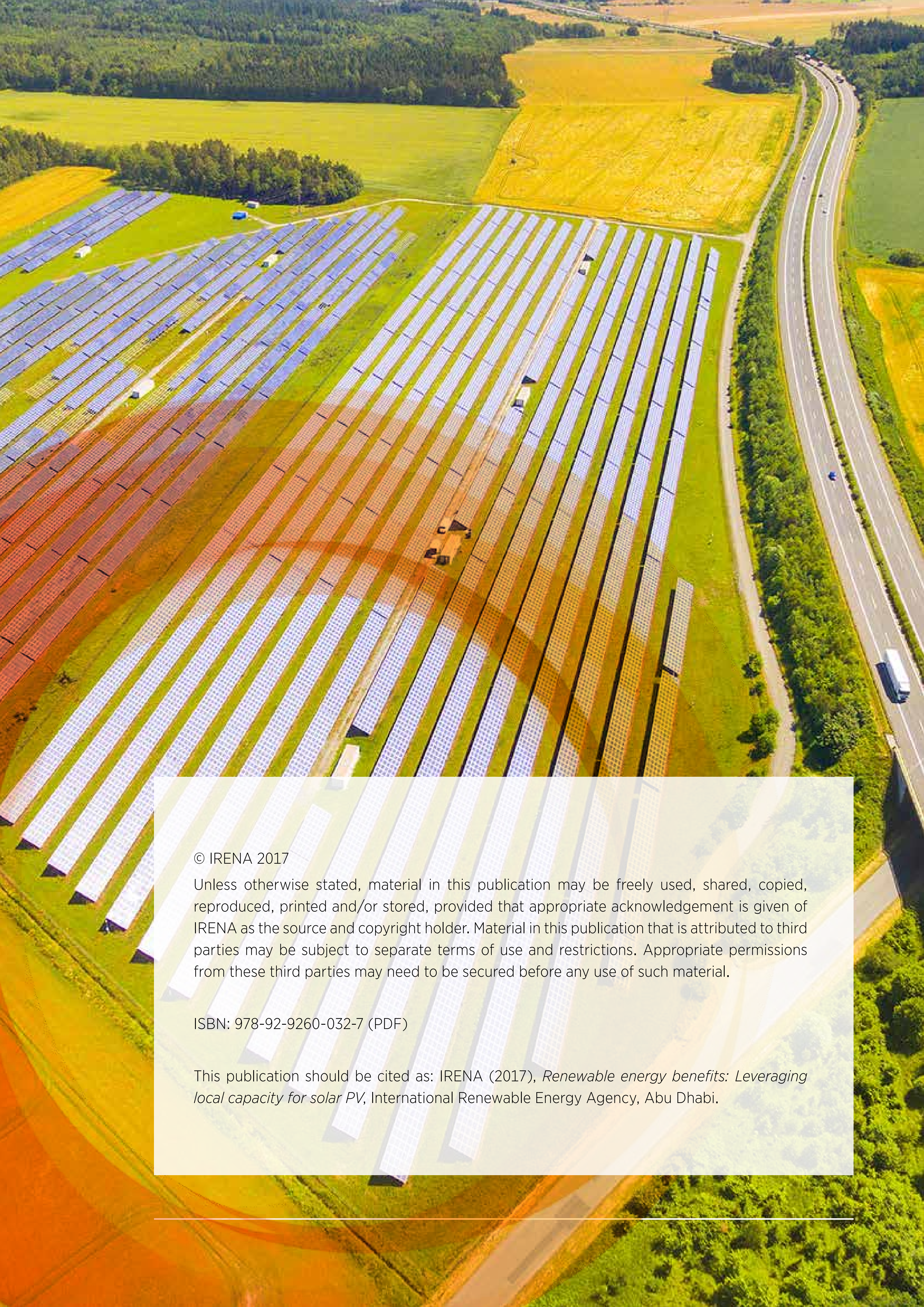
IRENA
International Renewable Energy Agency

RENEWABLE ENERGY BENEFITS

LEVERAGING LOCAL CAPACITY FOR SOLAR PV

EXECUTIVE SUMMARY



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ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

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DISCLAIMER

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INTRODUCTION

Developing a renewable energy sector brings immense opportunities to fuel economic growth, create new employment opportunities and enhance human health and welfare. Many countries increasingly consider the socio-economic benefits of renewable energy development as a key driver to support its deployment (IRENA, 2016a).

