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IRENA
International Renewable Energy Agency

Trading into a bright energy future

The case for open, high-quality solar photovoltaic markets

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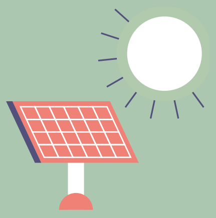
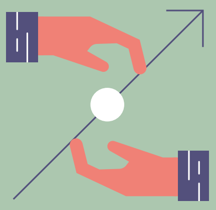
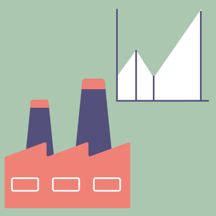
EXECUTIVE SUMMARY



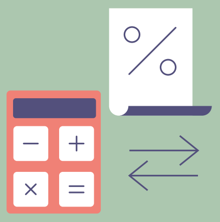
Solar photovoltaic (PV) technologies use solar panels to convert sunlight into electricity. Having been rapidly deployed, solar PV has become the cheapest source of new electricity generation in many parts of the world. The cost of the electricity generated by PV plants declined by 77 per cent between 2010 and 2018, while the cumulative installed capacity of solar PV increased 100-fold between 2005 and 2018. As a result, solar PV has become a pillar of the low-carbon sustainable energy system needed to foster access to affordable and reliable energy and help achieve the goals of the Paris Agreement and the 2030 Sustainable Development Agenda.



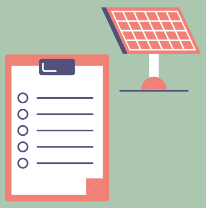
Underpinning the rapid deployment of solar PV is a globally integrated market in which PV components such as wafers, cells, modules, inverters and combiner boxes, as well as the machines which produce them, routinely criss-cross the world. Trade in solar PV components, which has grown faster than overall manufacturing trade since 2005, has become a critically important means for firms, governments and consumers around the world to access the most efficient, innovative and competitive goods (and services) needed for the transition to sustainable energy systems.



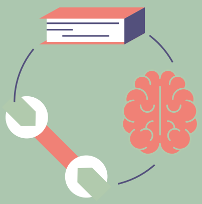
The continued trade-led deployment of solar PV and other renewable energy technologies can help to strengthen the critical infrastructure needed to fight the COVID-19 pandemic and support post-pandemic economic recovery. Off-grid solar energy solutions, including standalone systems and mini-grids, can be ramped up quickly to help healthcare centres improve their level of care and power mobile testing centres and vaccine refrigerators, for example. As well as contributing to tackling the immediate health crisis, trade-led solar PV deployment can help to support economic recovery from the pandemic, not least by creating jobs, which are expected to reach over 40 million worldwide by 2050 in the renewable energy sector.



Open, transparent and inclusive trade policies can support further cost reductions, deployment and job creation in the solar PV sector. Trade policies could build on past efforts to reduce or eliminate solar PV tariffs, which act as a hidden tax on solar PV equipment. On average, tariffs range from a low of 2.2 per cent for PV cells to a high of 10 per cent for PV backsheet (the outermost layer of a PV module). Tariff reduction initiatives should be complemented with efforts to address broader technological, economic, policy and regulatory barriers that hamper the deployment of solar PV.



A well-functioning and robust quality infrastructure (QI) system is essential to ensure that trade fully plays its role in the sustainable energy transition. QI, which refers to the institutional, legal and regulatory framework for product standards, promotes safe and inclusive trade in solar PV goods and services, reduces the risks of underperforming and of unreliable products entering the value chain, and ensures stability for investors and other value chain participants. It can also help domestic companies to meet the requirements of export markets, increasing the likelihood that such companies will participate in solar PV value chains.



International standards are a crucial part of QI. They enable countries to participate in a globalized PV market by promoting regulatory convergence, stimulating competition and fostering innovation. The top countries in terms of solar PV manufacturing and deployment have adopted international standards for solar PV and participate in their development, but many other countries would benefit from more active participation. Technical assistance and capacity-building to improve QI in developing countries, especially the poorest, could support the widespread adoption and enforcement of international solar PV standards, help bring uniformity to regulatory requirements and systems, and provide further impetus to trade safe, high-quality solar PV products.

International cooperation is critically important for a well-functioning QI system that can help governments move to sustainable energy systems, while helping companies along the solar PV value chain to seize trade opportunities and avoid unnecessary costs. International cooperation can range from mutual recognition of standards and regulatory provisions in trade agreements, to formal cooperation partnerships and regulatory harmonization. The International Renewable Energy Agency (IRENA), as the leading intergovernmental organization for global renewable energy, and the World Trade Organization (WTO), as the only global organization dealing with the rules of trade between nations, support collective efforts to promote a safe and inclusive global solar PV market through the effective use of QI.

1

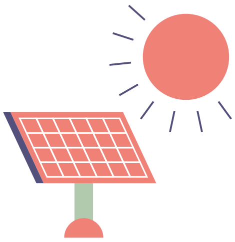
THE SOLAR PHOTOVOLTAIC INDUSTRY AND THE COVID-19 PANDEMIC

The COVID-19 pandemic has caused the most acute health crisis in generations and has sent shockwaves across economies worldwide. Renewable energies can play a dual role in helping the world to recover. First, they can strengthen healthcare and other critical public infrastructures. Second, when integrated into response plans and strategies to "build back better" (i.e. rebuild economies in light of the numerous problems which arose as a result of the pandemic), renewable energies can help mitigate the economic effects of the COVID-19 pandemic by supporting economic recovery, boosting job creation, fostering access to electricity and economic diversification and putting the world on a climate-safe path.

Solar photovoltaic (PV) technologies use solar panels that convert sunlight directly into electricity. PV is a key renewable energy technology, which has experienced plummeting costs and increasing deployment across the world (IRENA, 2019a). Global value chains allow manufacturers of solar PV equipment to source goods and services from the most cost-competitive suppliers and reap economies of scale, helping to reduce costs (IRENA, 2019a). Well-designed policies geared at eliminating remaining trade barriers and facilitating trade could further enhance solar PV supply chains and accelerate the deployment of solar PV and other renewable energies.

These efforts should go hand-in-hand with the development of a robust quality infrastructure (QI) to ensure that goods and services traded along the solar PV global value chain can be delivered efficiently. QI, which is the set of institutions and the legal and regulatory frameworks for standardization, certification, accreditation, metrology and conformity assessment, can contribute to reducing the cost of renewable electricity even further and minimize the risks for investors, producers, consumers and traders, thereby adding momentum to the worldwide transformation of energy systems.

KEY FACT



Solar photovoltaic (PV) technologies use solar cells to convert sunlight directly into electricity. They have become the cheapest source of new power generation in many parts of the world, and one of the pillars of sustainable energy systems.

A.

Benefits of the transition to a sustainable energy future

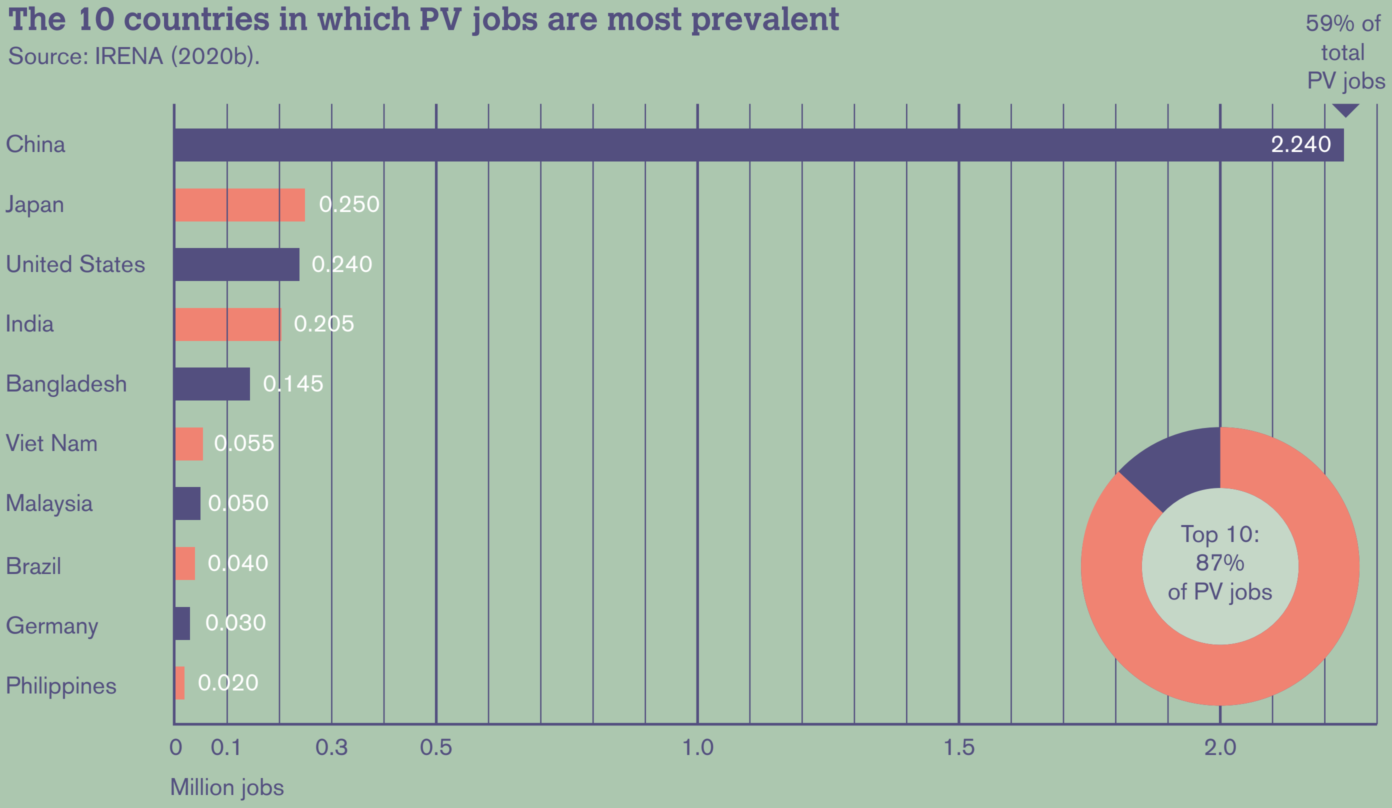
The immediate focus for governments in the context of the COVID-19 pandemic is to tackle the health crisis, not least by strengthening healthcare and other critical public infrastructures. Reliable and sufficient energy can help to ensure basic services, such as lighting and water supplies, and to power vital medical appliances, such as vaccine refrigerators and ventilators. Many primary healthcare centres in developing countries must operate without access to electricity or must resort to costly diesel backup generators. Renewable energy, including off-grid solar PV (i.e. PV systems not connected to the local electricity grid), can be ramped up relatively quickly and could help healthcare centres not connected to the electricity grid to improve their level of care. Such solutions could also improve access to water and sanitation services, and ensure the continued operation of critical infrastructures, such as mobile testing centres and laboratories, as well as of the cold supply chains (e.g., for vaccines) on which so many healthcare services rely (IRENA, 2015).

As well as contributing to tackling the COVID-19 health crisis, renewable energies can play a key role in helping countries to overcome the economic fallout from the pandemic. The pandemic has disrupted production and supply chains, shrunk demand for goods and services, and depressed commodity prices. Overall, global gross domestic product (GDP) is expected to contract by 5.2 per cent in 2020 (World Bank Group, 2020a). Four hundred million people lost their jobs in the second quarter of 2020, and another 140 million people are expected to have lost

FIGURE 1

The 10 countries in which PV jobs are most prevalent

Source: IRENA (2020b).



> As well as contributing to tackling the COVID-19 health crisis, renewable energies can play a key role in helping countries to overcome the economic fallout from the pandemic.

their jobs in the third and fourth quarters of 2020 (ILO, 2020).

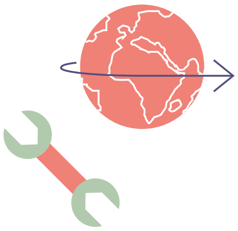
The recent crisis has exposed massive gaps in energy access, which affect healthcare, water supply, information and communication technologies and other vital services. Recovery plans incorporating the transformation of energy systems toward sustainable energy could help tackle these challenges while helping to overcome the economic slump and create much-needed jobs.

Due to the global diversification and decentralization of the solar PV market, as well as its rapid growth, renewable energies present an opportunity for job creation across the globe. It is estimated that 11.5 million jobs will be created in the solar PV industry by 2050 (IRENA, 2019b). In 2019, the number of jobs in the solar PV sector reached 3.8 million, a threefold increase since 2012. Asia accounts for 3 million of these jobs (Figure 1). A growing number of jobs, especially in Africa, are being created in off-grid decentralized renewables, which are also propelling employment in agro-processing, health care, communications and local commerce, among other sectors. Employment in the renewable energy sector as a whole, which totalled 11.5 million jobs worldwide in 2019, could almost quadruple by 2050 (IRENA, 2020b).

