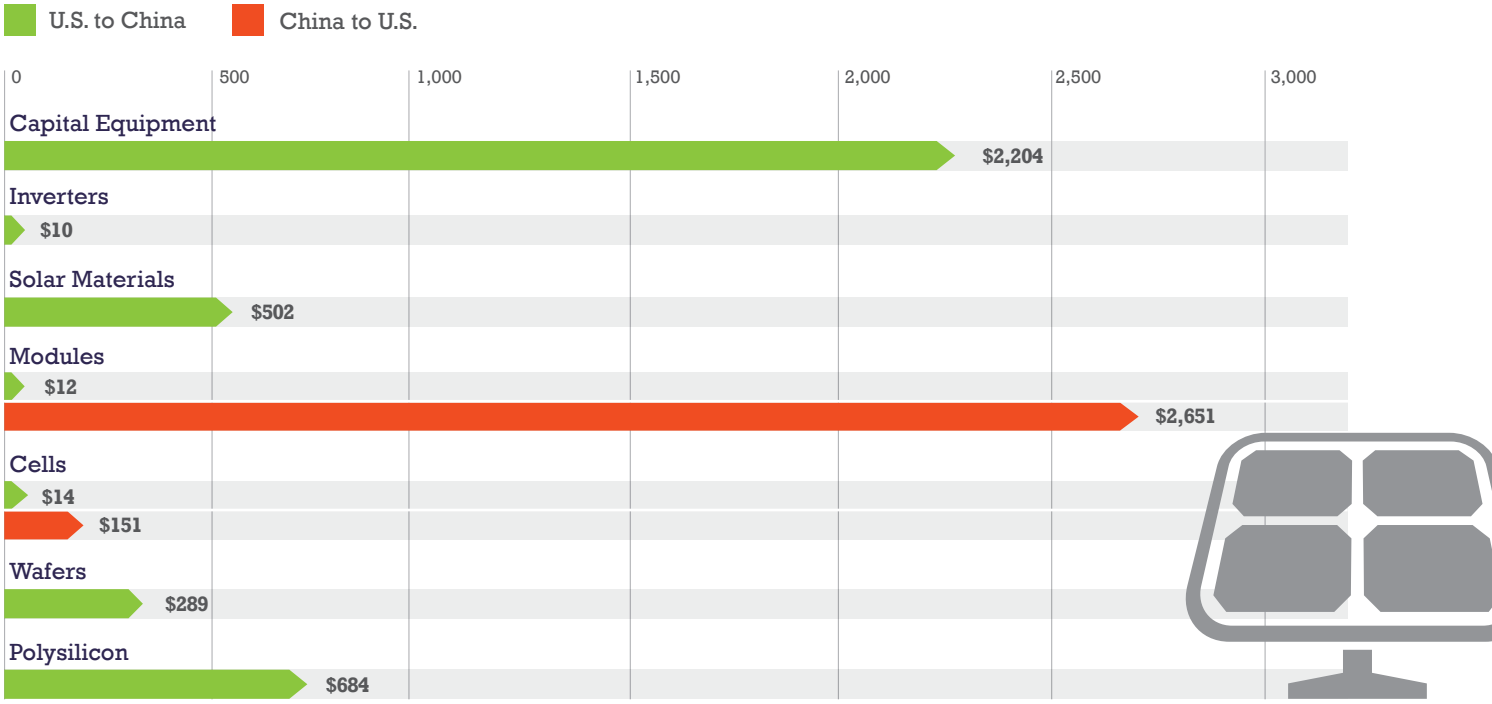
Case study: GT Advanced Technologies

GT Advanced Technologies Inc. is an equipment and services provider for two clean energy sectors: solar and light-emitting diodes, or LEDs. For the solar sector, it provides polysilicon reactors and systems used to cast silicon ingots for mono- and poly-crystalline cells. For LEDs, it provides sapphire growth furnaces. Headquartered in Nashua, NH, the company has offices throughout the United States, as well as in South Korea, Taiwan, Beijing, Shanghai, and Hong Kong.

GT Advanced Technologies has been a American clean energy success story. Its 2011 revenue was $899 million, the most recent year for which annual data are available, up from $544 million in 2010 and $244 million in 2008. The company also increased its operating margins from 19 percent in 2008 to 30 percent in 2011. Ninety-five percent of its 2011 revenue came from Asia, with China providing 52 percent.

Shutterstock

FIGURE 5: U.S.-China Solar Energy Trade Flows, 2011 (in millions of U.S. dollars)



Adding it up in the solar sector

Solar energy product exports are the largest component of U.S.-China clean energy trade for both countries. Combined, firms based in the two nations traded more than $6.5 billion worth of products and services to each other in 2011. (See Figure 5.)

As shown in Figure 5, China's trade contribution is highly concentrated; it exports only two related products, PV cells and modules. Both components lend themselves to mass assembly and high-volume manufacturing, which has been the strength of Chinese companies in recent years. Accordingly, China is the dominant PV cell and module producer and the leading exporter of both products. All of the world's major solar installation markets rely heavily on Chinese cells and modules.

But China's strength in high-volume production of solar modules is matched on the U.S. side by leadership in high-tech goods and services that are key components in the solar value chain. The U.S. clean energy strength in trading derives from its competitive advantage in producing high-value inputs (polysilicon and wafers, both for making PV cells), materials used in making PV modules, and the capital equipment and systems necessary in solar factories.

Firms based in the United States exported more than $3.7 billion worth of goods and services to Chinese interests in the solar PV sector, while Chinese companies exported $2.8 billion worth of products to the United States. On a net basis, the United States enjoyed a $913 million surplus in the solar sector.

Firms based in the two nations traded more than $6.5 billion worth of solar products and services to each other in 2011.

U.S.-China trade in wind energy products

A wind turbine is not a single manufactured product; it is an assembly of many specialized components and subcomponents, each with an independent supply chain. Although the largest manufacturers, such as General Electric, make many components in-house, a finished turbine invariably comprises parts sourced from a variety of firms. In this way, turbines are like automobiles manufactured by Ford Motor Co. or General Motors Co. The finished automobile is an assembly of many separate systems: engine, drivetrain, controls, communications, specialty materials for components and body, and interior. Each of these systems has its own value chain. Likewise, in the wind energy sector, the turbine manufacturer's role is not to make individual components but rather to integrate them and ensure the performance of the whole.

As in the automobile industry, wind energy's supply chains are global and specialized. U.S. and European manufacturers have particular dominance in the systems that control the turbine as well as in the specialty materials used for blades. Given the size of blades, nacelles (the housing that contains the turbine's drivetrain), and towers, these components are often manufactured in proximity to end markets. (See Figure 6 for a complete look at the wind energy value chain.)