Analysis by the International Renewable Energy Agency (IRENA) shows that an accelerated deployment of renewable energy and energy efficiency, as needed to meet the goals laid out in the Paris Agreement, would increase global GDP by 0.8% in 2050 and support around 26 million jobs in the global renewable energy sector by 2050 (IRENA, 2017a). In recent years, job creation has been an important co-benefit of accelerated renewable energy deployment. IRENA estimates that the sector employed 9.8 million people in 2016 (IRENA, 2017b). Employment opportunities are created throughout the value chain for renewable energy deployment, from project planning to manufacturing, installing, operating and maintaining, as well as decommissioning.

This report assesses the types of jobs created along the value chain[1], in order to provide policy makers with an understanding of the human resources and skills required to produce, install and decommission renewable energy plants. It assesses the materials and equipment needed in each segment of the value chain to identify areas with the greatest potential for local value creation. The objective is to allow for an informed feasibility assessment of procuring the components and services domestically rather than from abroad. The study can help decision makers identify ways to maximise domestic value creation by leveraging existing industries if they choose to do so. It is part of IRENA's extensive work on renewable energy benefits (see Box 1).

Box 1 ■ **IRENA's work on renewable energy benefits**

This summary is part of a growing body of work by IRENA which began in 2011. It includes *Renewable Energy and Jobs (2013), The Socio-Economic Benefits of Solar and Wind Energy (2014), Renewable Energy Benefits: Measuring the Economics (2016) and Renewable Energy and Jobs: Annual Review (2014, 2015, 2016 and 2017)*. This study is part of a series of reports analysing the opportunities for value creation through deployment of renewable energy technologies, including onshore wind (IRENA, 2017c) as well as upcoming reports on solar water heaters and offshore wind.

The full report can be downloaded from **www.irena.org/Publications**

[1] The assessment covers both large-scale and distributed installations using crystalline silicon and thin-film technology.

The data presented in the report were obtained through surveys and interviews with internationally recognised experts and from desktop research that gathered information published by leading companies and specialised institutions in the solar industry. Forty-six stakeholders were interviewed or responded to questionnaires on the requirements to develop a solar photovoltaic (PV) industry. They included project developers, component manufacturers, service providers, energy authorities and national and global associations for solar and renewable energy. The study also draws on public reports of solar PV energy companies, including annual reports; technical specifications and equipment handbooks; and public price lists.[2] The scope of the study is global, covering Canada, Chile, China, the European Union and the United States.

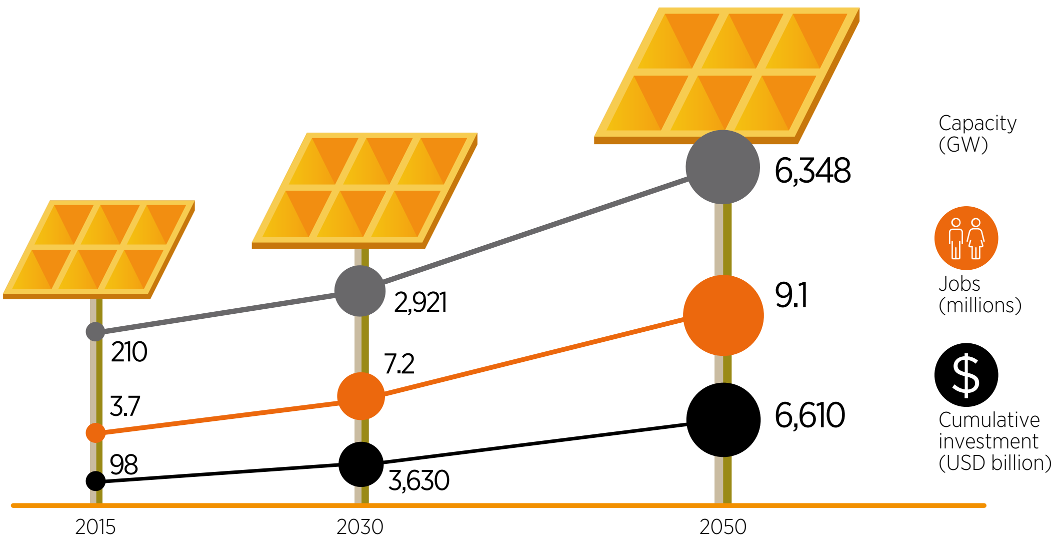
The first section of the report discusses the current and projected socio-economic benefits of solar photovoltaics (PV) deployment. The second section analyses the requirements (in terms of skills, materials and equipment) to develop solar PV projects along each segment of the value chain. The third section presents recommendations on how to maximise value creation from the development of a domestic solar PV industry while leveraging existing industries.