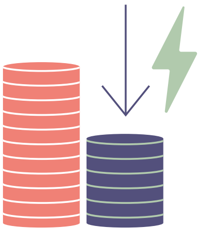
A vast majority of these jobs is performed by workers and technicians, while engineers, experts and administrative jobs represent a smaller share (IRENA, 2020c). Around 27 per cent of the off-grid solar PV jobs are performed by women, while 32 per cent of women occupy renewable energy jobs (IRENA, 2019c). This is a substantially larger share than in traditional energy jobs (in which women represent 22 per cent of jobs) and can be seen across all types of employment in the sector, including in administration and in technical areas, as well as in science, technology, engineering and mathematics (STEM) (IRENA, 2019d). While there are still barriers for women who wish to enter the renewable energy workforce, there is also high potential, and many policies and projects are being implemented to raise the numbers of female employees, including in developing countries.

Policy measures that foster an enabling environment for investments in the deployment of solar PV and other renewable energies can create a bridge between short-term recovery and medium- and long-term sustainable development strategies. An enabling environment for renewable energies would help drive a more widespread structural shift to build resilient economies and societies in line with the United Nations (UN) Sustainable Development Goals (SDGs) and the Paris Climate Agreement.

KEY FACTS



The solar PV sector has been underpinned by the emergence of an increasingly globally integrated supply chain over the past two decades, in which vital components such as wafers, cells, modules, inverters and combiner boxes, as well as the machines which produce them, routinely criss-cross the world.



Between 2010 and 2018 the cost of electricity generated by PV plants declined by 77 per cent, making solar PV the most competitive electricity generation technology in many countries.

B.

The role of solar PV in the transition towards sustainable energy systems

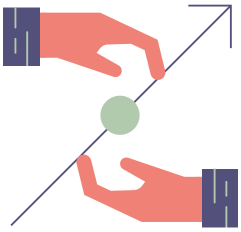
Solar PV, which can be deployed rapidly in a wide variety of locations, is one of the strategic renewable energy solutions needed to transform energy systems. It has the potential to generate over 25 per cent of all necessary electricity in 2050 and to reduce CO_2 emissions by 4.9 Gt per year in 2050, equivalent to 21 per cent of the total emission mitigation potential in the energy sector (IRENA, 2020d).[1]

The rapid deployment of solar PV has led to a sharp increase in installed capacity. Between 2005 and 2018, the cumulative installed capacity of solar PV increased 100-fold to 480 GW,[2] helped greatly by the emergence of a globally integrated solar PV supply chain.[3] During the same period, the overall installed renewable energy capacity grew 2.5 times. According to IRENA projections, the installed capacity of solar PV will continue to increase to more than 5,200 GW in 2030 and to 14,000 GW in 2050 (Figure 2), which would account for 43 per cent of the global installed energy capacity (IRENA, 2021). Already in 2018, the installed solar PV capacity increased by 100 GW, faster than fossil fuels and nuclear power generation technologies combined.

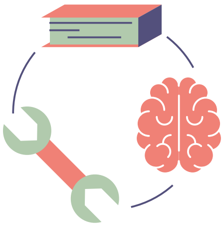
The deployment of solar PV varies across world regions (Figure 3). In 2018, two-thirds of new solar PV installations worldwide occurred in Asia, followed by Europe and North America.[4] At the country level, China spearheads the group of countries with the largest PV deployment, followed by Japan, the United States and Germany (Figure 4). New markets are expected to gain significance in the future, namely those of Latin America, the Middle East, North Africa and Southern Asia (IRENA, 2017a). Investments in solar PV grew massively from US$ 77 billion in 2010 to US$ 114 billion in 2018, and are expected to reach US$ 165 billion by 2030 (IRENA, 2019b).

The rapid deployment of solar PV in different continents was enabled by dramatic cost reductions in solar PV. As capacity increased, the costs for installing solar PV panels as well as the levelized cost of electricity (LCOE)[5] for PV decreased drastically (Figure 5). Increasingly, newly installed solar PV capacity costs less than the cheapest power generation options based on fossil fuels (IRENA, 2019e), with current IRENA predictions stating that the total installed costs could decrease to as low as US$ 340/kilowatt (kW), and that the LCOE could fall to US$ 0.02/kilowatt-hour (kWh) by 2030 (Figure 5). This would mean a reduction of roughly another three-quarters compared to current values. While these cost reductions are not taking place to the same extent in all regions, a substantial decrease in costs can be witnessed across the globe (Figure 6).

KEY FACTS



Trade in solar PV components has grown faster than overall manufacturing trade since 2005.



The globalization of solar PV value chains, supportive policies and technological innovation contributed to a 100-fold increase in solar PV installed capacity between 2005 and 2018.

Endnotes

1. Estimates are according to the REmap (i.e. renewable energy roadmap) programme, which is based on a scenario developed by IRENA that includes the deployment of low-carbon technologies to transform the global energy system in order to limit the rise in global temperature to well below 2 degrees Celsius above pre-industrial levels.
2. This corresponds to more than double Germany's net nominal capacity (223 GW) in 2019 (see the Bundesnetzagentur's list of power plants at https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/SecurityOfSupply/GeneratingCapacity/PowerPlantList/PubliPowerPlantList_node.html).
3. See https://www.irena.org/Statistics.
4. See https://www.irena.org/Statistics.
5. The LCOE of a given technology is the ratio of lifetime costs to lifetime electricity generation, both of which are discounted back to a common year using a discount rate that reflects the average cost of capital.

FIGURE 2

Cumulative solar PV capacity: historical and projected data

Source: IRENA (2021).

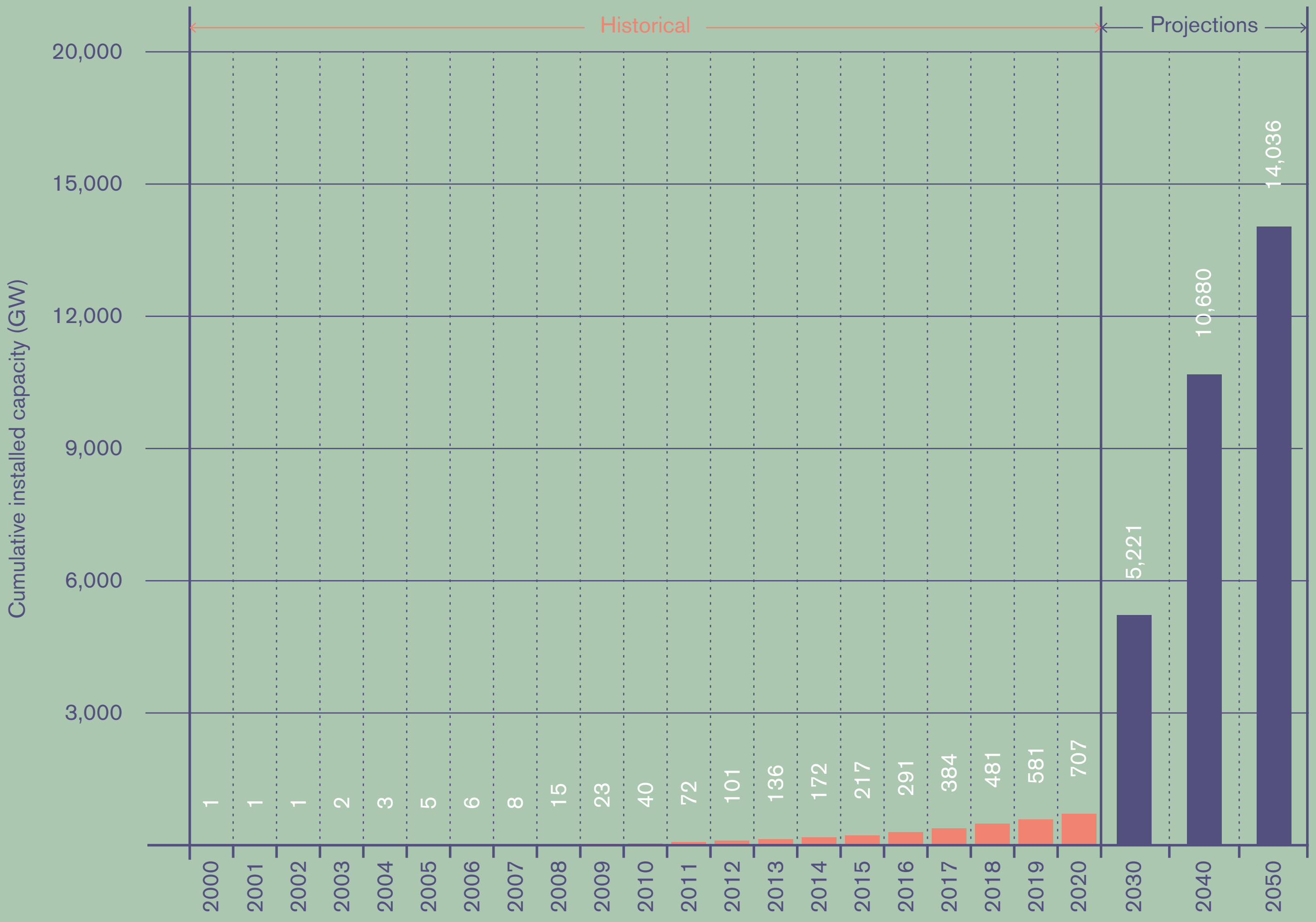


FIGURE 3

Solar PV installed capacity by region

Source: https://irena.org/Statistics.

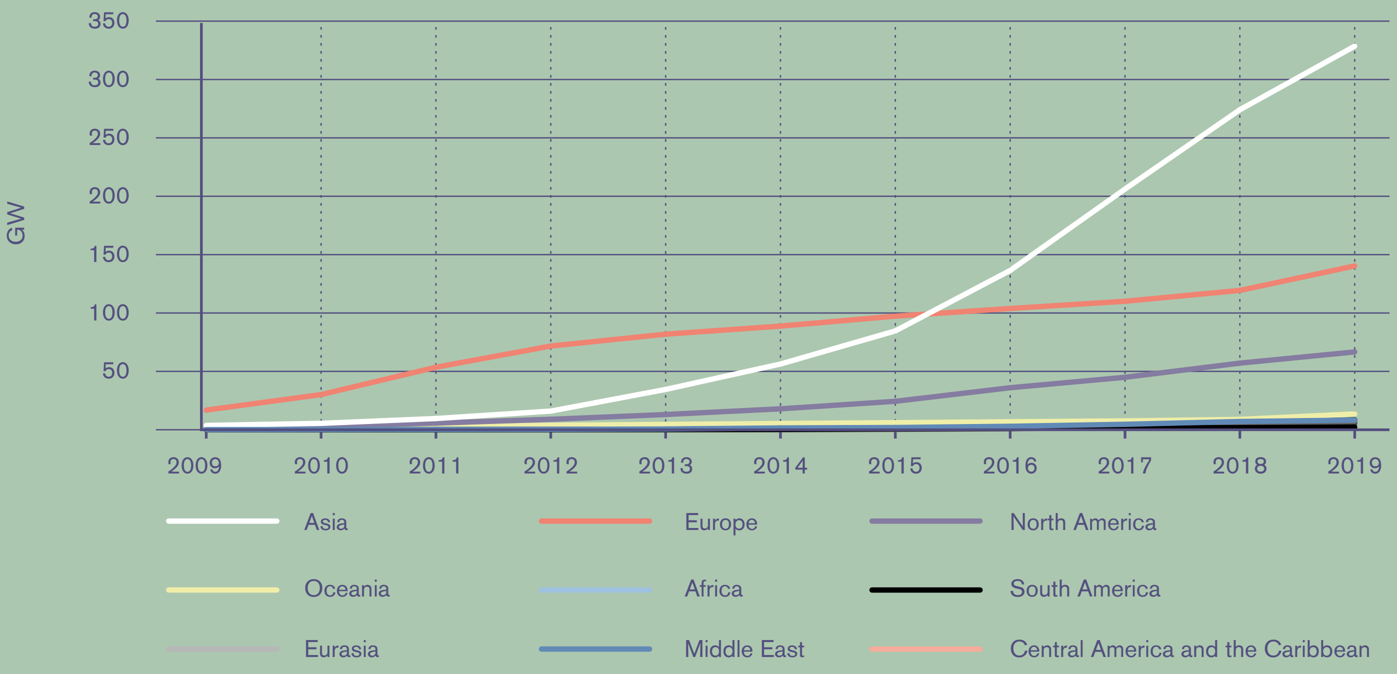


FIGURE 4

Solar PV installed capacity

Source: https://irena.org/Statistics.