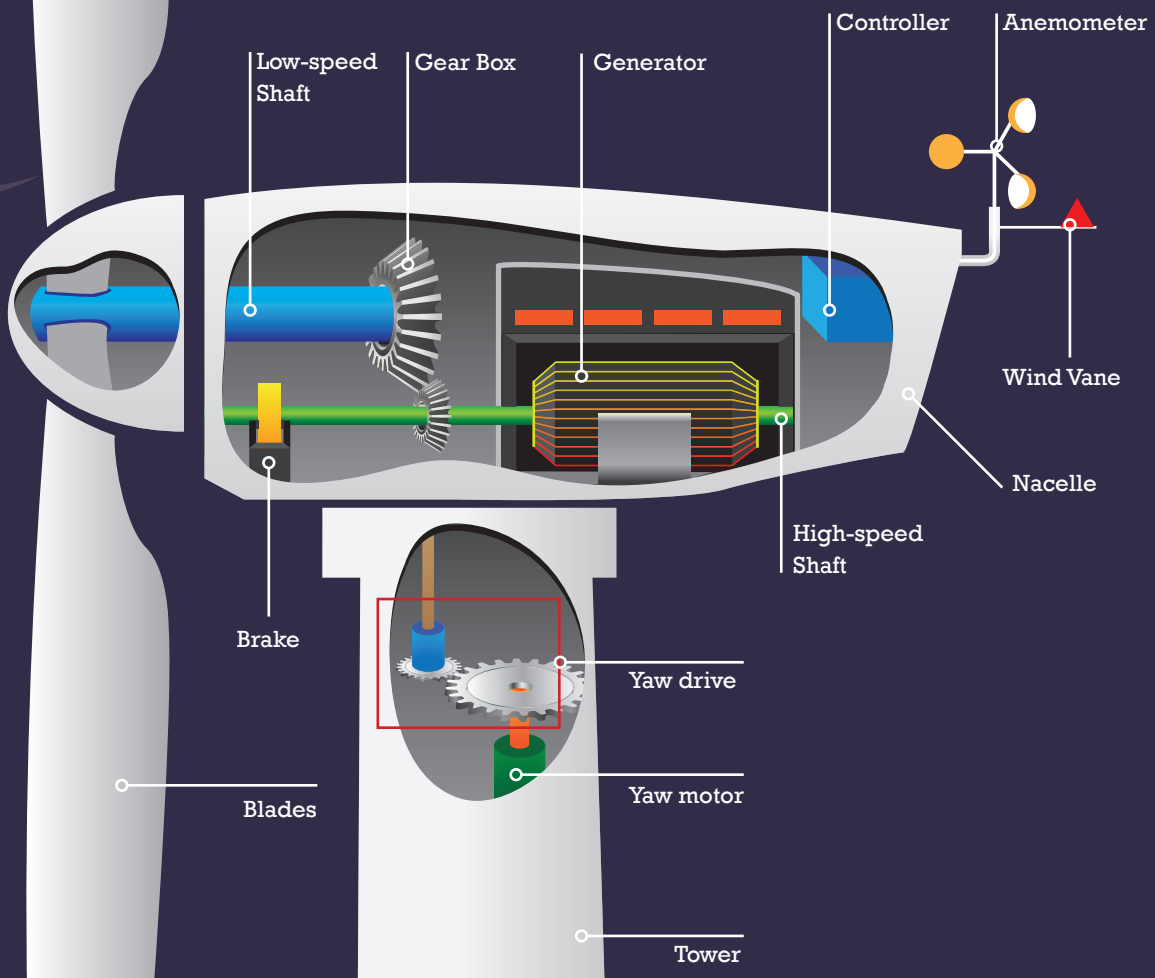
U.S. and European specialty manufacturers have particular dominance in the systems that control the turbine and in the specialty materials used for blades.

The components of a turbine, with associated trade flows, include nacelles, rotors, drivetrains, yaw systems, switchgear products, specialty materials for blades, and towers. There is little trade in complete wind turbines. A brief examination of each component follows.

Nacelles

The nacelle is the housing at the top of the turbine that contains the drive system and most of its control mechanisms. The turbine's blades are connected to the front of the hub assembly and drive a rotor that, through a series of gears and a generator, creates electricity.

FIGURE 6: Wind Turbine Value Chain



SOURCE: Department of Energy, Energy Efficiency and Renewable Energy, http://www1.eere.energy.gov/wind/inside_a_wind_turbine.html

Today's largest turbines have nacelles more than 20 feet long. They are not complex pieces of engineering but require welding specialists for assembly. For this reason, many nacelles are assembled close to their final markets because it is easier to ship the main component than the finished form.

As a result, there was no trade in wind turbine nacelles between the United States and China in 2011.

Rotors

The rotor of a wind turbine connects the three or more turbine blades to the drivetrain systems which ultimately produce power. At the front of this assembly is the hub, to which blades are attached, and behind it a series of bearings. Although the bearing is not electronically sophisticated, it is one of the most technically specific aspects of a wind turbine. Bearings need to be precise and durable, able to withstand the stresses of operation and perform to tight tolerances for many years.

U.S. firms sold $34 million worth of rotors to Chinese interests in 2011. One-fifth of U.S. sales were to Chinese firms operating in the United States, and the remainder were sold in the Chinese market by U.S. firms operating abroad.

Drivetrains

The drivetrain sits inside the wind turbine, behind the rotor, and transfers the rotational force to the generator. It consists of gearboxes, bearings, and the brakes, couplings, and guards that control the turbine if it needs to be shut down or if wind speeds are too high for safe operation.

Drivetrains are among the largest categories of U.S.-China cross-border trade in the wind sector. China exported $160 million worth of turbine gearboxes to the United States, and U.S. firms exported $103 million worth of drivetrain bearings to China.

China's gearbox exports come almost entirely from China High Speed Transmission Equipment Group, which has its headquarters in Hong Kong and is listed on the Hong Kong Stock Exchange. General Electric, the world's fifth-largest wind turbine manufacturer, is a large purchaser of these gearboxes.

Yaw systems

Yaw is the movement of a body around an axis in order to change the direction it faces. For wind turbines, yaw control is essential, because it keeps the turbine pointed upwind to maximize power output. The yaw system sits at the top of the turbine tower, connecting it to the tower and also controlling how it faces the wind.

The United States and China did not have any trade in yaw systems in 2011.

Switchgear products

To generate electricity and control their operations, wind turbines require

sophisticated equipment categorized as switchgear products. These include ultracapacitors, which are used to regulate voltage and provide the short bursts of power that turbines require to operate within safe parameters. Other switchgear products serve to protect turbines from power system faults, which would otherwise curtail turbine life span.

U.S. companies have a distinct production advantage in this specialized, high-tech subsector. U.S. firms exported $73 million worth of switchgear products to Chinese turbine makers and imported none.

Specialty materials for blades

Three key specialty materials are used in wind turbine blades: fiberglass, resin, and coatings. Fiberglass can be molded into complex turbine blade shapes just as it is for boat hulls. Resin is used to bind fiberglass into a durable material. And coatings are used to ensure that the outer surface of the blades resists the corrosive impact of the elements.

Fiberglass is made by U.S. chemicals and materials firms such as Owens Corning Corp., Hexcel Corp., and PPG Industries Inc., all of which have operations in mainland China to meet its high demand for different chemicals. Fiberglass sold by U.S.-based companies to Chinese interests for wind products totaled $135 million in 2011.