[2] The report draws on public information from the following institutions: AEG Power Solutions, Alter Enersun, Asociación de Productores de Energías Renovables (APPA), Atersa, Bosch Rexroth, Braux, Canadian Solar, CEGASA Portable Energy, the China Datang Corporation, Clean Energy Resource Teams, the Comisión Nacional de la Energía, the Danish Energy Agency, Deutsche Energie Agentur, EDF, EDP Renovavéis, Enel Green Power, Enerpack, EUROFORES, Exide Technologies, First Solar, Fotowatio Renewable Ventures, B.V., Fraunhofer, Iberdrola, Ingeteam, the Inter-American Development Bank, the International Energy Agency, the International Monetary Fund, Isolux, Jinyi Solar, Kostal, Onyx Solar, REN21, Renovalia, Schneider, Sharp Corporation, SkyPower, the Solar Power Europe Association, Solarpack, SunEdisson, Sungrow Power, SunPower, Trina Solar, T-Solar, the U.K. Energy Agency, the World Bank and Yingli Solar.

1. VALUE CREATION IN THE PHOTOVOLTAIC SECTOR

Solar PV energy deployment has risen steadily for nearly two decades, from less than 9 gigawatts (GW) installed capacity in 2007 to more than 290 GW in 2016 (IRENA, 2017d). IRENA estimates that achieving the energy transition in the G20 countries would require cumulative investments in the solar sector of about USD 3,630 billion by 2030 and USD 6,610 billion by 2050 (IRENA, 2017a). Such investments can create value, and result in economic benefits, including income generation and job creation (see Figure 1).

Figure 1 **Estimated cumulative capacity, investments and employment in solar PV, 2015, 2030 and 2050**



Note: Jobs include solar water heating jobs.

Sources: IRENA, 2016b; IRENA, 2017a

1.1 Potential for job creation

The solar PV sector employed 3.1 million people in 2016, mainly in China, Japan, the United States, Bangladesh and India (IRENA, 2017b) (see Box 2). Furthermore, IRENA estimates that the solar sector (including solar water heaters) could support around 9 million jobs in 2050 (IRENA, 2017a) (see Figure 1).

Some studies in the literature have analysed the impacts of solar deployment on the economy. They project that the solar industry will generate nearly EUR 6.67 billion gross value added (GVA) with a cumulative installed capacity of almost 139 GW in distributed and large-scale installations and employ more than 136,000 people in Europe in 2020 (EY, 2015)

Box 2 ■ **Overview of Jobs in solar PV in 2016.**

Global employment in solar PV increased by 12% in 2016, to 3.1 million jobs. China – the leader in both manufacturing and installation – employed 1.96 million people in the solar PV sector, up 19% from 2015. Strong growth in annual installation in the United States and India, boosted employment by 17% and 24%, respectively. By contrast, jobs in solar PV declined in Japan for the first time and continued to decrease in the European Union due to contracting markets. Overall, jobs in the sector continue to shift towards countries in Asia due to rising deployment and manufacturing.

The manufacturing of PV components has been concentrating in the manufacturing hubs in Asia. While China remains the leader in manufacturing, Malaysia, the Republic of Korea and Thailand, for example, have leveraged their semiconductor industries to produce solar panels.

The shift of jobs from Europe to Asia also reflects increasing levels of deployment in Asian countries – accounting for about 70% of the total installation in 2016. Driven by policies and declining costs, installation has been soaring in countries such as China and India, resulting in related job creation.