Top 10 countries/areas

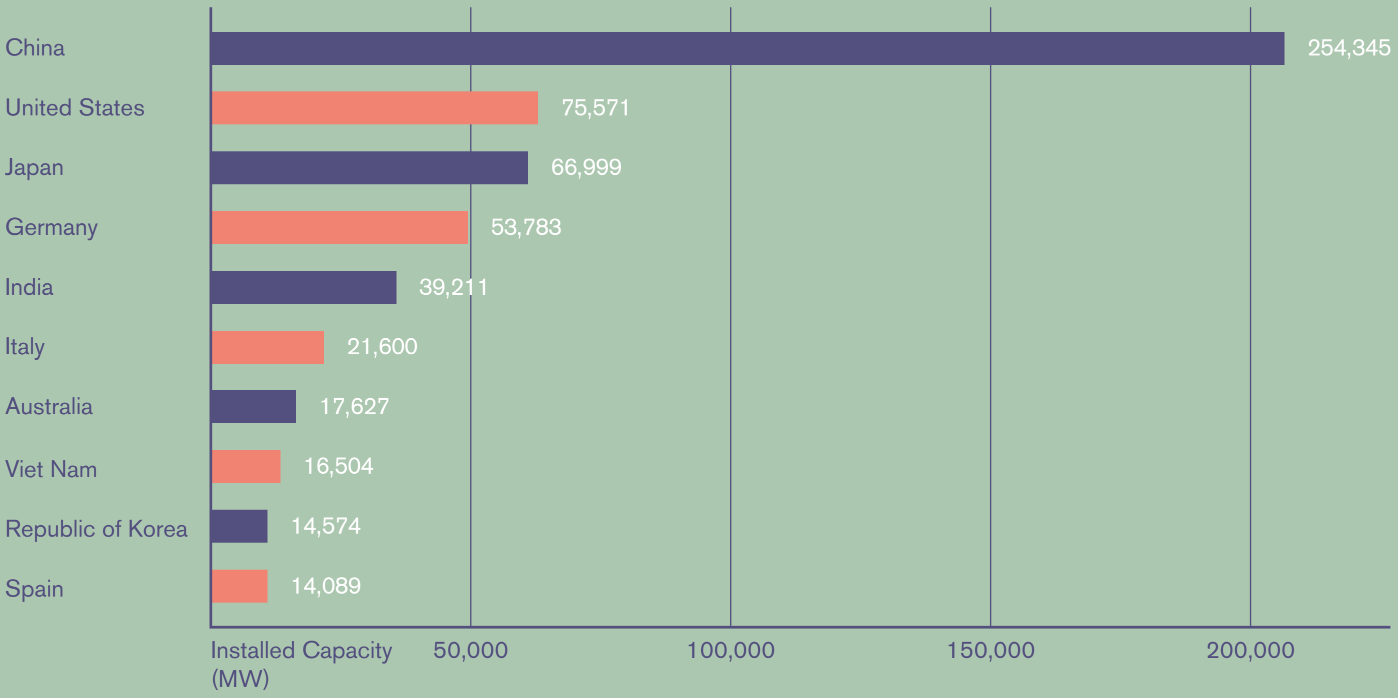


FIGURE 5

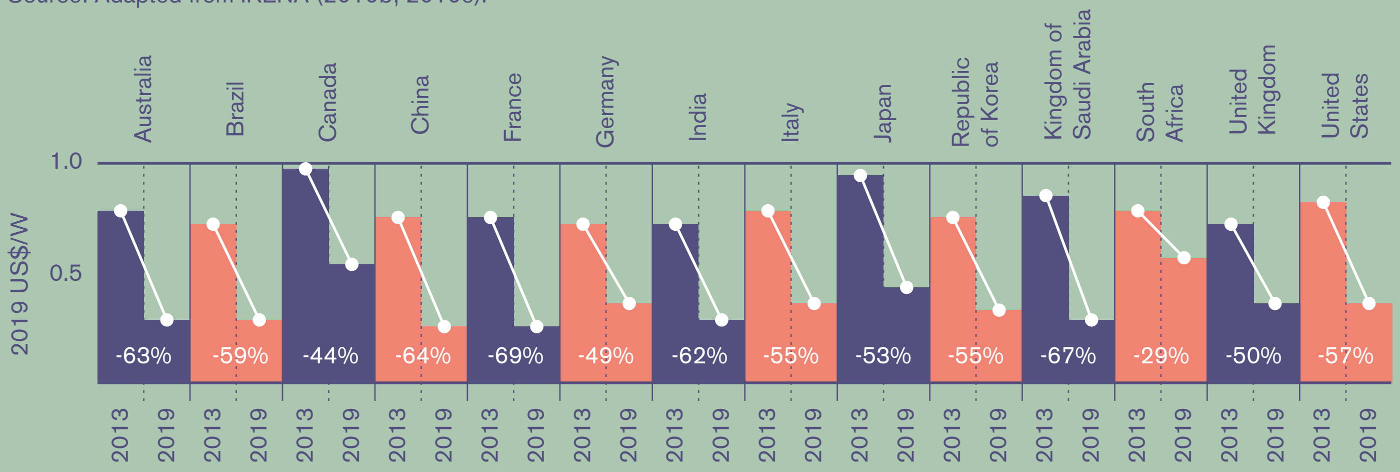
Global weighted average total installed costs and LCOE for solar PV (2010-18) and projected installed costs (2030, 2050)

Source: IRENA (2019a).

FIGURE 6

Average yearly module prices by market (2013-19)

Source: Adapted from IRENA (2019b; 2019e).



C.
The role of international trade and quality infrastructure in the development of solar PV

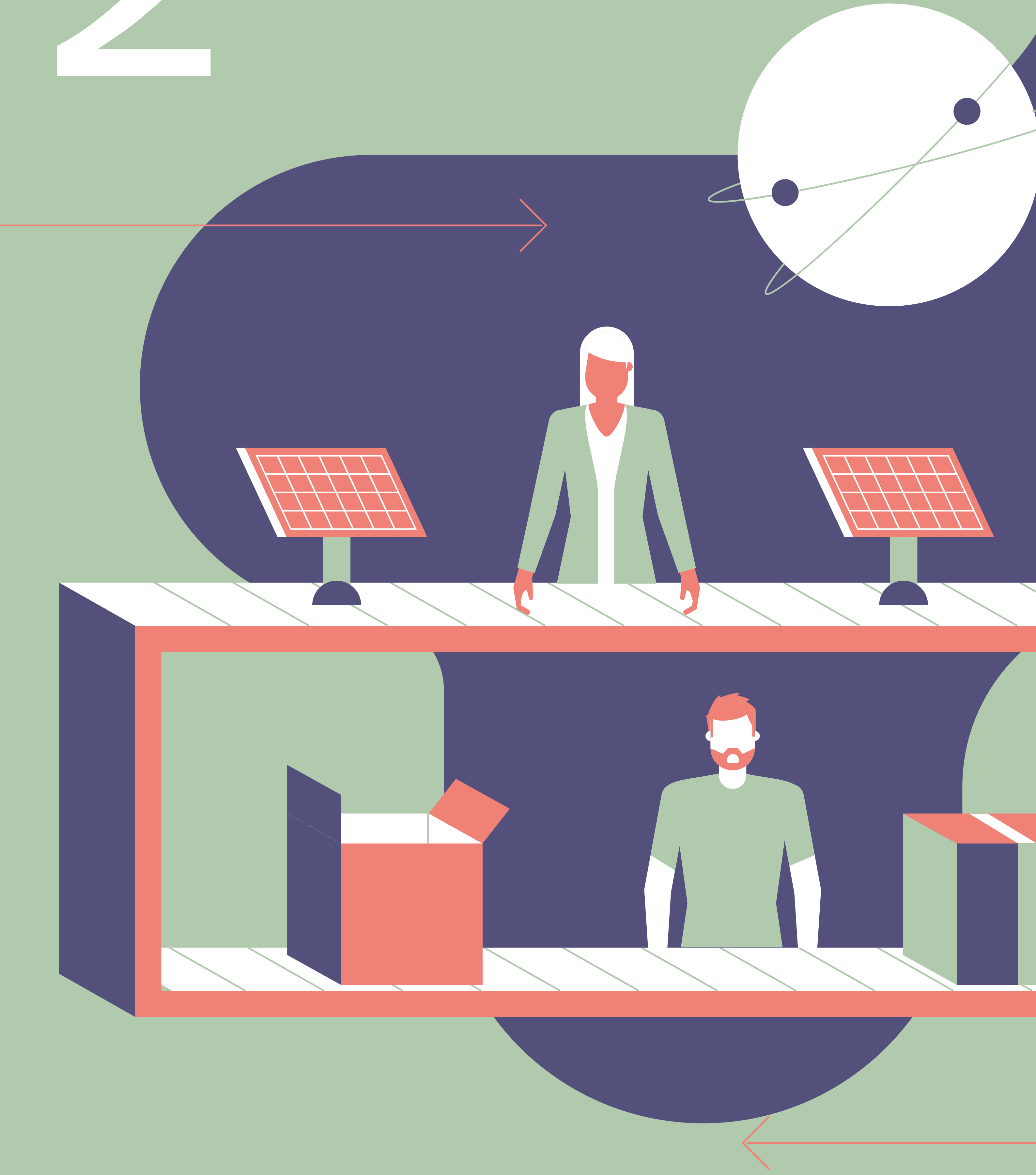
The globalization of the solar PV market has been a major factor driving the decrease in the price of solar PV. Part of the reason for this is that the emergence of globally integrated solar PV value chains has allowed solar PV equipment manufacturers to source goods and services from the most competitive suppliers in terms of cost, quality, skills, materials and other location-specific advantages. In addition, the globally integrated solar PV equipment market has expanded opportunities for solar energy companies to reap significant economies of scale and to “learn by doing”, while stimulating competition and strengthening incentives to invest in research and development (IRENA, 2017a).

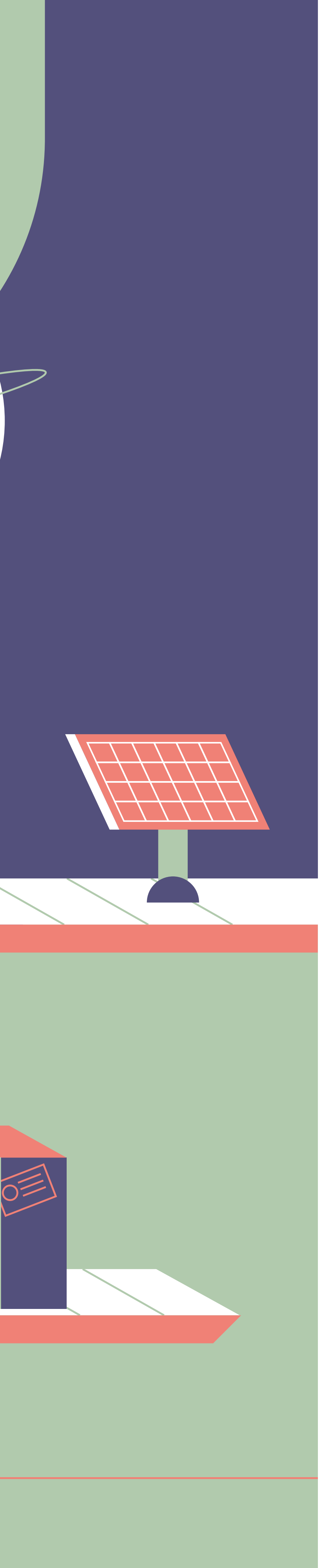
The COVID-19 crisis has disrupted cross-border supply chains, including in the renewable energy sector. Looking ahead, further diversification of solar PV supply chains may be needed to improve their long-term resilience against exogeneous shocks (IRENA, 2020a). The current momentum for policymakers to consider ways to “build back better” offers a unique opportunity to pursue policies that facilitate trade and spur diversification through the integration of newcomers into value chains. Trade policies can also accelerate the cross-border dissemination of affordable and high-quality solar PV technologies, taking them from where they are produced to where they are needed. This could boost the competitiveness of solar energy across countries, helping to deepen the transition towards sustainable energy systems and to secure the jobs that go with it.

In order to expand the dissemination of solar PV technologies across borders and ease the entry of new firms into solar PV value chains, it is necessary to develop a well-functioning QI. A robust QI system is a powerful tool to help local companies meet the requirements of export markets. Moreover, QI can help mitigate risks for the international PV project value chain that arise from underperforming, unreliable and failing products, which can create barriers to the development, enhancement and trade of this technology. Countries across the globe are at different stages of developing QI, which entails the use of metrology (i.e. the science of measurement and its application), testing methods, standards, certification, accreditation and market surveillance.

2

GLOBAL VALUE CHAINS IN THE SOLAR PV SECTOR





Value creation along the solar PV supply chain involves a broad range of goods and services (Box 1). Some of these goods and services are supplied domestically, but many others are traded across borders. This section provides an overview of global trade flows in selected goods along the solar PV value chain. Included in the analysis are machines to manufacture solar PV wafers, cells, modules and panels, along with selected solar PV components, such as PV generators, inverters, PV cells and, where relevant, the parts needed to produce some of these goods (see Appendix).