Resins are likewise manufactured in Asia by U.S. companies such as Dow Chemical Co. and Huntsman International. Total resin sales from U.S. companies to Chinese firms in 2011 are estimated at $150 million.

Coatings, the final element of wind turbine blades, are also made and sold overseas by U.S. companies such as Dow Chemical, PPG Industries, and the Lubrizol Corp. Sales in China in 2011 totaled $40 million.

As with the solar panel value chain, specialty materials constitute an important component of the flows in U.S.-China clean energy trade. They redound in favor of the United States, whose companies sell $325 million worth of products in China, compared with China's sales of $7 million in materials to U.S. companies.

Towers

Wind turbine towers are similar to nacelles in that they are large steel bodies that are expensive to transport when completed. Most turbine towers are welded from steel sheets into tubular sections, which are then transported by ship, rail, and truck to their final point of assembly at the project site. To minimize transport costs, towers are usually made relatively close to where they will be finally deployed.

The United States has a number of wind turbine tower manufacturing facilities, most of which are in the industrial Midwest, close to major wind markets in Texas, Iowa, and the Dakotas. Beginning in 2009, wind project developers showed renewed interest in the West Coast, where the industry began in the 1970s. Yet because of high transportation costs associated with shipping large, heavy wind components from Midwestern manufacturing sites over the Rocky Mountains, imports of Chinese wind towers were often more attractive for project developers. So the United States imported $196 million in wind towers from China in 2011 while exporting none.

Complete wind turbines

Considering the size of today's industrial wind turbines, it is not surprising that there is little trade in completed turbines. Still, the United States imported $26 million worth of complete Chinese wind

U.S. firms sold $34 million worth of rotors to Chinese interests in 2011. One-fifth of U.S. sales were to Chinese firms operating in the United States, with the remainder sold into the Chinese market from U.S. firms operating abroad.

turbines in 2012, although this represents a small number—only about 20 utility-size turbines. Few U.S.-based developers use Chinese wind turbines, and given the current global oversupply of turbines and the excess of U.S. manufacturing capacity, a surge in imports of Chinese turbines is unlikely.

Adding it up in the wind sector

Wind energy products represent the smallest component of the three sectors of clean energy trade between the United States and China examined in this report. Overall, more than $923 million worth of wind energy goods and services were exchanged between the countries in 2011. (See Figure 7.)

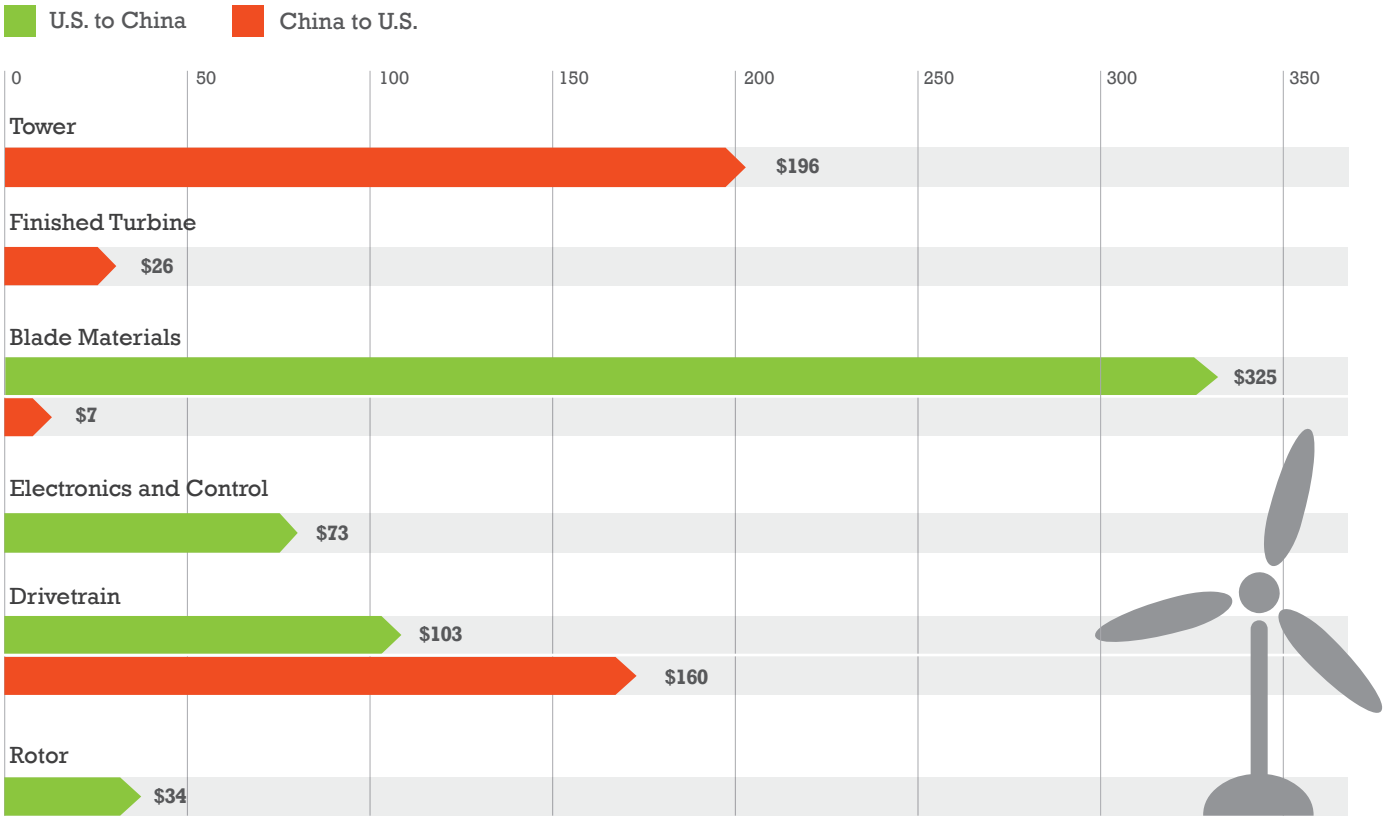
Trade in wind energy components between the United States and China is similar to other clean energy sectors in that it is defined by a small number of large flows in particular items, with each country having defined specialties in the cross-border relationship. As with solar, the U.S. wind industry excels in relatively high-margin specialty materials (fiberglass) produced by large firms and in sensitive electronic and other control systems, with U.S. trade to China totaling $534.9 million.

China's largest trade contributors are wind turbine towers—a trade driven almost entirely by logistical concerns rather than pure cost advantages—and turbine rotors manufactured under a U.S.-China joint venture. China's wind energy exports to the United States totaled $388.7 million.

Overall, U.S. firms had a net trade surplus of just over $146 million.

FIGURE 7: U.S.-China wind energy trade flows, 2011

(in millions of U.S. dollars)



Source: Bloomberg New Energy Finance, US Department of Commerce, company data


Shutterstock


Shutterstock

Overall, U.S. firms had a net trade surplus in wind of just over $146 million.