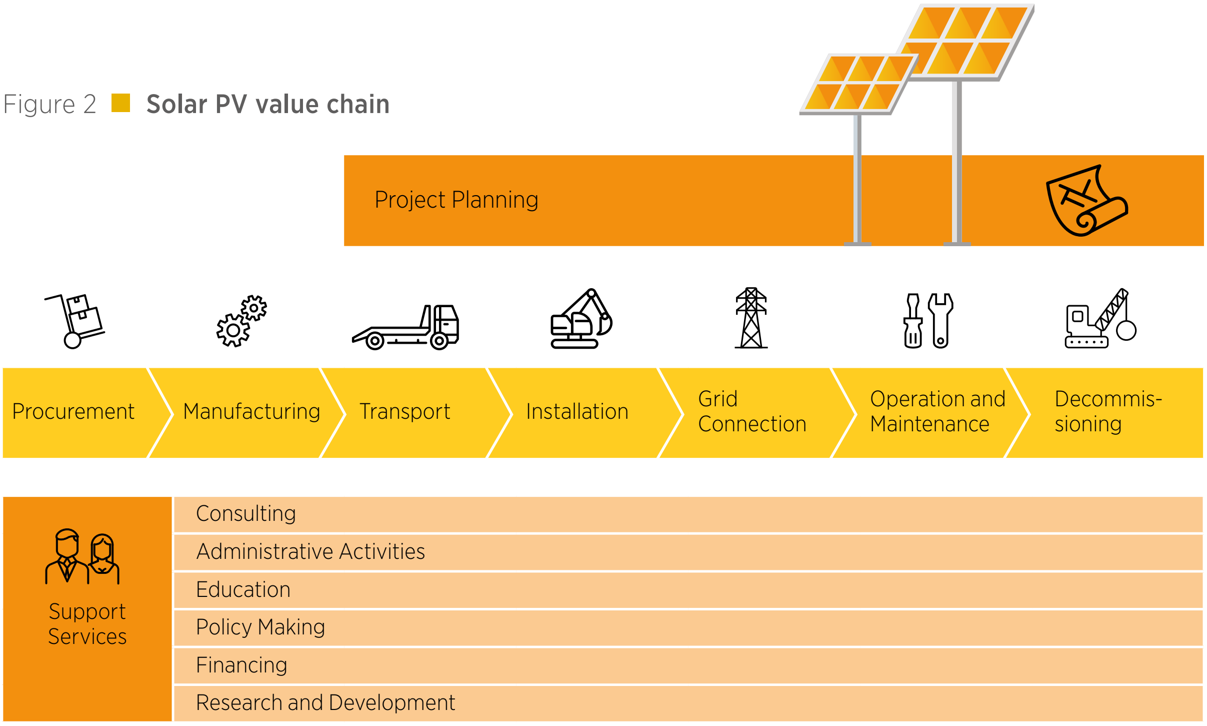
In addition, distributed solar installations have contributed to value creation in countries such as Bangladesh, India and Kenya in assembly, distribution and after-sales service.

Trade policies are driving this shift in manufacturing. India, following a World Trade Organization (WTO) ruling against its domestic content rules, is searching for other measures to support its PV manufacturing industry that will not run afoul of global trade norms. Duties imposed by the United States and the European Union on panel imports from China led Chinese manufacturers to relocate their facilities to countries such as Malaysia, Thailand, the Republic of Korea, India, Brazil and the United States.

Sources: IRENA, 2017b; Osborne, 2015

For a country deploying solar PV, the potential to generate income and create jobs will depend on the extent to which industry along the different segment of the value chain can employ people locally, leverage existing economic activities or create new ones. The analysis in this study focusses on the core segments of the solar PV value chain: project planning, procurement, manufacturing, transport, installation and grid connection, operation and maintenance (O&M) and decommissioning (see Figure 2).

Figure 2 ■ **Solar PV value chain**



In designing policies to support value creation from the development of a domestic solar PV industry, a deeper understanding of the requirements in terms of labour, skills, materials and equipment is needed.