Estimating international trade flows of goods along the solar PV value chain is very challenging. Many goods related to sustainable energy systems are highly specialized and often relatively new in the market. Others have multiple uses, so they are used in both renewable energy and non-renewable energy applications. This means that the classification and identification of solar PV and other renewable energy goods are difficult to achieve uniformly across governments. Even the Harmonized System (HS) – a multipurpose international product nomenclature developed by the World Customs Organization (WCO) and comprising about 5,000 commodity groups, each identified by a six-digit “subheading” – lacks the required level of detail. As a result, internationally comparable estimates of trade for solar PV goods must rely on product categories that are often quite broad and that include other goods besides solar PV goods.

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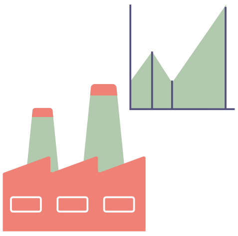
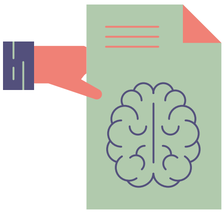


Solar PV and other renewable energies can help to strengthen the critical infrastructure needed to fight the COVID-19 pandemic. They can help support economic recovery by creating employment opportunities in the sector, which counted 3.8 million jobs in 2019.



The deployment of renewable energy technologies depends on an open and transparent global trading system and will support a more sustainable energy system and the fulfilment of the United Nations (UN) Sustainable Development Goals (SDGs) and the Paris Climate Agreement.

BOX 1

The solar PV project value chain

Source: IRENA (2017b).

The outline below of a supply chain for a utility-scale solar PV plant illustrates the specific goods and services that typically comprise solar PV supply chains.

Project planning

Activities at the project planning phase comprise site selection, technical and financial feasibility studies, engineering design, and project development. Project planning requires equipment to measure solar resources at the site, such as pyranometers and pyrheliometers, along with solar energy simulators and programmes to predict the availability of solar resources. It also requires computers and software to run simulations and produce feasibility analyses.

Procurement and manufacturing

The materials needed to manufacture commonly used PV panels are glass for the panel surface, as well as polymers, aluminium, silicon, copper, silver and other metals. The materials required to produce inverters depend on their size, model and casing, and may include aluminium, polymers and steel (in the screws and clamps). The materials needed to build the structures depend on the type of installation and may include aluminium, steel, concrete, plastic, polymers and corrugated board. Manufacturing the main components of a solar system requires specialized equipment and other machinery. In addition, it requires equipment which is commonly used in other industries such as machines for cutting, welding, washing, bending, melting and joining. Electronic and information technology tools are also extensively used in manufacturing for monitoring and controlling machinery.

Transport

The components of a solar PV plant can be transported by truck, plane, train or boat, with no special handling needed apart from proper packaging to avoid damage.

Installation and grid connection

Relevant activities mainly comprise site preparation and civil works. The materials and equipment needed during the installation phase principally include glass, steel, aluminium, concrete, silicon, copper and plastic. Equipment includes loaders, cranes, high-tonnage trucks and excavators, as well as supervisory control and data acquisition (“SCADA”) equipment and electrical and electronic instrumentation and control systems used for grid connection.

Operation and maintenance activities

These take place during the entire expected lifetime of a PV plant (about 25 to 30 years). Modern PV plants are automated and controlled by SCADA. Their operation is normally monitored remotely. Key activities during this phase are preventive and corrective maintenance, such as cleaning the panels.

Decommissioning a PV plant

This involves planning the activity, dismantling the project, recycling or disposing of the equipment, and clearing the site.

Trade estimates presented in this information note were calculated based on the data corresponding to the (six-digit) HS subheading where the relevant solar PV good is classified. As noted, at the six-digit HS level, product descriptions are, in many cases, too general to capture solar PV goods exclusively or predominantly, which means that other goods besides solar PV goods may be included in the trade data; hence, the need to treat the results of the analysis with caution. In particular, the figures on trade values presented below likely overestimate actual values and should therefore be seen as proxies. More research would be needed to estimate trade flows in solar PV with a greater level of precision.

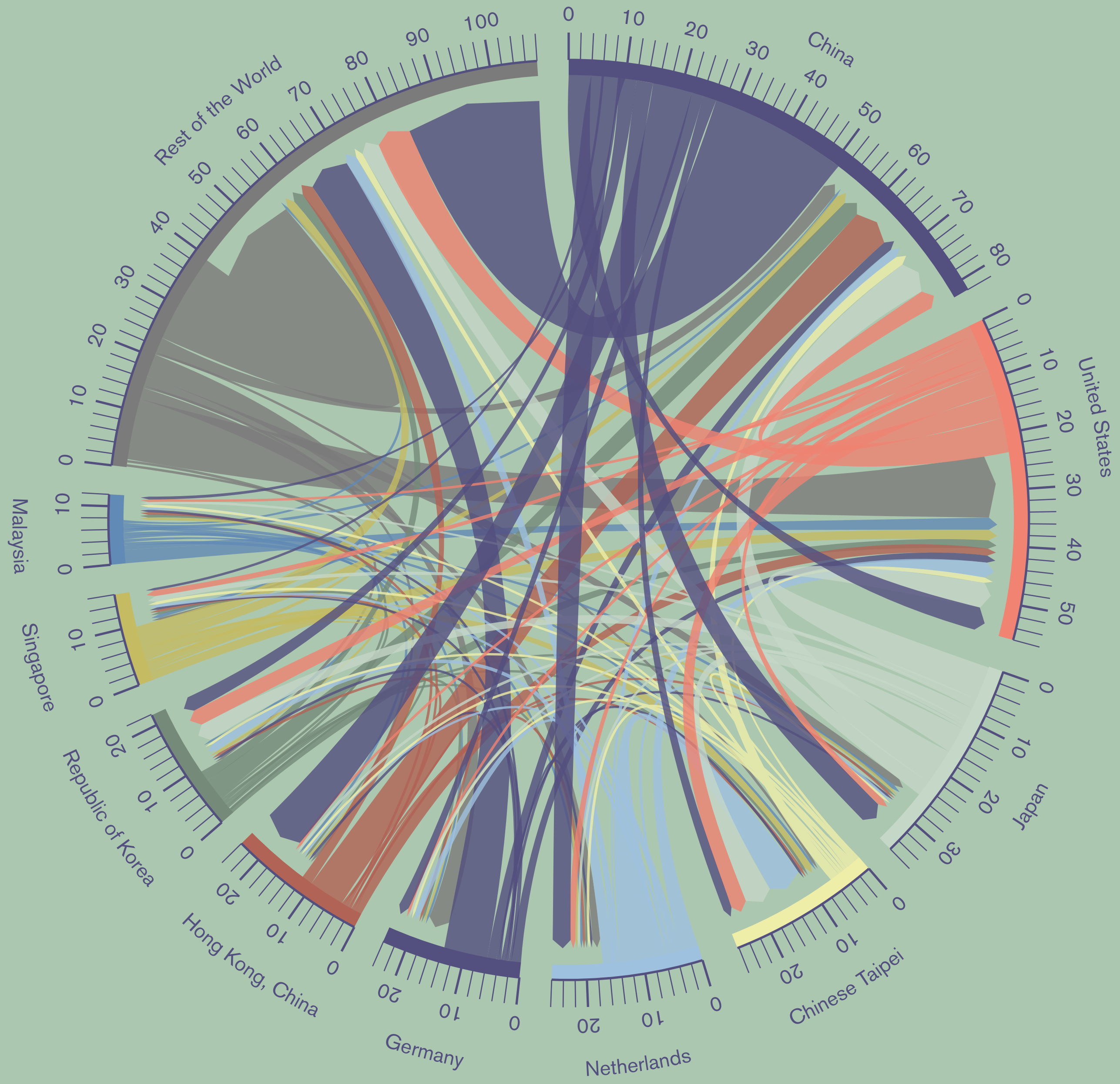
Trade patterns reveal how solar PV supply chains have become increasingly globalized over the past two decades. Trade (imports plus exports) in the HS subheading where selected solar PV components are classified increased significantly between 2005 and 2019, the latest year for which data are available.[1] In 2019, trade in these goods totalled slightly more than US$ 300 billion, up from around US$ 111 billion in 2005. Trade in the HS subheadings where selected PV components are classified, which represented around 1 per cent of world trade in manufactures in 2019, grew at a brisk pace of 7.4 per cent per year between 2005 and 2019, compared with 4.2 per cent for manufactured goods overall. Trade in the HS subheadings where machines to manufacture PV panels, along with their parts, are classified registered a significant increase too, totalling close to US$ 136 billion in 2019, up from around slightly less than US$ 52 billion in 2007 (the earliest year for which data are available).

The globally integrated nature of solar PV supply chains is also visible in the relatively high levels of two-way trade between countries, as both the components and machines to manufacture solar PV equipment criss-cross the world. The top 10 exporters in the HS subheading where selected solar PV components and machines to manufacture solar PV panels are classified are all important importers too (Figure 7). For example, Germany, the sixth-largest trader, represented, on average, 6.5 per cent of world exports and 5 per cent of imports of these goods in 2019, while Malaysia – the tenth-largest trader – represented, on average, 3.4 per cent of exports and almost 2 per cent of imports. Together, the 10 largest exporters

FIGURE 7

The 10 largest exporters of PV components and related machinery, 2019 (US$ billions)

Source: WTO Secretariat, based on data from the UN Comtrade database.



Note: The chart shows the 2019 value (in US$ billions) and destination of selected solar PV component and machinery exports from the 10 largest exporters of these goods and from the rest of the world (RoW). For example, exports of these goods from the Republic of Korea totalled US$ 9.4 billion (shown by the arrows from the Republic of Korea to other destinations), while imports totalled almost US$ 13 billion (shown by the arrows pointing to the Republic of Korea from other destinations, including Japan, the United States and China).

TABLE 1

Developing countries among the 10 largest exporters in HS subheadings that include solar PV goods (averages for 2017-19)

HS code	Included component	Country	Rank	Exports (US$ millions)	Share of world exports in relevant HS subheading
850131	PV generators	Mexico	3	1,451.3	13.2
850132	PV generators	Mexico	7	78.2	4.3
850161	PV generators	India	8	23.9	2.4
850161	PV generators	Mexico	10	19.7	2.0
850440	Inverters	Mexico	7	1,381.8	2.4
850440	Inverters	Thailand	8	1,353.6	2.4
850440	Inverters	Philippines	9	1,279.6	2.2
850490	Parts of inverters	Viet Nam	9	321.1	2.7
850490	Parts of inverters	India	10	239.5	2.0
854140	PV cells	Malaysia	2	4,411.1	8.2
854140	PV cells	Viet Nam	8	2,611.1	4.9
854190	Parts of PV cells	Malaysia	2	1,455.8	18.3
854190	Parts of PV cells	Viet Nam	10	152.5	1.9

represented around 82 per cent, on average, of the total value of exports of these goods between 2017 and 2019, and around 70 per cent of imports.

Two-way trade is also prevalent for specific solar PV products. For example, China is both the top exporter and top importer of goods under HS code 854140, which includes solar PV cells and modules.[2] China represented, on average, around 36 per cent of the value of world exports and almost 16 per cent of the value of world imports of these goods for the period 2017-19. Japan is the fourth-largest exporter and importer of these goods, with around 7 per cent of world exports and 7 per cent of imports on average between 2017 and 2019. The United States, another major trader of goods along the solar PV value chain, is the ninth-largest exporter of goods under HS 854140, with 4.4 per cent of world exports, and the second-largest importer, with 13.2 per cent of world imports during the same period.

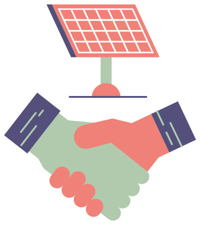
The results of recent empirical research imply that globally integrated supply chains have played a key role in helping to reduce solar PV costs over the last few decades. For example, one study found that the increasing size of solar PV module plants serving the global market through trade allowed those plants to reap significant economies of scale, which contributed almost 40 per cent to the decline in the cost of solar PV modules since 2001 (Kavlak, 2018). Another study, which used a sample of 15 countries over the period 2006-15, found that an increase in imports of solar PV cells and modules was associated with lower solar PV module prices at home (Hajdukovic, 2020). These findings suggest that trade policies geared at promoting globally integrated markets can play a role in supporting broader action to reduce costs and make solar PV and other renewable technologies more affordable. Given the critical importance of services in solar PV supply chains, trade policies must seek to promote the global integration of markets, not only for solar PV-related goods, but also for services. International trade enables firms, governments and consumers around the world to access the most efficient, innovative and competitive goods and services needed to tap the potential of solar and other renewable energies (Garsous and Worack, 2021). Trade can therefore boost the efficiency of solar PV at home and can help to replace old, polluting energy technologies, thereby catalysing efforts to accelerate the transition towards sustainable energy systems and achieve the SDGs. Access to affordable, reliable, sustainable and modern energy is one of the principal paths to fulfilment of the goals on health (SDG 3), jobs and economic growth (SDG 8), sustainable cities (SDG 11), sustainable production and consumption (SDG 12) and climate change (SDG 13), among others.