Shutterstock


iStockphoto

U.S.-China trade in energy smart technologies

Energy smart technologies include services and products that can improve energy performance and efficiency, store energy, and reduce carbon emissions. Like solar and wind, energy smart technologies have diversified global supply chains, and most of the technology sales in this sector are assemblages of various components. For this report, U.S.-China trade was tracked in four leading energy smart technologies: light emitting diodes, or LEDs; advanced lithium-ion batteries; electric vehicles; and smart meters. Trade flows associated with each of these products are examined below.

Light-emitting diodes

A light-emitting diode is a semiconductor-based illumination source. When electrons flow through an LED's semiconductor material, they produce light. Unlike traditional incandescent bulbs, LEDs are efficient because they lose little of their energy to heat and because they produce light in only one direction rather than radiating it outward in all directions. LEDs also have a long product life—tens of thousands of operational hours—unlike incandescent bulbs, which last hundreds of hours.

LEDs were first used in electronics but are now being used in light fixtures and large arrays. There are four main parts of the LED value chain:

- **Manufacturing equipment** used to make LEDs.
- **Sapphire substrates,** or the crystalline material used as the basis for LED chips.
- **Chips and modules** that produce light.
- **Fixtures**, the final structures that consumers can buy and plug in to produce light.

Each subsector has its own dynamics.

LED manufacturing equipment

LEDs require specialty manufacturing equipment, which tends to be expensive and designed for particular tasks, as is the case with solar. The necessary equipment includes deposition reactors, which place layers of semiconductors onto the sapphires used for LED chips. U.S. companies, in particular Veeco Instruments Inc., are world leaders in LED manufacturing equipment and exported $618 million worth to China in 2011. This is the single largest component of U.S.-China trade in energy smart technologies, and it goes in one direction; China does not yet produce or export LED capital equipment yet.

LED substrates

Sapphire substrates, used to make LED chips, are the greatest contributor to LED costs. Firms based in the United States exported $49 million worth

to China in 2011 while China exported none to the United States. Two U.S. companies, specialty sapphire maker Rubicon Technology Inc. and solar and LED equipment maker GT Advanced Technologies, are the primary exporters to China, which does not produce sapphires domestically. It imports them from Japan and Taiwan as well as the United States.

LED chips and modules

LED chips are the semiconductors that convert electrical energy into light. LED modules are integrated units consisting of chips, drive electronics, heat sinks, and a mechanical and electrical interface. The majority of global LED chip and module production is located in Asia, where Japan, South Korea, and Taiwan have been the leaders. Since 2010, however, China has been actively supporting its LED chip market in an effort to dominate the export business. Nevertheless, U.S. firms exported $90 million worth of LED chips and modules to China, which exported only about one-sixth as much ($15 million) to the United States.

Two firms dominate U.S. exports: Cree Inc., a publicly listed manufacturer based in Durham, NC, and Bridgelux Inc., a venture capital-backed firm based in Livermore, CA. Cree exports from the United States even though it has virtually equal floor space devoted to module production in the United States and China (48 percent and 52 percent, respectively). The United States is not a significant market for Chinese LED chipmakers, even though China has a number of leading companies. Chinese manufacturers export a modest amount to countries including the United States, but are they primarily focused on serving domestic markets.

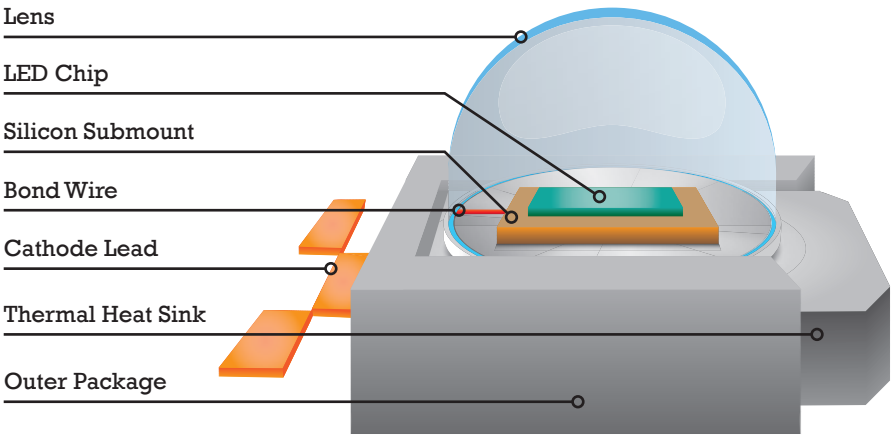
LED fixtures

LED fixtures, the final assembled bulb or lighting product, are the only part of the LED value chain in which China has a net trade surplus with the United States. China exported $118 million worth of fixtures to the United States in 2011against U.S. exports of $50 million to China.

There are two types of Chinese LED fixture exporters. The first are the hundreds of small, family-owned export-oriented companies with revenues of less than $10 million. Most of these companies export to Western Europe, because the costs of certification for the U.S. market are too high for small exporters to incorporate into their business models.

The second group is large manufacturers such as Elec-Tech Electrical Services Inc., Foshan Electrical and Lighting Co., and Dongguan Kingsun Optoelectronic Co., all of which are major exporters to the U.S. market. In addition, international manufacturers such as Royal Philips Electronics (Philips), Siemens AG, and General Electric have facilities in China and ship LED fixtures to the United States.

FIGURE 8: LED Configuration



U.S. companies are world leaders in LED manufacturing equipment.

U.S. firms exported $49 million worth of sapphire substrates to China while importing none.

China plans to be an LED export leader, but in 2011 it was a net importer of LED chips and modules from the United States.

Advanced lithium-ion batteries

Power storage is an increasingly important part of the renewable energy and smart technologies ecosystem. It allows vehicles to operate without fossil fuels, enables home systems to store and dispatch energy, powers consumer electronics, and helps generators and grid operators to address challenges associated with the intermittency of renewable sources such as wind and solar.

This analysis focuses on advanced lithium-ion batteries, the most developed power storage system. Lithium-ion batteries, which are used for power storage in a number of applications, are commonly found in laptop and tablet computers and mobile phones. Because of their power density (the amount of energy they can store per unit of volume), lithium-ion batteries are also emerging as an important part of energy smart technologies, both for stationary applications and for hybrid and electric vehicles. (See Figure 8.)

The lithium-ion battery market is still nascent. Trade flows in 2011 between the United States and China were relatively small, with $29 million in exports from the United States to China and $66 million from China to the United States.

U.S.-China trade in lithium-ion batteries remains limited for a number of reasons. First, electric vehicles, which could drive much larger demand for advanced power storage technologies, are in the early stages of rollout to consumers. U.S. sales of electric vehicles, which totaled 20,000 in 2011, are expected to increase tenfold by the end of 2014 to almost 211,000. (See Figure 9.)

Second, stationary storage applications face a number of impediments to mass adoption, in particular high costs and regulatory barriers. Finally, neither U.S. nor Chinese companies are global players in electric vehicle power storage production, which is led by South Korean and Japanese companies. Automotive Energy Supply Corp., a joint venture between the Japanese companies NEC and Nissan, and South Korea's LG Chem Power Inc. are the largest producers of power storage technologies.