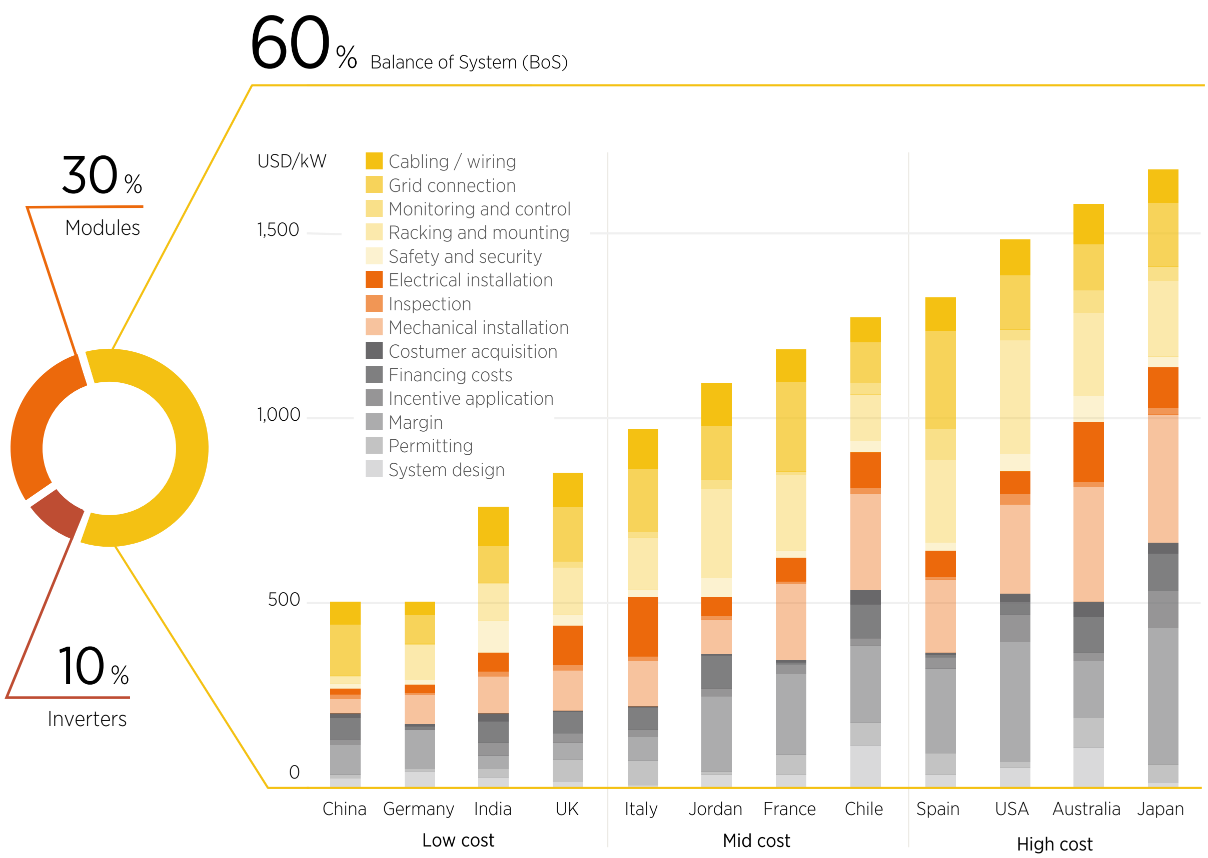
1.2 Cost breakdown of a PV project

The total cost of a utility-scale ground-mounted solar system can be divided into three categories: the cost of modules, the cost of inverters, and balance of system costs (other hardware, installation and soft costs). In 2015, balance of system costs were the major cost component of solar projects, accounting for about 60 percent of total cost; modules accounted for 30 percent and inverters 10 percent (IRENA, 2016b).

Hardware costs other than modules and inverters include cabling, racking and mounting, safety and security, grid connection and monitoring and control. Installation costs involve construction and electrical installation and health and safety inspection. Soft costs include those related to financing, permitting, system and engineering design (IRENA, 2016b).

Balance of system costs vary significantly across countries. Figure 3 shows the average costs for utility-scale projects in 12 markets.

Figure 3 **Balance of system costs of solar systems in selected countries, 2015**



Source: IRENA, 2016b

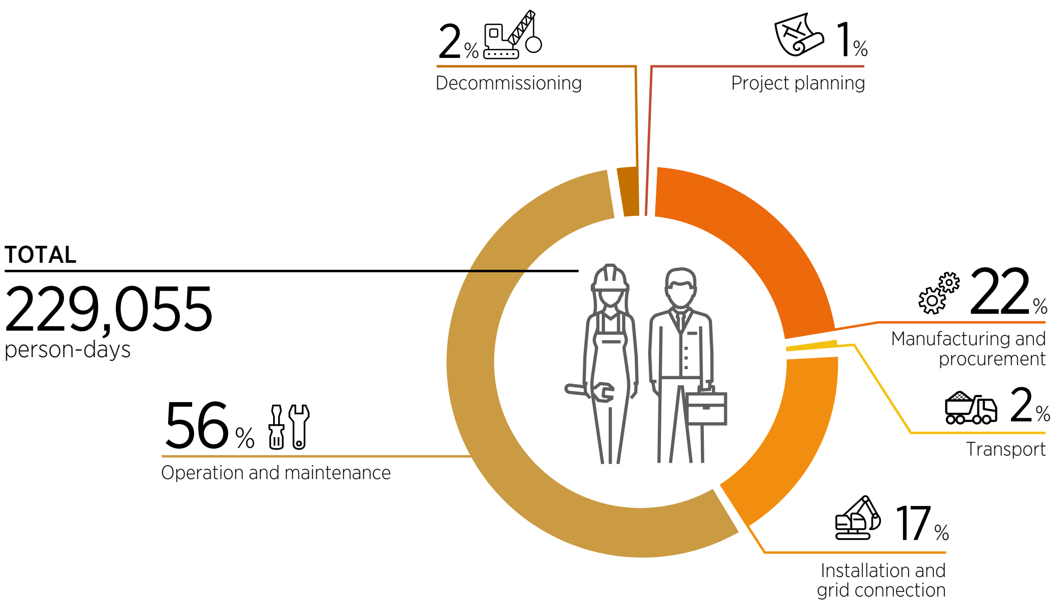
Soft costs and installations costs constitute a large percentage of total costs in many countries, suggesting opportunities for value creation beyond the manufacturing of the main components. This study analyses the requirements for undertaking various activities, focusing on the seven core segments: project planning, procurement, manufacturing, transport, installation, grid connection, operation and maintenance and decommissioning.[3]

[3] Analysis of support services is beyond the scope of this study.