> Trade can boost the efficiency of solar PV and help replace old, polluting energy technologies, catalysing efforts to accelerate the transition towards sustainable energy systems and achieve the SDGs.

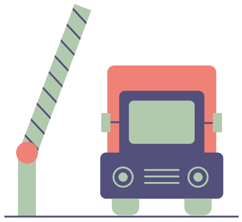
What is more, the ability to “split up” a production process by locating its different stages in different sites makes it more likely that more countries can participate in trade by specializing in tasks of varying degrees of complexity along the solar PV chain (World Bank Group, 2020b; WTO, 2014). Several developing countries are already part of global value chains in solar PV components, or have the potential to become part of these chains by building on existing industrial capabilities in related sectors (Jha, 2017; Nahm, 2017) (Table 1).

However, a country’s ability to participate in the solar PV supply chain, or any other type of supply chain, is by no means assured. It depends on fundamentals such as factor endowments, geography, market size and institutions, along with policies to promote trade and foreign direct investment, upgrade the information and communications technology infrastructure, strengthen skills, improve access to finance and ensure a balanced and effective intellectual property system (World Bank Group, 2020b). A robust QI is another key element to enable participation in global value chains, as discussed later (Section 4).

KEY FACTS



The International Renewable Energy Agency (IRENA), as the leading intergovernmental organization for global renewable energy, and the World Trade Organization (WTO), as the only global organization dealing with the rules of trade between nations, play an important role in supporting collective efforts to promote a safe and inclusive global solar PV market through an effective institutional and regulatory framework.



Trade-opening initiatives could help to lower solar PV costs, accelerate the dissemination of this technology across borders, and strengthen the resilience of solar PV supply chains against future shocks. Efforts to address technological, economic, policy and regulatory barriers that hamper the deployment of solar PV should also be considered as part of economic recovery initiatives.

Endnotes

1. See the Appendix for the list of HS subheadings used as proxies to estimate trade in solar PV components.
2. Estimating trade in solar PV cells and modules based on HS subheadings is particularly challenging because they are classified under the same HS subheading (HS 854140) as light-emitting diodes (LEDs). The new 2022 edition of the HS, which will enter into force on 1 January 2022, gives PV cells their own subheadings (854142 and 854143), which are separate from the subheading for the individual diodes used in LED lamps (Steenblik, 2020).

3

TRADE POLICIES FOR A RENEWABLE-POWERED FUTURE

A.

Enhancing the global supply chain for solar PV: remaining challenges

Open and transparent trade policies implemented over several decades have resulted in lower barriers to goods and services trade, including goods and services related to renewable energies in general and solar PV in particular. More open and transparent trade regimes have enabled the emergence of a globally integrated solar PV market where silicon, wafers, cells, modules, inverters, mounting systems, combiner boxes and other solar PV components, along with the machines to manufacture PV cells, modules and panels, are routinely traded back and forth among countries along tightly integrated value chains. Additional policy efforts to reduce remaining trade barriers and facilitate trade could further enhance solar PV supply chains, reduce costs and accelerate the dissemination of solar PV and other renewable energies to where they are needed.

More open and transparent trade regimes have enabled the emergence of a globally integrated solar PV market.

Trade policy has important implications for the ability of countries to access affordable, top quality solar PV equipment. Access to affordable and quality solar PV equipment from abroad can, in turn, lead to significant job creation, given that the bulk of jobs in solar PV projects is associated with services which are often delivered locally (such as operations and management), rather than with the manufacturing of the solar equipment itself (see below).

In addition, trade policy has implications for the participation of domestic companies in solar PV supply chains. Part of the reason for this is that tariffs and other trade barriers increase the cost of imported intermediate inputs and limit the likelihood of so-called “backward” participation in global supply chains (that is, importing inputs to produce goods or services that are then exported). Tariffs and other trade barriers also result in higher costs for a country’s exports and make “forward” participation in global supply chains (that is, exporting domestically produced inputs to partners to produce goods or services that are then exported) less likely.

Using trade policy to maximize the likelihood that more companies across more locations participate in solar PV supply chains could also help diversify solar PV supply chains and make them more resilient to disruptions caused by a future pandemic, extreme weather conditions, or other external shocks. When a disaster occurs in one location, companies with access to a diversified production network spanning many different countries can adjust their production. When disaster strikes, it is preferable to be able to tap the productive capacity of the world, rather than to have to rely on production from a few companies or a single location.

Significant progress has been made in opening up trade in solar PV goods over the last decade. Tariffs affecting solar PV equipment and related goods have gradually decreased, in line with the reduction of tariffs on manufactured goods. WTO members on average apply most-favoured-nation (MFN) tariffs of around 3.8 per cent on components of solar PV.[1] Regarding the machinery to manufacture PV panels, the average MFN tariff is slightly higher, at around 4 per cent. Other materials used to produce solar PV systems, such as films and encapsulant sheets (classified under HS subheadings 3920.91 and 3921.90), are subject to average applied MFN tariffs that are more than twice as high (Table 2).

Despite progress in lowering tariff levels, the trade costs resulting from even relatively low tariffs can still be significant. Part of the reason is that, in the case of solar PV and other globally integrated supply chains, the many inputs that are used in the production of final goods cross borders multiple times as they make their way through the stages of production. This causes tariffs (and non-tariff barriers) to accumulate before the finished goods reach the final consumer.

Although average tariffs on solar PV goods are relatively low, important differences persist across WTO members (Figure 8). For example, most WTO members (58 per cent) apply tariffs of 2.5 per cent or less to machines for PV panels, with 61 members offering duty-free entry. This group is a combination of developed and developing economies, including the European Union, Iceland, Malaysia, Mexico, Norway, the Philippines, Sri Lanka, Tunisia, the United States and Viet Nam. Among the high-tariff countries, a few apply tariffs higher than 15 per cent, while an additional 23 apply tariffs of between 10 per cent and 15 per cent, many of them in Africa (e.g., Côte d'Ivoire, Gabon, Ghana, Nigeria, Senegal and Togo) and some in Latin America (Argentina, Brazil and the Bolivarian Republic of Venezuela).

Regarding solar PV components, slightly more than three-quarters of WTO members apply tariffs of 5 per cent or less. Of these members, 33 provide duty-free entry, including several in the Americas (e.g., Canada, Colombia, Costa Rica, Jamaica and Peru) and Africa (Angola, Kenya, Mauritius, Rwanda, Seychelles, Tanzania and Uganda). Only seven WTO members apply tariffs higher than 10 per cent (Argentina, Brazil, Cambodia, Djibouti, Maldives, Samoa and the Bolivarian Republic of Venezuela). Other materials used in solar PV, such as polysilicon, films and certain plastic sheets, are generally subject to higher tariffs. Just 11 WTO members apply duty-free entry to these goods, while 31 apply tariffs in excess of 10 per cent.[2]

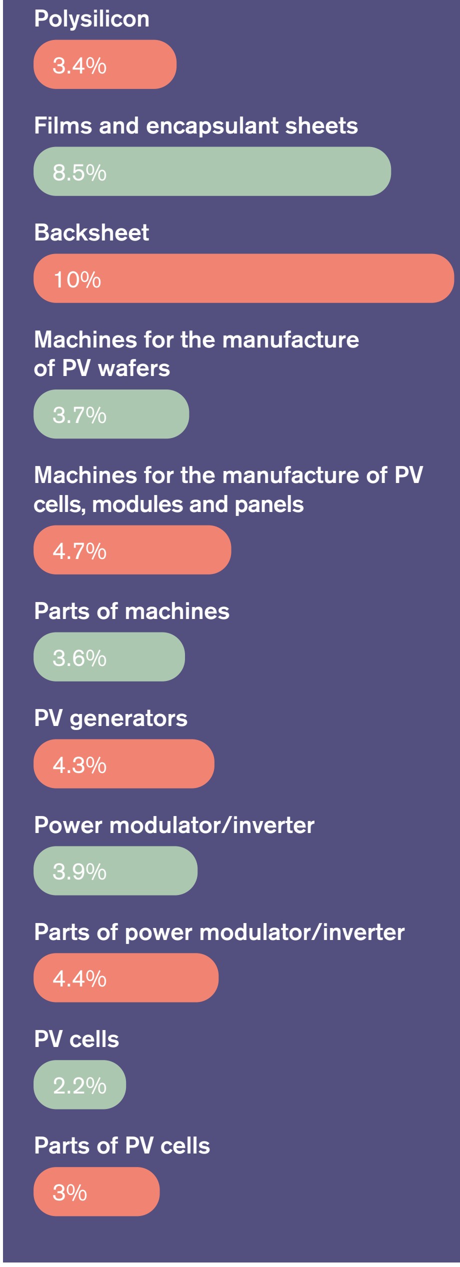
Several measures besides MFN tariffs affect trade in the solar energy sector. A case in point is the so-called "trade remedies" imposed by countries against imports to protect their domestic industries from unfair practices such as dumping and subsidies or to cope with a sudden surge of foreign goods. One study found that the 41 trade remedy cases (anti-dumping and countervailing duties) by WTO members on renewable energy products between 2008 and 2012 affected imports worth almost US$ 32 billion. Of the 41 cases, 18 involved solar energy products, of which 11 involved solar cells and modules, five solar-grade polysilicon, and two solar glass (UNCTAD, 2014).

Besides trade remedies, domestic support schemes for renewable energy have also affected trade in the solar energy sector. Domestic support schemes for renewables are often combined with local content requirements requiring firms to use domestically manufactured goods or domestically supplied services to benefit from the support in question. These measures often seek to provide incentives for both the deployment of renewable energy and the expansion of local manufacturing capacity (and jobs) to supply renewable energy projects. Some WTO members have launched WTO challenges against these types of measures.

A sustainable energy transition underpinned by open and transparent trade policies can go hand-in-hand with the creation of renewable energy jobs, even in countries that do not produce their own renewable energy equipment and rely instead on imports of such equipment. Part of the reason for this is that most jobs along the solar PV and other renewable value chains are associated not with manufacturing renewable energy equipment, but with services related to renewable energy installations. For example, of the total 229,055 person-days needed to develop a solar PV plant of 50 MW, only 22 per cent are associated with manufacturing, compared with 56 per cent associated with services such as operations and maintenance and installation and grid connection (IRENA, 2017b). These and other services jobs related to renewables are often supplied locally. As a result, an open trade regime in solar PV that gives access to the most competitively priced and highest-quality equipment available in the global market can foster not only solar PV deployment but also the many (services) jobs that go with it.

TABLE 2

Average MFN tariffs of selected PV goods, latest year available



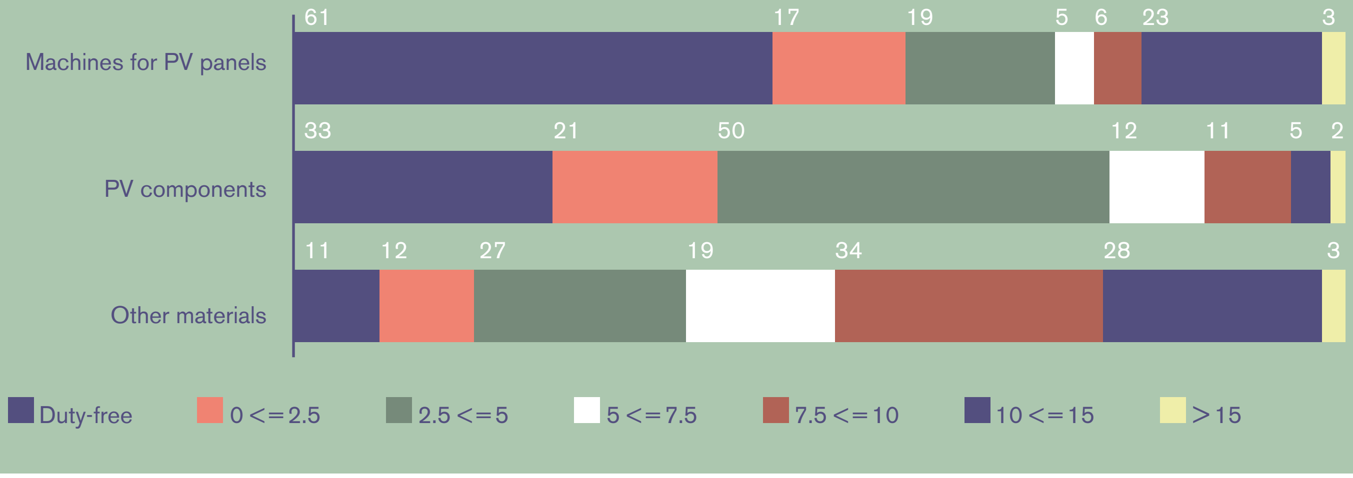
Endnotes

1. MFN tariffs are the tariffs that WTO members normally charge on imports from all other WTO members, unless those imports happen under a preferential trade agreement, such as a free trade area or a customs union. Of the WTO's 164 members (as of December 2020), 117 are developing countries or separate customs territories. See Appendix 1 for the list of HS subheadings comprising the category "solar PV components" and "machinery to manufacture PV panels".
2. The category "other materials used in solar PV" comprises the following HS subheadings: 2804.61 (polysilicon), 3920.91 (films and encapsulant sheets) and 3921.90 (backsheet).