China has a development plan for electric vehicles through 2020, which could drive demand for lithium-ion batteries in the future. (See Figure 10.) U.S. battery pioneer A123 Systems Inc., which has been purchased by Wanxiang Group, a major Chinese electrical and control systems company, has factories in China and works with its largest automaker, SAIC Motor Corp.

For stationary storage, the United States has a number of leading technology companies such as Xtreme Power, Maxwell Technologies, and Johnson

FIGURE 9: Battery Configuration

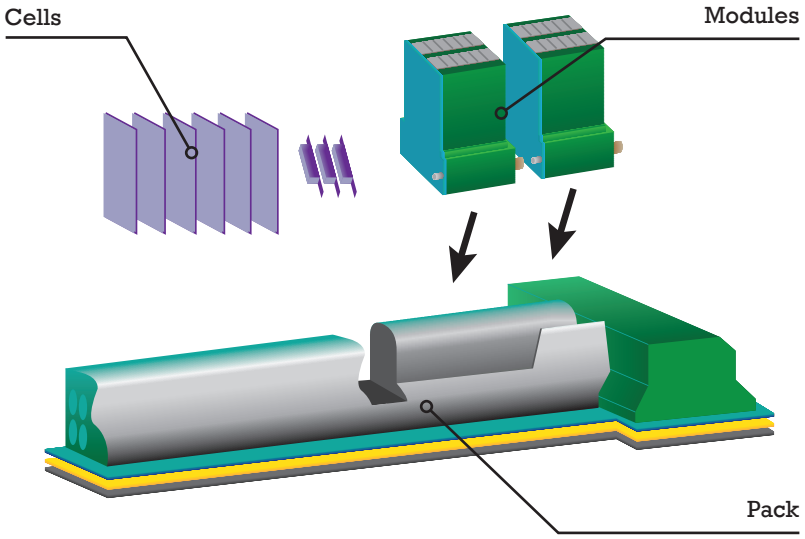
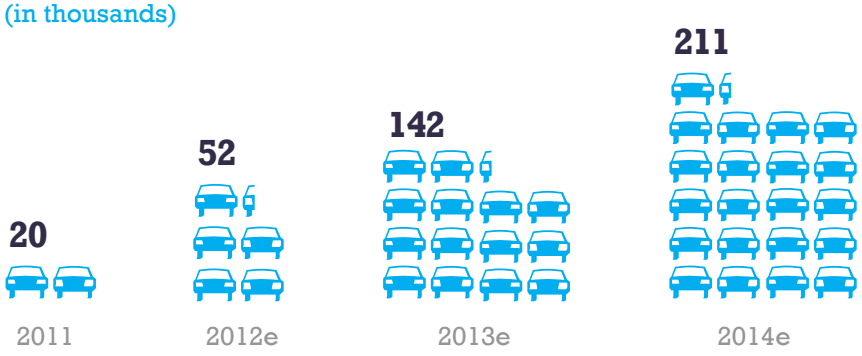


FIGURE 10: Projected U.S. Electric Vehicle Sales

(in thousands)



Source: Bloomberg New Energy Finance

Controls Inc. With its increasing penetration of renewable energy and its power network structure, China will have a need for lithium-ion batteries and other power storage technologies in the future. U.S. companies might help supply the growing Chinese stationary power storage market, but Chinese political and regulatory activities strongly favor domestic manufacturers and probably will continue to do so in the near term.

Electric vehicles are a growing market, but they still constitute only a small portion of U.S.-China clean energy trade. Net trade flows equal less than $1 million from the United States to China.

Electric vehicles began large-scale rollouts in 2011 with a limited number of cars: the Chevrolet Volt, Tesla Roadster, and Nissan Leaf in the United States and BYD, SAIC, and Chery models in China. The combined electric vehicle market in the two countries totaled $900 million in 2011, and trade flow in this subsector totaled $2.2 million, all from U.S. firms exporting to China. The trade volume tracked in the electric vehicle category is the result of U.S.-China joint ventures in manufacturing components, mostly onboard battery chargers for use in Chinese vehicles.

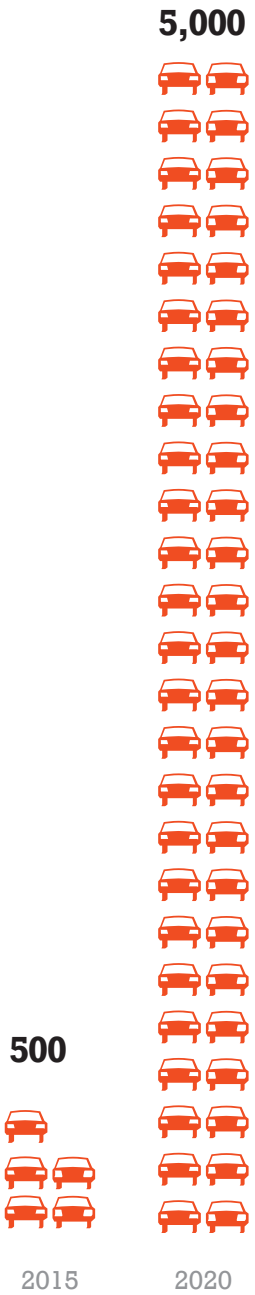
Rare earth minerals—a group of 17 minerals used to make semiconductors and permanent magnets—are a small but important component of clean energy trade. The rare earth elements neodymium and dysprosium are used to make permanent magnets in some electric vehicle motors. China produces many of the rare earth minerals used globally in advanced electronic products. In the clean energy field, China supplied $3.2 million in rare earth exports to the U.S. electric vehicle sector.

Although trade figures in the electric vehicle subsector are low, there should be major growth in the U.S. and Chinese

Shutterstock

FIGURE 11: Projected Chinese EV Sales Targets

(in thousands)



Source: Bloomberg New Energy Finance

markets through the decade. As noted, U.S. sales are forecast to grow roughly tenfold from 2011 to 2014. (See Figure 8.) The Chinese government has set 10-year plans for electric vehicle sales, aiming for sales of 500,000 by 2015 and increasing to 5 million by 2020. (See Figure 9.)

Smart meter systems

Smart meter systems allow electricity consumers and power distributors to communicate at the point of use. The systems usually include features such as interval measurement and automatic data collection with two-way communications. They allow power companies to obtain real-time information on customer usage patterns and needs while allowing consumers to better understand and control their energy use and reduce costs.

Smart meter systems allow electricity consumers and power distributors to communicate at the point of use.

The smart meter system has three primary components:

- Physical **meters**, which are installed at homes or commercial properties.
- **Meter data management** systems, which provide storage and handling of the large quantities of data that smart meters generate. These systems typically validate and scrub meter data before transmitting it to billing systems, but they can also be used in much more advanced analytical applications, such as forecasting electrical loads managing outages, or segmenting a utility's customer base.
- **Communications modules**, which allow communication with the network. Also called the network

Shutterstock

interface card, these modules can be supplied by the meter vendor or a third party.