2. REQUIREMENTS FOR SOLAR PV DEVELOPMENT

With a total at 229,055 person-days needed to develop a solar PV plant of 50 megawatt (MW), labour requirements vary across the value chain. People working on O&M are needed throughout the project lifetime, and therefore represent the bulk of the labour requirements (56 percent of the total)[4] (see Figure 4). Equipment manufacturing (22 percent) and installation and grid connection (17 percent) also require significant labour inputs.

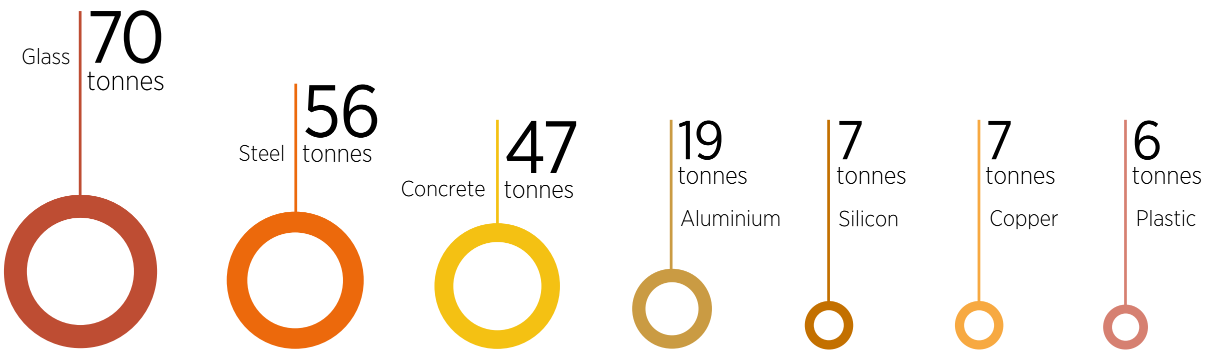
Figure 4 **Distribution of human resources required along the value chain for the development of a 50 MW solar PV plant, by activity**



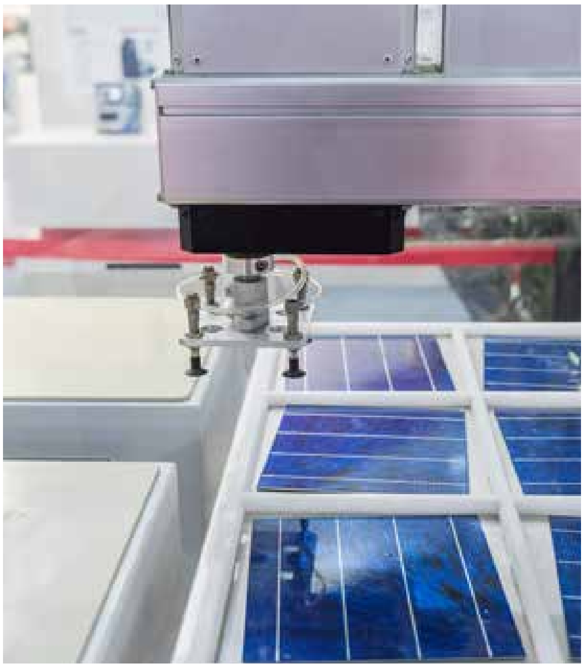
[4] The person-days required for the first year of O&M is estimated to be 13,560. The total is a cumulative person-days over a 25 years of project lifetime, assuming labour productivity improvement of 3.8% per year.

The composition of solar panels depends on the type of panel used. Silicon-based (c-Si) PV technology (including monocrystalline, poly and multicrystalline, ribbon and amorphous silicon) currently dominates the market, with a market share of about 92% (IRENA and IEA-PVPS, 2016). However, the materials used for the inverters, mounting structures and cables are often common regardless of the selected panel technology. Figure 5 illustrates the quantities of materials needed to manufacture and install 1 megawatt (MW) of silicon-based solar PV plant. Almost 70 tonnes of glass are needed for the PV panels, almost 56 tonnes of steel and 19 tonnes of aluminium go into the mounting structures and panels, and around 47 tonnes of concrete are required for foundations. Other key materials, such as silicon, copper and plastic make up smaller share of total weight of material for a solar PV plant.

Figure 5 ■ **Materials needed to develop a 1 MW Silicon-based solar PV plant (tonnes)**



Source: Results of surveys and questionnaires conducted for this study.



A more detailed breakdown of labour, materials, equipment and information required to undertake the various activities can be analysed at each segment of the value chain.