FIGURE 8

Number of WTO members per average applied tariff band

Source: WTO Integrated Database.



B. Recent trade initiatives

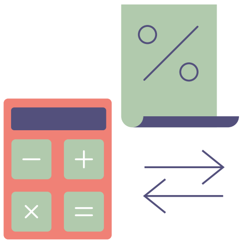
At the global level, there have been several efforts to tackle tariffs and other trade barriers affecting solar energy, often as part of trade initiatives targeted at broader categories of goods and services, including the category of environmental goods and services (Table 3). Environmental goods and services, according to a common definition developed in the 1990s by the Organisation for Economic Co-operation and Development (OECD) and Eurostat (the EU's statistical agency), are activities which produce goods and services to "measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems" (Eurostat, 2009).

> At the global level, there have been several efforts to tackle trade barriers affecting solar energy, often as part of trade initiatives targeted at broader categories of goods and services.

Provisions referring to trade in environmental goods and services have also been included in an increasing number of regional trade agreements. The provisions in question differ greatly across agreements, not least in their scope (Monteiro, 2016). For example, some of these agreements refer to specific categories of environmental goods and services, such as goods and services related to energy efficiency or to sustainable and renewable energy. A few others refer to goods and services that contribute to climate change mitigation and adaptation.

In general, the provisions on environmental goods and services in regional trade agreements range from general provisions that encourage parties to promote trade and foreign investment in environmental goods and services, to more specific commitments, such as the elimination of all tariffs on an agreed list of environmental goods and specific commitments on environmental services.

KEY FACT



Many governments are considering how they can support economic recovery in the wake of the pandemic, and this may provide opportunities to eliminate trade barriers facing solar PV value chains. Initiatives could include reducing or eliminating solar PV tariffs currently applied by WTO members.

TABLE 3

Overview of selected trade initiatives covering solar PV goods and related services

Agreement (participating countries)	**Goal**	**Coverage**	**Examples of solar and related products covered**	**Status**
APEC List of Environmental Goods (21 APEC member economies)	Reduce applied tariffs on environmental goods to 5% or less by the end of 2015.	54 goods relevant for: renewable energy generation; environmental monitoring, analysis and assessment; air pollution control; management of solid and hazardous waste and water treatment and waste-water management.	PV cells, solar power electric generating sets, solar water heaters, heliostats (used for concentrated solar power).	Endorsement of the APEC List of Environmental Goods in 2012, followed by individual economies' implementation plans.
Expansion of the Information Technology Agreement (concluded by over 50 WTO members)	Eliminate tariffs and other duties and charges with respect to information technology products.	201 high-tech products, including new generation multicomponent integrated circuits, touch screens, GPS navigation equipment, portable interactive electronic education devices, video game consoles and medical equipment, such as magnetic resonance imaging products and ultrasonic scanning apparatus.	Machines to manufacture solar PV wafers, cells and modules; inverters; mirrors (for concentrated solar power applications) and electricity meters (PV cells and modules are covered in the 1996 Information Technology Agreement).	Agreement reached in July 2015.
Environmental Goods Agreement (46 WTO members)	Achieve global free trade in environmental goods.	Participants considered a broad range of environmental goods used in a variety of functions, including generating renewable energy, improving energy and resource efficiency, reducing air, water and soil pollution, managing solid and hazardous waste, noise abatement, and monitoring environmental quality.	Wide range of solar equipment, parts and machinery.	Negotiations have not been active since December 2016.
Agreement on Climate Change, Trade and Sustainability (Costa Rica, Fiji, Iceland, New Zealand, Norway and Switzerland)	Elimination of tariffs on environmental goods and new commitments on environmental services; disciplines on fossil fuel subsidies and guidelines for voluntary eco-labelling.	To be determined.	To be determined.	Launch of the initiative announced in September 2019.

C.
Broader challenges

Solar PV is a technology with extremely high potential, but there are many barriers besides those affecting trade that could hinder its deployment. Such barriers may be of a technological, economic, policy-related or regulatory nature (Figure 9). With declining costs and financial schemes to support further deployment, some of the remaining challenges are often of a technical nature. They relate mostly to keeping the energy supply and demand balanced at all times. These concerns are often not exclusive to solar PV, but are general issues that arise with an increasing integration of variable renewable energy.

While some of these barriers are universal, many vary across regions. This poses an additional challenge to the deployment of solar PV. Not all countries have the same preconditions in terms of starting points within the energy transition, degree of fossil fuel dependency, means of implementation, and diversity and strength of supply chains (IRENA, 2019b). Overcoming these barriers while considering local conditions is crucial to achieving a just and inclusive transition, which in turn calls for innovation, investment, and an enabling and integrated policy framework focused on deployment. While such policies must be country-specific, the solutions may have an impact on a much broader scale and may influence global markets.

Apart from deployment challenges, a growing challenge with PV panels is their end-of-life management. With an average panel lifetime of 20 to 30 years, the amount of waste will increase drastically by the early 2030s, when an estimated 1.7 to 8 million tonnes of PV panel waste will have accumulated. By 2050 this value is projected to increase further to reach up to 79 million tonnes (IRENA and IEA-PVPS, 2016). However, there is much potential to create value through a circular economy framework geared at recovering the raw materials and other components of solar PV panels. This could open an entirely new market with significant global trade opportunities. It is important to seize these opportunities both in the deployment phase and by means of a well-functioning QI.

FIGURE 9

Existing barriers to fostering solar PV deployment

Source: IRENA (2019b).

Technological barriers

- Grid-connection and integration challenges
- Grid-flexibility challenges
- Lack of capacity/skilled labour
- Architectural and space barriers

Policy barriers

- Complex/outdated regulatory framework
- Lack of long-term and stable policy targets and well-coordinated policy mix
- Lack of quality control measures
- Concerns about technology maturity and performance

Market and economic barriers

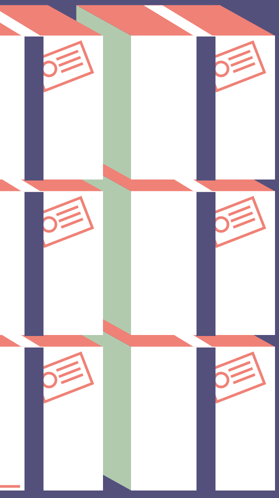
- Long payback periods
- Carbon emissions and local air pollutants are not priced or fully priced
- Low wholesale power prices in countries with low levels of irradiation

Regulatory, political and social barriers

- Lack of consumer information on performance, cost competitiveness and economics of solar PV
- Lack of relevant standards and quality control measures
- Lack of skilled professionals and experience

4

TRADE AND QUALITY INFRASTRUCTURE



A.

A robust quality infrastructure is essential to participate in solar PV trading markets

Trade in solar PV goods and services can only help to build a competitive solar energy sector if the goods and services in question meet customer requirements and are otherwise fit for the purpose for which they are intended. Underperforming, unreliable and failing products create barriers to the development and enhancement of solar PV and hamper the role of trade in promoting the technology's rapid diffusion across borders. A well-functioning QI system is a key tool to keep deficient, sub-standard quality products from entering the supply chain and to build a competitive solar PV sector that delivers economic, social and environmental benefits (IRENA, 2017a).

A QI system is made up of the institutions and the legal and regulatory frameworks responsible for standardization, accreditation, metrology and conformity assessment (IRENA, 2017a). These frameworks are essential to build trust among consumers, producers, investors, traders and governments that imported and domestic products and services will meet all the relevant state-of-the-art requirements and best practices. QI systems thereby contribute to ensuring stability and predictability for investors and other stakeholders and are essential instruments for protecting and accelerating future investments in PV deployment.

A QI system is also a powerful tool to help domestic companies meet the requirements of solar PV markets abroad, thereby facilitating their entrance into global markets. Without adequate QI, and international recognition of its competence, companies usually find it difficult and costly to demonstrate that they meet quality and other standards. Moreover, products sent abroad may need to be tested again in export markets because there is insufficient confidence that they comply with quality or safety requirements. Lack of QI thus becomes a major obstacle to the export of solar PV equipment and to efforts to diversify into new markets.

A better implementation of QI reduces trade costs and increases the likelihood that domestic companies can participate in solar PV value chains. As discussed earlier, creating the conditions for more companies across more locations to participate in solar PV supply chains could help to diversify supply chains and increase their resilience in case of disruptions caused by a pandemic or other shock. Implementing QI in the solar PV market benefits the entire value chain and involves all stakeholders, including governments, investors, project developers, manufacturers, installers and end users.

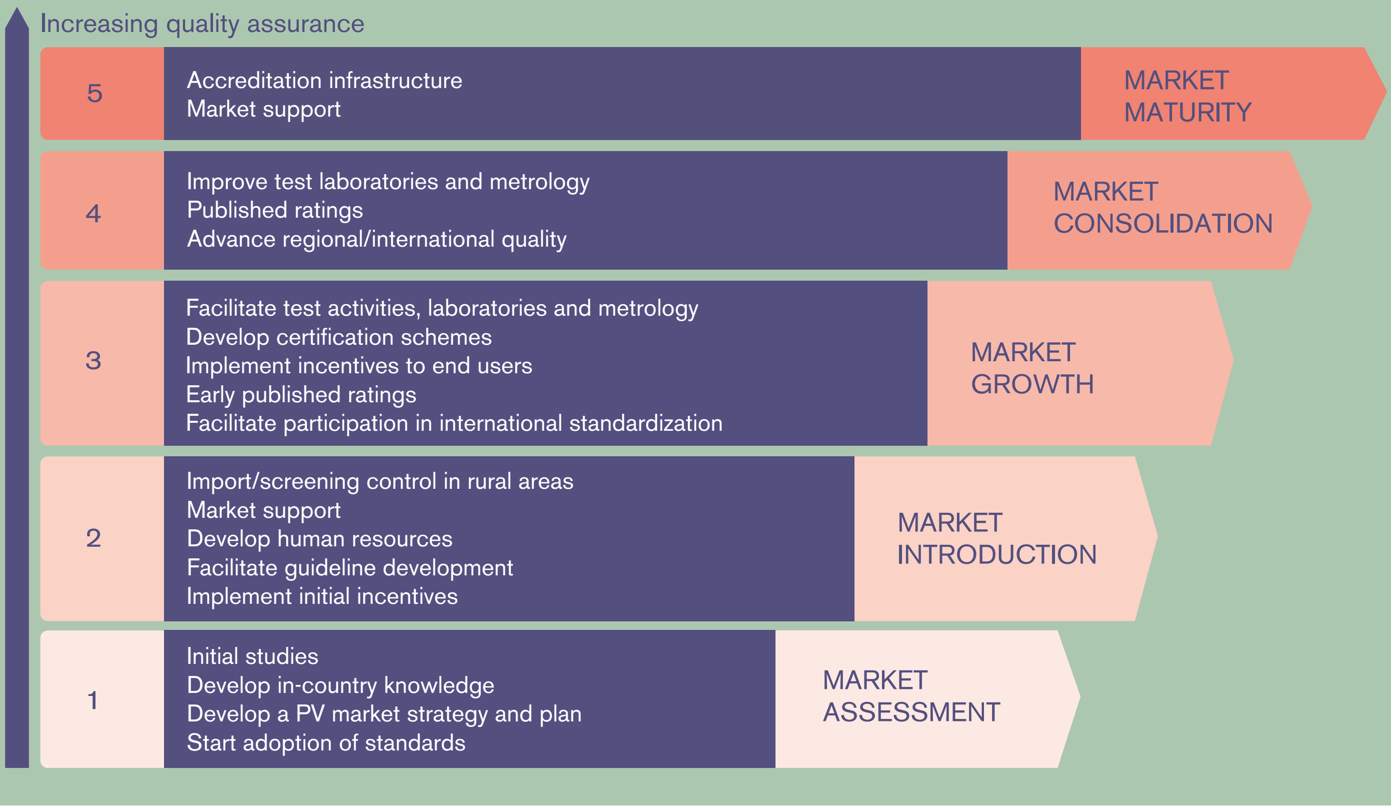
Developing a robust QI requires that policymakers maintain a balance between market needs, affordability, local capacity and QI implementation. The maturity and pace of QI development varies from country to country. Policymakers can develop QI systems incrementally to match the needs of an increasingly mature solar PV market. At different market maturities, the measures should allow enough flexibility for country-specific considerations. Countries with high levels of market maturity in solar PV have developed a high degree of quality assurance, including accreditation infrastructure and market support for solar PV markets. At mature market stages, the private sector is engaged in building up and operating a QI, as there is a commercial demand for those services. In contrast, countries with incipient solar PV markets can initially focus on building local knowledge, developing a PV market strategy and putting in place other basic building blocks of a well-functioning quality assurance system (Figure 10).