Neither the United States nor China has meaningful exports in the smart meter systems subsector. China did not export any smart meters to the United States in 2011. The United States is home to four leading smart meter firms—Echelon Corp., General Electric, Itron Inc., and Sensus USA Inc.—that do most of their manufacturing for the U.S. market within its borders. Likewise, China did not export any meter data management systems to the United States in 2011. The market is dominated by a small number of U.S. and European companies, including giant industrial and information technology firms Siemens AG and Oracle Corp.

The only significant smart meter trade flow came from Chinese exports of the communications modules. More than 18 million modules were shipped to the United States in 2011, with 59 percent coming from China at an average cost of $6, for a total of $65 million worth of exports to the United States.

Adding it up in the energy smart technologies sector

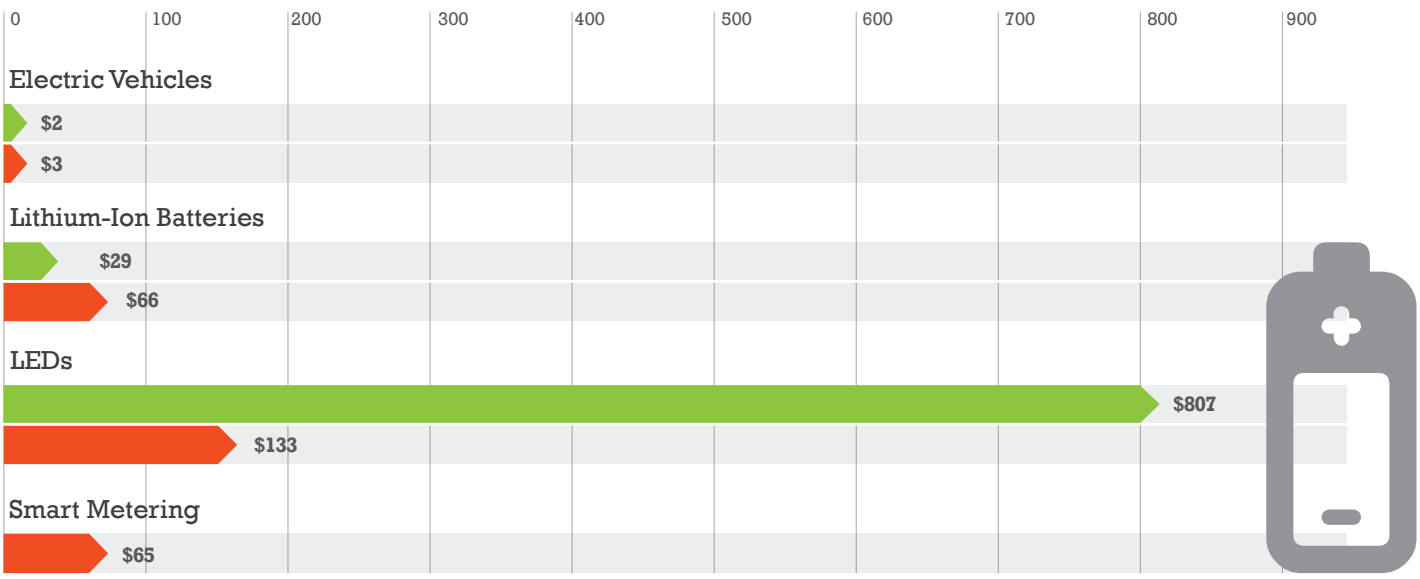
Trade in goods and services in the energy smart technology sector constitutes the second-largest component in U.S.-China trade flows. Overall, more than $1.1 billion worth of equipment was traded in 2011. (See Figure 12.)

Each subsector of energy smart technology has its own industry dynamics. China leads in smart metering and lithium-ion batteries, with trade to the United States valued at more than $130 million. In addition, China exports $133 million worth of LED products, primarily fixtures, to the United States. Cross-border trade in electric vehicles is quite small. The LED is the technology with the largest trade flow: Both countries export chips, modules, and fixtures to each other, with U.S. firms exporting more than $800 million worth of LED capital equipment to China while importing none. The United States also traded $29 million worth of lithium-ion batteries.

In total, the United States had a net trade surplus of $571 million in the energy smart technology sector in 2011.

Trade patterns in this clean energy subsector could change in the next five years, particularly if Chinese manufacturers increase their technical and analytical capabilities and form partnerships with international vendors. At the same time, risk-averse major utilities and strict U.S. certification requirements could prove barriers to entry for Chinese firms.

FIGURE 12: U.S.-China energy smart technologies trade flows, 2011 (in millions of U.S. dollars)



Source: Bloomberg New Energy Finance, US Department of Commerce, company data

Conclusions

Our analysis of U.S.-China clean energy trade highlights six key trends that underscore the complexity and interconnectedness of trade relations in this sector between the largest and second-largest economies in the world. Specifically:

- Clean energy markets are global.
- The United States has a $1.63 billion clean energy trade surplus with China.
- U.S. competitive strengths stem from innovation and entrepreneurship.
- A global presence helps U.S. firms.
- Chinese strengths are manufacturing and assembly.
- U.S. policy uncertainties present a challenge to domestic manufacturing.

Each of these conclusions is detailed below.

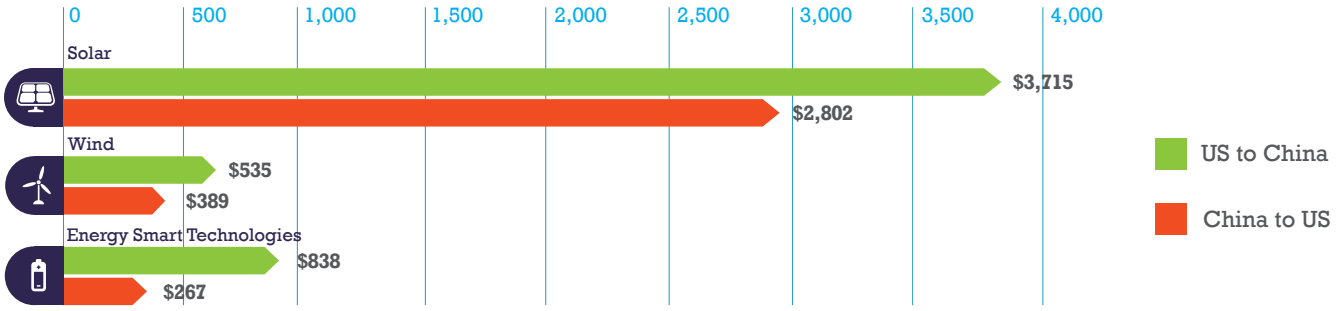
Clean energy markets are global

Trade flows between the United States and China demonstrate the global nature of clean energy markets and the opportunity they present for businesses. In 2011, the United States and China exchanged more than $8.5 billion worth of clean energy goods and services, with trade in products and materials covering all sectors: wind, solar, and energy smart technologies. Solar represented by far the largest portion of overall trade flows, with more than $6.5 billion worth of products moving between countries.