2.1 Project planning

Activities at the project planning phase comprise site selection, technical and financial feasibility studies, engineering design and project development. The first two activities involve measuring the solar resource potential and estimating the environmental and social impacts of developing a solar plant on an identified site. Engineering design involves identifying the technical aspects of the mechanical and electrical systems, the civil engineering work and infrastructure, the construction plan and the operations and maintenance (O&M) model. Project development consists of administrative tasks such as obtaining land rights, permits, licenses and approvals from different authorities; managing regulatory issues; negotiating and securing financing; negotiating and signing insurance contracts; contracting an engineering company; negotiating the rent or purchase of the land; and managing the procurement processes.

Site selection

Feasibility studies

Engineering design

Project development

Planning a 50 MW solar PV plant requires an estimated 2,120 person-days of labour. Project development activity accounts for about 59 percent of this labour (1,250 person-days), followed by site selection (17%), engineering design (12%), and feasibility analyses (12%). Table 1 presents a breakdown of the total workforce needed in project planning by activity.

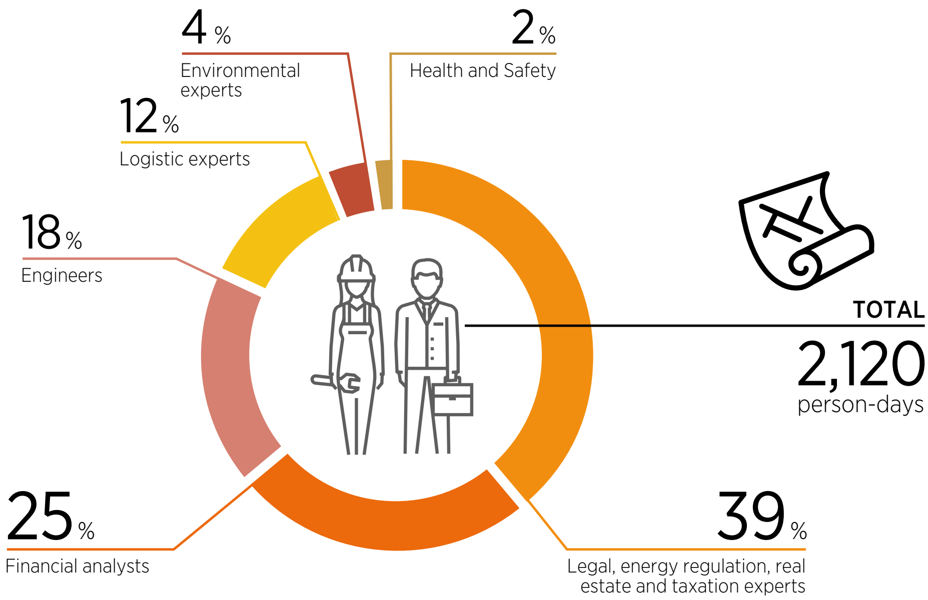
Table 1 ■ **Human resources required for the project planning of a 50 MW solar PV plant (person-days) and breakdown by activity**

TYPE OF HUMAN RESOURCES	Site selection	Feasibility analyses	Engineering design	Project development	Total by occupation
Legal, energy regulation, real estate and taxation experts	180	60	85	500	**825**
Financial analysts	–	30	–	500	**530**
Electrical, civil, mechanical and energy engineers	120	130	135	–	**385**
Logistic experts	–			250	**250**
Environmental experts	60	30	–	–	**90**
Health and safety experts	–	–	40	–	**40**
Total (as %)	**360** (17%)	**250** (12%)	**260** (12%)	**1,250** (59%)	**2,120**

Almost 40 percent of the total person-days needed are for legal, energy regulation, real estate and taxation experts (see Figure 6), indicating the importance of the knowledge of the local context. While some of these needs can be fulfilled by foreign experts, they offer considerable opportunities for domestic employment.

About 24 percent of the total labour (515 person-days) requires engineers, environmental experts and health experts and safety experts (385, 90 and 40 person-days, respectively) (see Figure 6). These professionals can be hired from abroad on a temporary basis or skills can be developed domestically as part of education and training policies designed to meet future needs in human resources.

Figure 6 **Distribution of human resources required for the project planning of a 50 MW solar PV plant (person-days), by occupation**



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.[5] It also requires computers and software to run simulations and produce feasibility analyses.

Technical information is required to describe climatic features at the site that might affect a project's structural and operational requirements or place limitations on the solar panels. Knowledge of policies and regulations related to support schemes for renewable energy, grid connection and land use is crucial for informing decisions about whether or not to proceed with the development of the solar plant.