> A better implementation of QI reduces trade costs and increases the likelihood that domestic companies can participate in solar PV value chains.

FIGURE 10

Stages in the development of QI

Source: IRENA (2017a).



B.

International standardization and facilitating the acceptance of conformity assessment results can promote trade along the solar PV supply chain

Standardization is a key foundation of robust QI. When technical requirements vary from market to market, traders must contend with the costs of both product adaptation (or redesign) and conformity assessment associated with each market they wish to enter. This can segment markets, hindering the diffusion across borders of solar PV technologies and limiting entry of new participants in the supply chain. International standards can help countries overcome these problems.

International standards help to ensure compatibility across countries and convey information to producers, investors, consumers and traders about goods that have been produced abroad or processes that took place in another country. They can enable economies of scale and production efficiencies, boost competition and reduce costs. Moreover, because international standards codify the related scientific and technical knowledge developed at the global level, their development and use are important means of disseminating knowledge and fostering innovation.

International standards also play a key role in safeguarding against low quality or unsafe technology imports. International standards set globally recognized benchmarks for imports and are especially important tools to prevent situations where lower quality or unsafe products are exported to countries with less developed markets. To play their full role, standards must be adequately enforced, hence the importance of strengthening QI systems, including local capacity for inspection and market surveillance.

Various international and other standards exist that establish quality and safety levels in solar PV systems and help to set a proper quality baseline for imports (Table 4). For example, today, 37 countries have officially stated that they have adopted International Electrotechnical Commission (IEC) standards for solar PV technologies. Top solar PV manufacturing countries such as Canada, China, the Republic of Korea and the United States participate actively in the development of IEC standards for PV systems, as do top deployers of solar PV.[1]

In addition to the IEC standardization process, several other standards are also relevant for the solar PV sector, including for example CEN/CENELEC (i.e. European Committee for Standardization/

TABLE 4

Examples of relevant standards for solar PV

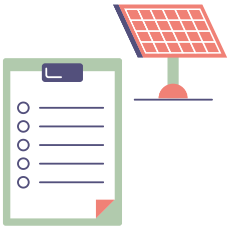
Source: IRENA (2017a).

	International Electrotechnical Commission (IEC)	Australia	China	United States
PV module	IEC 61730 and IEC 61215, or IEC 61646 as applicable	Same as IEC	IEC and other	UL 1703 UL 61215/ IEC 61646
Inverter	IEC 62109-1, IEC 62109-2, IEC 62093 (Qualification)	AS/NZS 4777, AS/NZS 3100		UL 1741 UL 62109
Design, installation	IEC 62548 (Primary) and IEC 60364 series	AS/NZS 5033	GB 50797- 2012	National Electrical Code (NEC) Article 690
Commissioning	IEC 62446	Same as IEC	Same as IEC	Not specified; multiple industry-group recommended practices
Performance, operations	IEC 61724 Future IEC 62446-2 (2017)	Same as IEC	Same as IEC	ASTM E2848, multiple industry-group recommended practices
Grid-code related	Country-specific, but grid function testing per IEC 62116, IEC 62910	AS/NZS 4777		IEEE 1547 and regional/ state requirements
Off-grid specific	IEC 62257 Series for off-grid and rural electrification	AS 4509		
Utility-scale specific	Future IEC 62738 (2016)			NEC Article 691

Note: AS is Australian standards; ASTM is American Society for Testing and Materials; GB is Guobiao standards; IEC is International Electrotechnical Commission; IEEE is Institute of Electrical and Electronics Engineers; NEC is National Electrical Code; NZS is New Zealand standards; and UL is Underwriter Laboratories.

KEY FACTS

A well-functioning institutional, legal and regulatory framework for product standards is necessary to promote safe and inclusive trade in solar PV goods and services, to reduce the risks of underperforming and unreliable products entering the value chain, and to ensure stability for all those involved. It can help domestic companies meet the requirements of export markets, increasing the likelihood that such companies will participate in solar PV value chains.



International standards are crucial to enable countries to participate in a globalized PV market and to promote regulatory convergence, stimulate competition and foster innovation. The top countries in terms of solar PV manufacturing and deployment have adopted international standards for solar PV and are active in their development, but many other countries also play a role in this area.

European Committee for Electrotechnical Standardization) standards from Europe, UL (i.e. Underwriter Laboratories) standards from the United States, AS/NZS (i.e. Australian standards/New Zealand standards) standards from Australia and New Zealand, GB (i.e. Guobiao) standards from China or industry-level standards such as IEEE (i.e. Institute of Electrical and Electronics Engineers) or ASTM (i.e. American Society for Testing and Materials) standards (Table 4).

The widespread adoption and enforcement of international standards is key to bringing regulatory requirements and systems for solar PV closer to one another, thereby reducing the costs resulting from unnecessary differences. Moreover, by providing a common reference point for regulation, and a framework against which to judge divergence, the adoption of relevant international standards can support regulatory harmonization and cooperation in solar PV (WTO and OECD, 2019). All this can result in benefits both for trade and for the energy transition.

To ensure that international standards for solar PV are widely adopted among countries, it is essential to promote broad-based participation in the development of such standards. In 2000, the WTO set out six principles for the development of international standards, i.e.:

(i) transparency;
(ii) openness;
(iii) impartiality and consensus;
(iv) effectiveness and relevance;
(v) coherence; and
(vi) the development dimension.

> The widespread adoption and enforcement of international standards is key to bringing regulatory requirements and systems for solar PV closer to one another.

Limited technical and institutional capacities, along with market constraints, may limit the extent to which developing countries can adopt international standards as a basis for their regulations and standards. In recognition of this, the WTO Technical Barriers to Trade (TBT) Agreement (see below) contains provisions on technical assistance (Article 11). In addition, the Agreement recognizes that developing-country members should not be expected to use international standards that are not appropriate to their development, financial and trade needs (Article 12.4 of the TBT Agreement).

An additional factor affecting the widespread adoption of international standards is the extent to which they are relevant to all countries. For example, emerging markets for PV systems in Latin America, Africa and Southern Asia face weather conditions (e.g., extreme ambient temperatures, humidity or ultraviolet radiation) that may not always be covered by international standards. Article 12.6 of the TBT Agreement requires WTO members to take such reasonable measures as may be available to them to ensure that international standardizing bodies, upon request of developing-country members, examine the possibility of, and, if practicable, prepare international standards concerning products of special interest to developing-country members.

The greater participation of developing countries in the development of international standards for solar PV, within the limits of their market needs, local conditions and resources, can help to increase the global relevance and acceptance of international standards, along with the likelihood of regulatory alignment across borders. Thus, it is necessary to find innovative ways to help developing countries to overcome the constraints that prevent them from participating effectively in international standardization, including through the formation of regional or other types of alliances that would allow countries to share costs and leverage existing human and financial resources.

The prevalence of divergent systems used by trading partners to verify conformity with applicable standards and regulations is an important factor that can hamper regulatory harmonization and cooperation. When countries apply different systems to verify conformity, products that have demonstrated conformity to technical regulations in domestic markets may fail to conform to, or be recognized as conforming to, the regulatory requirements of importing countries, even if both countries have aligned their technical regulations with relevant international standards. This may happen, for example, The greater participation of developing countries in the development of international standards for solar PV can help to increase the global relevance and acceptance of those standards.

when regulators in one country are unwilling to accept a test report or certificate from a foreign body that they do not know or may not trust. The resulting additional costs create impediments to trade and to the participation of new manufacturers in solar PV supply chains.

Policymakers can draw from a variety of approaches to facilitate acceptance of conformity assessment results. At the global level, one approach involves the development of international networks to facilitate the recognition and acceptance of results of conformity assessment. These networks take the form of multilateral recognition agreements or arrangements, whereby each participant undertakes to recognize the accreditation granted or certificates issued by any other party to the agreement or arrangement as being equivalent to that granted by itself and to promote that equivalence throughout its territory of operation. There are international guides for such arrangements. One example of this approach in the solar PV sector is the IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications (Box 2).

Developing a robust QI system, along with its supporting laws and policy frameworks, is an important tool to help ensure that issues around conformity assessment do not become a source of unnecessary trade friction and costs. A robust QI system gives regulators a range of options when choosing their conformity assessment procedures, which allows them to apply the least trade-restrictive alternatives. Moreover, robust QI systems can improve regulatory cooperation between countries, not least because they help to build trust and confidence among regulators from different countries. In this way, QI can also facilitate the formulation and adoption of international systems of conformity assessment, such as IECRE.

BOX 2

The IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications (IECRE)

Source: IEC (2019).

IECRE operates a global certification system based on IEC standards for equipment and services used in the marine, solar PV and wind energy sectors. IECRE seeks to reduce trade barriers caused by different certification criteria in different countries and helps industry access new markets. By avoiding multiple and sometimes duplicative testing, manufacturers and users can save time and costs and receive confirmation that equipment and services are safe and reliable.

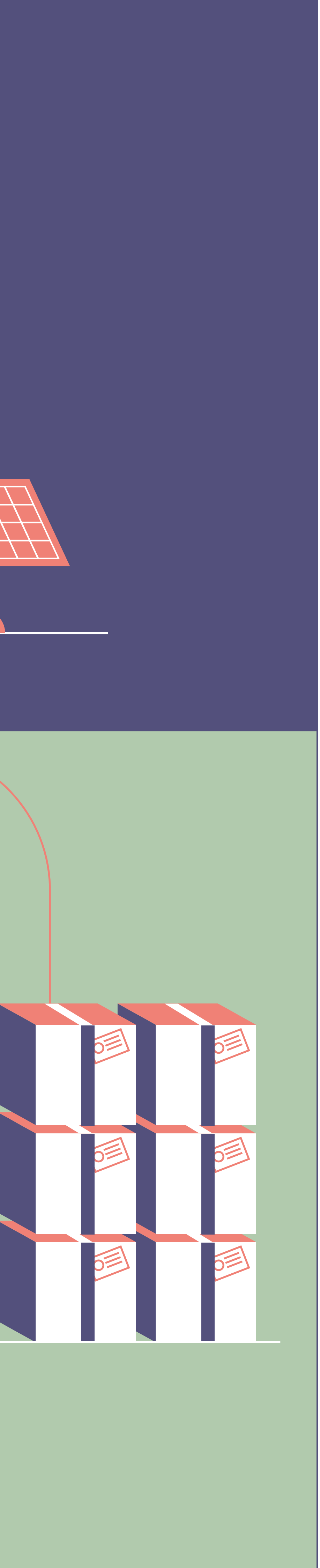
IECRE members use the principle of mutual recognition (reciprocal acceptance) of test results and the resultant certifications to obtain certification or approval at national level. This means that all certification bodies which operate within IECRE accept the IECRE test reports and certificates that are issued by an accepted IECRE testing laboratory or associated certification body, if applicable. These test reports and certificates can be used in national certifications without the need to repeat the tests. For the solar PV sector, there are nine countries with IECRE member bodies, a list that includes the top producers and deployers of solar PV.[2]

Endnotes

1. https://www.iec.ch/dyn/www/f?p=103:29:9698209351354::::FSP_ORG_ID,FSP_LANG_ID:1276,25. Examples of the IEC standards in question include: IEC 61730 Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction; IEC 61215-1 Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements; and IEC 62941 Terrestrial photovoltaic (PV) modules – Guideline for increased confidence in PV module design qualification and type approval.
2. https://www.iecre.org/dyn/www/f?p=110:7:::::P7_ORG_TYPE:REMB

5

INTERNATIONAL COOPERATION FOR BETTER QUALITY AND BETTER TRADE



In today's globalized world economy, QI systems cannot operate in isolation. Cross-border cooperation on QI can help governments achieve sustainable energy systems, while helping companies along the solar PV value chain seize market opportunities and avoid unnecessary costs. International cooperation on QI takes different forms, from mutual recognition and regulatory provisions in trade agreements to formal cooperation partnerships and regulatory harmonization. The most appropriate approaches in any given situation differ depending on the compatibility of regulatory environments and systems, the sector, type and degree of regulation already in place and the level of technical and institutional capacity of the countries involved, among several other factors.