Robust trade between the two countries and around the globe is likely to continue in the future. Pew's research shows that private clean energy investments are rising in every region of the world, with rapid growth rates occurring in emerging economies in Asia and Latin America.[8] In fact, developing countries' markets in clean energy are projected to increase by 10 percent to 20 percent annually over the next 10 years as nations attempt to meet demand with clean, secure energy supplies.[9]

The U.S. Energy Information Administration estimates that global energy consumption will increase by 47 percent from 2010 to 2035.[10] Eighty-five percent of that growth will occur in emerging and developing economies. The International Energy Agency estimates that clean energy will provide half of the electricity generating capacity installed over the next 25 years.[11]

FIGURE 1: Total U.S.-China Clean Energy Trade Flows (in millions of U.S. dollars)



8 Pew Charitable Trusts, *Who's Winning the Clean Energy Race? 2011 Edition*, page 7. http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/FINAL_forweb_WhoIsWinningTheCleanEnergyRace-REPORT-2012.pdf

9 Ibid., page 2.

10 U.S. Energy Information Administration, Annual Energy Outlook 2012. June 2012, page 74. http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf

11 International Energy Association, *World Energy Outlook*, 2011, Executive Summary, page 2. http://www.iea.org/Textbase/npsum/weo2011sum.pdf

The United States has a $1.63 billion clean energy trade surplus with China

Considering all aspects of the value chain, U.S. exports and trade to China exceeded Chinese exports to the United States by $1.63 billion in 2011. (See Figure 11.)

When all 2011 trade is considered—including exports and sales by U.S. and/or Chinese companies operating overseas—the United States has a surplus in each of the three sectors examined in this report. Specifically:

- **Solar accounts for most of overall U.S.-China clean energy trade.** Chinese firms exported $2.8 billion worth of photovoltaic cells and modules to the United States in 2011. U.S. firms, in comparison, traded more than $3.7 billion worth of solar and solar-related clean energy products with China, led by polysilicon and capital equipment for high-volume solar cell and module manufacturing. The United States maintained a surplus of $913 million in the solar sector.
- **Wind energy product trade between the United States and China was the smallest of the three sectors.** In 2011, $924 million worth of goods and services were exchanged. China exported $389 million worth of turbine towers, drivetrains, and other wind energy products to the United States. U.S. firms traded $535 million worth of wind energy products, primarily bearings. The U.S.-based companies held a net trade surplus of $146 million in wind energy products.
- **Energy smart technologies were the second-highest volume of products traded.** In 2011, more than $1.1 billion worth of meters, LEDs, batteries, and electric vehicle components was exchanged between the United States and China. In both countries, LEDs were the major export subsector, with Chinese firms exporting mostly finished goods and U.S. companies trading mostly manufacturing equipment. Firms based in the United States exchanged almost $800 million worth of LED-related products with Chinese interests, while Chinese firms traded more than $133 million worth of LED modules and fixtures. Overall, the energy smart technologies trade balance tilted in favor of U.S. firms by $571 million.

> Trade in clean energy goods and services between the United States and China demonstrate the advantages that accrue to U.S. firms based upon national leadership in innovation and entrepreneurship.

U.S. competitive strengths stem from innovation and entrepreneurship

Trade in clean energy goods and services between the United States and China demonstrates U.S. firms' advantages from national leadership in innovation and entrepreneurship. The U.S. edge in wind, solar, and energy smart technologies indicates that these firms excel in production and sale of complex, high-margin, and performance-critical goods. These include capital equipment for manufacturing solar panels and LEDs, specialty chemicals, materials needed for production of solar and wind products, and controls for energy systems.

Specific U.S. strengths are found in the production of polysilicon, which requires highly specialized processes; the development of advanced manufacturing equipment for solar and energy smart technologies; specialty materials such as chemicals and fiberglass used in creation of wind blades; and advanced electronics and motors. Although major U.S. clean energy exporters include diversified giants such as Dow Chemical and PPG Industries as well as specialists in semiconductors and electronics such as Applied Materials, U.S. strength derives from its culture of innovation and entrepreneurship. Bloomberg New Energy Finance data show that:

- The United States is home to more than 15,000 clean energy firms. China has 5,200.
- U.S. firms have raised more than $34 billion in venture capital from more than 2,000 deals in the past decade. Chinese firms have raised less than $3 billion, from 90 deals.
- U.S. firms accounted for 31 percent of global corporate clean energy R&D in 2011. Chinese firms accounted for 2.9 percent.

The data indicate that continued U.S. leadership in clean energy innovation could help ensure ongoing competitiveness in the large and growing global clean energy sector.

A global presence helps U.S. firms

This report examined data for net exports and overall trade. Net exports capture the value of goods imported and exported between the United States and China. But in an age of global supply chains and sophisticated manufacturing, some

companies produce clean energy products abroad to service local markets. The data demonstrate that U.S. companies are more active overseas than are their Chinese counterparts, which have only small U.S. assembly operations for clean energy equipment.

The U.S. clean energy trade picture significantly improves when the global footprint of U.S. firms that manufacture products overseas is taken into account. The domestic clean energy surplus totaled just over $500 million if only the exports between the countries are considered. But when products manufactured by U.S. companies operating overseas are included, the U.S. trade advantage increased by more than $1.1 billion to $1.63 billion.

In other words, sales by U.S. firms operating overseas account for more than two-thirds of the U.S. trade surplus with China in the clean energy sectors examined in this report.

Sales by U.S. firms operating overseas account for more than two-thirds of the U.S. trade surplus with China in the clean energy sectors.

Chinese strengths are manufacturing and assembly

Whereas U.S. strength lies in a wide variety of high-technology products across the clean energy sectors, China's is more narrowly based on assembly and high-volume manufacturing. Data show that Chinese firms are relied upon for large-scale manufacturing and assembly of finished products such as solar modules and LED fixtures. China has become a dominant solar producer and is home to the bulk of the world's crystalline silicon PV module production capacity, as well as the majority of global production of PV cells and completed modules. The increase in Chinese PV production capabilities helped to lower worldwide prices and spur deployment of solar generating capacity around the world.

Chinese manufacturing operations in the solar and wind sectors have been helped in part by strong domestic targets for deployment of clean energy generating capacity. Chinese demand provides ready and proximate markets for the country's rapidly expanding manufacturing capacity and allows firms to gain a competitive advantage in the global marketplace.

Continued Chinese leadership in production of clean energy technologies may be challenged in coming months and years, however. The country's solar exports to the United States are in decline because of tariff penalties recently imposed as a result of trade violations, but tariffs are not the only hurdle facing Chinese firms. Increased competition from clean energy firms in other countries is also on the rise, according to Bloomberg New Energy Finance.