International organizations serve as institutional forums for governments to cooperate on QI-related issues. For example, international organizations enable countries to share practices in specific fields and to develop a common language and joint approaches.

As forums for dialogue, international organizations also provide an institutional framework and can catalyse relevant technical expertise to help countries develop joint normative instruments and guidance, align their regulatory approaches, and build capacity in countries with less-developed QI systems, in line with their respective mandates.

A broad range of international organizations support global cooperation on QI. This section briefly describes the roles of IRENA and the WTO in supporting collective efforts to promote a safe and inclusive global market in solar PV through the effective use of QI.

KEY FACT

Technical assistance and capacity-building to improve the institutional and regulatory framework in developing countries, especially the poorest, could support the widespread adoption and enforcement of international solar PV standards, help bring uniformity to regulatory requirements and systems, and provide further impetus to trade safe, high-quality solar PV products.

A.
The role of IRENA

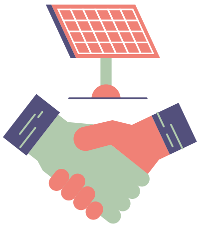
IRENA supports countries in using international standards and quality control instruments to support national efforts for the implementation of renewable energy systems and to facilitate global market growth. While IRENA is not a standardization, testing or certification body, it helps countries to improve their understanding of how to build up and operationalize quality control measures, as well as of the impact of QIs on renewable energy markets.

IRENA produces analytical work on how to develop a QI for a number of technologies, including wind power, solar thermal energy, solar PV and electricity grids. The INSPIRE (International Standards and Patents in Renewable Energy) web tool on renewable energy patents and international standards has become an important reference for stakeholders (Box 3).

IRENA has also provided direct assistance to countries in implementing technical standards and quality control mechanisms via workshops and trainings. To achieve this, IRENA is collaborating with partner organizations, such as the IEC, the International Organization for Standardization (ISO), the German Metrology Institute (Physikalisch-Technische Bundesanstalt – PTB) and the WTO.

IRENA supports countries in using international standards and quality control instruments to support national efforts for the implementation of renewable energy systems and to facilitate global market growth.

KEY FACT



International cooperation – ranging from mutual recognition of standards and regulatory provisions in trade agreements, to formal cooperation partnerships and regulatory harmonization – can help governments move to sustainable energy systems, while helping companies along the solar PV value chain to seize market opportunities and avoid unnecessary costs.

BOX 3

IRENA's web-based tool – INSPIRE

IRENA's INSPIRE platform provides information on how to access international standards for renewable energy, as well as on the countries and actors participating in the international standardization process. INSPIRE has identified more than 400 standards related to renewable energy commonly applied worldwide. INSPIRE has manufacturing and product standards, including test methods and performance evaluation. The platform also offers standards in breakthrough topics such as information technologies, smart grids and mini-grids.

INSPIRE offers three key elements: search engines, learning sections and a networking space that reflects the key organization and technical committees involved in the development of standards. For more information, refer to: www.irena.org/inspire.

B.
The role of the WTO

The WTO plays an important role in supporting cooperation on trade and QI. It does so by providing a multilateral framework for the conduct of trade relations among its 164 members which helps ensure that trade flows as smoothly, predictably and freely as possible. A key element of the WTO framework comprises disciplines that promote cooperation on reducing technical barriers to trade and using QI effectively. The disciplines in question, which are contained in the WTO TBT Agreement, pertain to transparency, the use of international standards, and the recognition of foreign conformity assessment results to reduce the costs resulting from regulatory diversity.

More specifically, the TBT Agreement establishes obligations for WTO members relating to the preparation, adoption and application of technical regulations and conformity assessment procedures to facilitate the conduct of international trade in goods. It sets notification requirements for proposed regulatory measures with potentially significant trade effects (Box 4). In doing so, it creates a unique multilateral transparency framework that facilitates the implementation of quality assurance. Moreover, the TBT Agreement strongly encourages WTO members to use relevant international standards as the basis for their measures. Its disciplines on the recognition of foreign conformity assessment results help ensure that traders do not face duplicative requirements or procedures when regulations differ across markets. These disciplines promote the use of quality assurance to encourage the reduction of regulatory diversity and associated trade costs.

To support the implementation and operation of these disciplines, the TBT Committee provides a forum for countries to learn about each other's regulatory systems, discuss draft and implemented regulations affecting international trade and collaborate bilaterally and multilaterally to achieve less trade-restrictive regulations. In particular, members use the TBT Committee to raise specific trade concerns

BOX 4

TBT notifications related to solar energy

Source: WTO Environmental Database, available at: http://edb.wto.org.

Under the TBT Agreement, WTO members are required to inform each other when they plan to change product requirements and to provide an opportunity for other members to comment on these requirements. They do so by submitting a two-page notification on the regulation, providing information on products covered, a brief summary of the regulation and the deadline for providing comments.

WTO members submitted close to 60 notifications related to solar energy technologies to the TBT Committee between 2009 and 2018. Most notifications (around three-quarters) pertain to solar water heaters and other solar thermal heating systems and components. The rest comprise solar PV energy systems (14 per cent of notifications) and batteries for use in PV energy systems, solar PV lighting systems and other solar applications, such as laminated solar PV glass for use in buildings (10 per cent of notifications). The notifications consist mostly of technical regulations, with a small share consisting either of conformity assessment procedures or of both technical regulations and conformity assessment procedures. Countries in Africa have submitted close to 60 per cent of all notifications related to solar energy technologies, followed by countries in South and Central America, with 14 per cent of notifications, the Middle East (10 per cent), and Asia, Europe and North America, each with slightly less than 6 per cent.

TBT Committee notifications may reveal measures which are not fully aligned with international standards or they may flag the absence of relevant international standards in specific product areas. They can also indicate areas where further cooperation may be needed to facilitate trade. The reason is that the notification requirement under the TBT Agreement applies to proposed technical regulations or conformity assessment procedures which are not in accordance with or are not substantially the same as the content of relevant international standards (or where relevant international standards do not exist), and which may have a significant effect on trade of other members.

In collaboration with the UN and the International Trade Centre (ITC), the WTO has developed a tool, known as "ePing" (epingalert.org), to which producers, traders and government officials can subscribe in order to receive email alerts on planned regulatory revisions covering products and/or markets of interest to them. ePing also includes a communication platform where users can discuss these upcoming changes with fellow stakeholders and government officials.

to provide feedback on draft measures of other members that may create unnecessary obstacles to trade (see Box 5). Moreover, the TBT Committee periodically adopts guidance tools (e.g. decisions and recommendations) to help members implement specific provisions of TBT Agreement more efficiently.

Finally, through its technical assistance activities, the WTO Secretariat helps developing countries to improve their understanding of matters such as the disciplines of the TBT Agreement and the implementation thereof, the operation of transparency procedures, and the work of the TBT Committee. In addition, the WTO Secretariat helps members take advantage of opportunities provided by the TBT Agreement to pursue their trade interests, including through participation in the TBT Committee, at which specific measures may be discussed and the implementation of the Agreement's provisions are reviewed.

> The WTO plays an important role in supporting cooperation on trade and QI by providing a multilateral framework for the conduct of trade relations among its 164 members.

Technical assistance activities are often delivered with the cooperation of other organizations such as IRENA, IEC, the ISO and the UN Industrial Development Organization (UNIDO). The WTO also helps to build trade capacity in developing and least-developed countries through its Aid for Trade initiative and through partnerships such as the Enhanced Integrated Framework (EIF) and the Standards and Trade Development Facility (STDF).

BOX 5

Specific trade concerns in the TBT Committee

Sources: WTO official documents G/TBT/M/52-G/TBT/M/57 and G/TBT/M/59-G/TBT/M/62 (available at https://docs.wto.org/).

Since its first meeting in 1995, WTO members have used the TBT Committee to discuss trade issues arising from specific measures (for example, technical regulations, standards or conformity assessment procedures) maintained by other members. These specific trade concerns (STCs) are a form of peer review which allows WTO members to identify and iron out potential problems associated with the specific measures of their trading partners.

When raising STCs, members often seek to find pragmatic solutions to those problems through technical exchanges among trade, standards and regulatory experts. The overall purpose of STCs, therefore, is to promote and facilitate cooperation to allow trade to flow as smoothly as possible so that it can play a full role in supporting WTO members' wider policy goals.

One example of an STC involving solar PV started in 2010, when several WTO members raised concerns that a certification standard used by the Korea Management Energy Corporation (KEMCO) excluded several types of thin-film solar panels, thereby preventing those panels from receiving certification and thus from entering the market of the Republic of Korea. Concerns partly revolved around the methodology of a study launched by KEMCO in 2010 to assess the environmental risks related to the types of solar panels excluded from the Republic of Korea's certification standard.

Following the study's completion in 2012 and discussions in the TBT Committee, the Republic of Korea informed WTO members that it would not extend the coverage of its certification system to one type of thin-film solar panel due to concerns about the use of toxic substances in the manufacturing process or in the product itself. At the same time, the Republic of Korea indicated that it would develop a certification system for another type of module previously excluded from the certification standard, provided that the modules in question satisfied national environmental standards. The Republic of Korea indicated that the certification system for the latter type of module had started to operate on a pilot basis in 2013 and would officially start from 2014.

APPENDIX: SELECTED GOODS ALONG THE SOLAR PV VALUE CHAIN

In this report, the category “machines to manufacture PV cells” comprises the following HS subheadings:

Machinery to manufacture PV cells

Product	Function	HS classification (HS 2012)	Corresponding HS nomenclature
Machines	For the manufacture of PV wafers	8486.10	Machines and apparatus of a kind used solely or principally used for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays; machines and apparatus specified in Note 9 (C) to this Chapter; parts and accessories. - Machines and apparatus for the manufacture of boules or wafers
Machines	For the manufacture of PV cells, modules and panels	8486.20	Machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays; machines and apparatus specified in Note 9 (C) to this Chapter; parts and accessories. - Machines and apparatus for the manufacture of semiconductor devices or of electronic integrated circuits
Parts	Of machines of 8486.10x and 8486.20x	8486.90	Machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers, semiconductor devices, electronic integrated circuits or flat panel displays; machines and apparatus specified in Note 9 (C) to this Chapter; parts and accessories. - Parts and accessories

The category “Solar PV components” comprises the following HS subheadings:

Solar PV components

Product	Function	HS classification (HS 2012)	Corresponding HS nomenclature
PV generator	Generates direct current (DC)	8501.31	Electric motors and generators (excluding generating sets): - Other DC motors; DC generators: of an output not exceeding 750 W
PV generators	Generates DC current	8501.32	Electric motors and generators (excluding generating sets): - Other DC motors; DC generators: of an output exceeding 750 W but not exceeding 75 kW
PV generator	Generates alternating current (AC)	8501.61	Electric motors and generators (excluding generating sets): - AC generators (alternators): of an output not exceeding 75 kVA
Power modulator/ inverter	Converts DC current from the solar panel to synthetic AC current for grid consumption	8504.40	Electrical transformers, static converters (for example, rectifiers) and inductors: - Static converters
Parts	Of power modulators/ inverters	8504.90	Electrical transformers, static converters (for example, rectifiers) and inductors: - Parts
PV cells	Component of PV modules	8541.40	Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezoelectric crystals: - Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes
Parts	Of PV cells	8541.90	Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezoelectric crystals: - Parts

ABBREVIATIONS

Gt	gigaton
GW	gigawatt
HS	Harmonized System
IEC	International Electrotechnical Commission
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of electricity
MFN	most-favoured nation
OECD	Organisation for Economic Co-operation and Development
PV	photovoltaic
RTA	regional trade agreement
QI	quality infrastructure
SDGs	Sustainable Development Goals
STC	specific trade concern
TBT	technical barriers to trade
UN	United Nations
WTO	World Trade Organization

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Open global trade, supported by a well-functioning “quality infrastructure”, has been an important factor in the rapid deployment of solar photovoltaic (PV) technologies around the world. Keeping markets open is critically important to ensure that all countries can benefit from solar PV, a pillar of the low-carbon, sustainable energy system needed to help achieve the goals of the Paris Agreement and fulfil the United Nations’ Sustainable Development Goals.

This report by the World Trade Organization (WTO) and the International Renewable Energy Agency (IRENA) looks at how open, transparent and inclusive trade policies can support cost reductions, deployment of components and job creation in the solar PV sector, strengthening the critical infrastructure needed to fight the COVID-19 pandemic and supporting efforts to rebuild the world economy.

The report examines the need for countries to develop a robust quality infrastructure to promote safe trade in solar PV goods and services. This would reduce the risks of unreliable products entering the value chain, and ensure stability for investors and other participants in the value chain. The report also looks at the need to strengthen international cooperation, and demonstrates how IRENA and the WTO can support efforts to promote a secure and inclusive global solar PV market through the effective use of quality infrastructure.

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