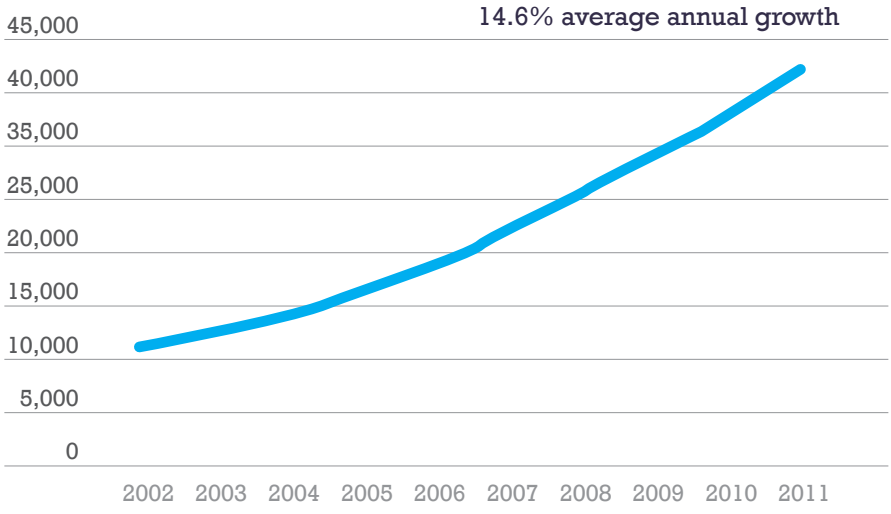
In addition, many jobs associated with China's high-volume manufacturing operations are low-skill, low-wage jobs. Over time, however, China's advantage in low-cost labor is eroding because of steady wage growth its workers. In coming years, higher labor costs and increasing automation could eliminate the physical cost differences between clean energy technology manufacturing in the United States and China. (See Figure 13.)

U.S. policy uncertainties present a challenge to domestic manufacturing

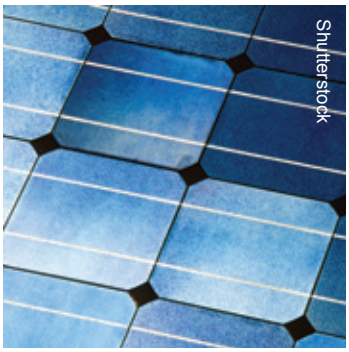
The uncertainties surrounding U.S. clean energy policies, rather than import trends from China or elsewhere, are likely to have the greatest impact on domestic

FIGURE 13: China Annual Wage Increase, 2001-2011

(in RMB)



Source: Bloomberg, National Bureau of Statistics of China



manufacturing in the clean energy industry. Given that there are numerous international competitors in the industry, diminished trade from China is unlikely to protect U.S. manufacturers in the marketplace. Most important, global production of solar and wind technologies is in oversupply. Increased demand at home and around the world is critical to industry growth, and local demand can be a driver of domestic production.

In the United States, clean energy policy is in flux. Several key federal initiatives have expired or will soon expire, such as the Advanced Energy Manufacturing Tax Credit, the Department of Energy's Loan Guarantee program for renewable energy deployment, and the Department of Treasury's clean energy grants initiative. In addition, the Production Tax Credit and Investment Tax Credit face an uncertain future in ongoing tax and budget policy discussions. Policy choices, not China's exports, will determine the direction of the U.S. clean energy industry in the months and years ahead.

Consider the U.S. wind industry, where demand could decline by 50 percent or more this year.[12] The inability of Congress to extend the production tax credit used by the wind industry until the end of 2012 caused new orders to slump last year and will result in a substantial imbalance between supply and demand until at least 2014.

In the months ahead, policymakers in the United States will have the opportunity to provide greater certainty in the clean energy marketplace. The Pew Charitable Trusts hopes that the information provided in this report supports those efforts.

12 Bloomberg News, *GE Sees U.S. Wind Credit Muting Slump in Turbine Demand*, http://www.bloomberg.com/news/2013-01-31/ge-sees-u-s-wind-credit-muting-slump-in-turbine-demand.html

Appendix:
Sources and methodology

Bloomberg New Energy Finance drew upon a number of sources in analyzing the size and scope of trade in clean energy goods between the United States and China for 2011, the most recent year for which complete and accurate data are available. The main source is the proprietary Bloomberg New Energy Finance Industry Intelligence Desktop, a Web-based data bank of clean energy and smart-technologies companies, manufacturing facilities, generation projects, and financial deals, including asset finance, public markets activity, venture capital and private equity, and mergers and acquisitions.

The Industry Intelligence Desktop includes more than 40,000 organizations, 2,700 clean energy and energy smart technologies manufacturing plants, more than 39,000 clean energy and energy smart technologies projects, and more than 37,000 financial transactions. It identified all relevant organizations for U.S. and China trade, in particular those with other sources of revenue besides clean energy or energy smart technologies manufacturing and export. This category includes diversified electronics and manufacturing firms, for which annual product revenue streams in the hundreds of millions of dollars may constitute only a small portion of total annual revenue.

Bloomberg New Energy Finance also drew upon available data from U.S. government databases, such as the International Trade Commission's Interactive Trade and Tariff DataWeb online database. Using the U.S. Harmonized Tariff Schedule, Bloomberg New Energy Finance identified specific trade items, such as photovoltaic cells and wind turbine generators, by unique 6-, 8-, or 10-digit codes. These codes were then used to query the ITC DataWeb for trade flows by item, country, and year of entry into the United States.

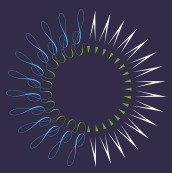
The queries captured the particular goods and services that are the subject of anti-dumping and countervailing duty trade cases. These data were initially identified at the beginning of the study, verified by checking against U.S. Federal Register and U.S. ITC factsheets on particular trade flows, and then tracked throughout the duration of Bloomberg New Energy Finance's research to capture revisions to earlier trade flows published by the U.S. government.

Bloomberg New Energy Finance also drew upon data from publicly traded (stock market-listed) companies which are required to publish financial data on their major areas of business. For companies whose sole business is manufacturing clean energy equipment, such as many solar module manufacturers and a number of wind manufacturers, revenue streams by country of destination were relatively straightforward: Revenues were often specified by country of origin. Others, such as large diversified multinational firms, required further analysis, discussed below.

Analysis of the U.S.-China clean energy relationship also drew upon the insights and experiences of Bloomberg New Energy Finance's analyst team of 100 members, who cover clean energy and energy smart technologies with both a sectoral and a geographical focus. Diversified and very large multinational U.S.-based companies do publish data on their revenues from sales overseas and from specific business groups. But these revenues and these business groups may not be large enough to trigger financial disclosure in stock exchange or regulatory filings. This is frequently the case for aspects of the wind and solar value chain, in particular specialty chemicals and materials, polysilicon, and wind turbine subassemblies.

In such cases, Bloomberg New Energy Finance's analysts used their contacts within industry to obtain trade figures from companies, where they could be disclosed. In addition, analysts modeled trade flows given historical revenue by company group and geography and also incorporated analysis from our Insight Services to capture changes in trade flows resulting from near-term market events within companies and markets.

Analysts also captured goods being produced overseas by companies of U.S. and Chinese corporate origin to further expand the understanding of clean energy trade. This analysis provided a full picture of trade flows to account for aspects of the U.S.-China clean energy relationship that are often obscured by strict trade measurements. Consistent with this approach, the total trade numbers presented in this report represent the value of goods and services exported between the two countries, as well as the value of goods and services sold by U.S. companies operating overseas to China and vice versa.



THE PEW CHARITABLE TRUSTS

Philadelphia, Pa.
Tel. 215-575-2000

Washington, D.C.
Tel. 202-552-2000

pewtrusts.org