In the project development stage, planners decide whether to procure domestically manufactured components (if available) or from foreign suppliers. The cost of technology and enabling conditions created by policies that support manufacturing, such as taxes on imports or local content requirements, affect this decision.

[5] IRENA's *Global Atlas* provides high-resolution maps displaying suitability for projects based on resource intensity, distance to power grids, population density, land cover, topography, altitude and protected areas (IRENA, 2016c).

2.2 Manufacturing and procurement

The main components of a solar plant that decision makers may consider manufacturing domestically are the solar cells, solar modules, inverters, trackers, mounting structures and general electrical components.

The existence of government policies incentivising local value creation, the availability of raw materials and the presence of related industries may drive decisions about local manufacturing of PV components. Moreover, increased competition, low prices and overcapacity (see Box 3) in the global market could discourage the development of a domestic manufacturing industry for modules, especially when a neighbouring country is a large producer or domestic demand for equipment is not expected to be high.

Solar cells

Modules

Inverters

Structures and trackers

Box 3 **Overcapacity and the decline in prices of PV equipment since 2010**

The rapid deployment of solar energy and growing revenues for producers coupled with expectations of increasing demand resulted in investments in manufacturing and eventually in global overcapacity for solar equipment. By 2010, there was so much inventory of solar equipment that prices dropped for all components. The overcapacity, along with technological advancement and more efficient manufacturing processes, contributed to the drop in technology costs. The cost of modules fell by about 80 percent between 2009 and 2015, reducing the share of modules in total system cost from about 57 percent to about 30 percent.

While all markets experienced some consolidation, manufacturers in the European Union, the United States, Japan and India were hardest hit. Competitive disadvantage, slowing domestic demand and lack of conducive policy frameworks encouraged several producers to shift manufacturing to China, Malaysia and Singapore.

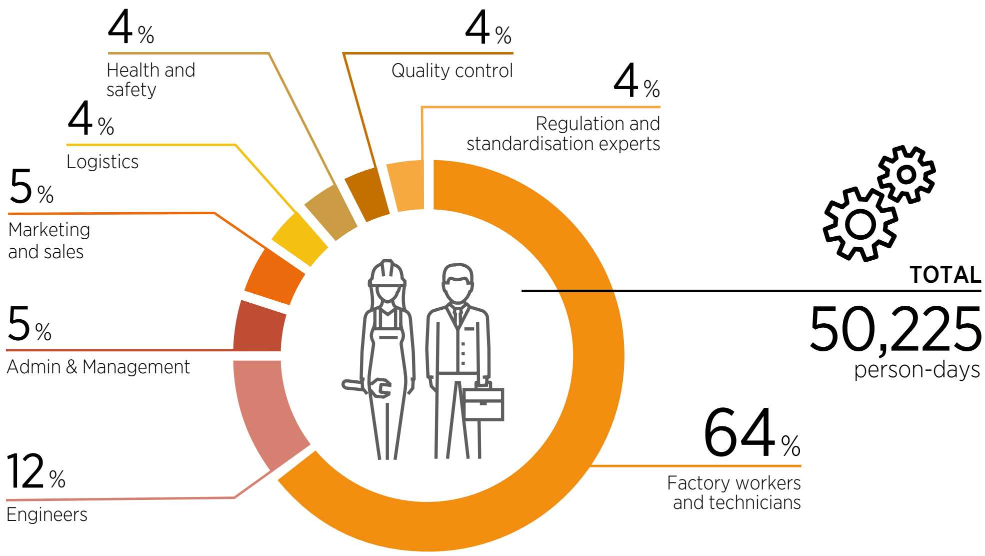
Manufacturing the main components of 50 MW solar PV plant requires 50,225 person-days. The production of solar cells requires most work (almost half of the total). Solar modules need another 21 percent of the total person-days, followed by inverters (17 percent) and solar trackers and structures (14 percent) (see Table 2).

Table 2 **Human resources required to manufacture the main components of 50 MW solar PV plant (person-days) and breakdown by main components**

TYPE OF HUMAN RESOURCES	Solar cells	Solar modules	Inverters	Solar trackers and structures	Total by occupation
Factory workers and technicians	16,800	6,300	4,970	3,850	**31,920**
Industrial engineers	2,310	1,050	980	840	**5,180**
Administrative personnel	770	770	490	420	**2,450**
Marketing and sales personnel	770	1,540	–	–	**2,310**
Logistic experts	770	350	490	420	**2,030**
Quality control experts	770	175	490	420	**1,855**
Health and safety experts	770	175	490	420	**1,855**
Regulation and standardisation experts	770	175	490	420	**1,855**
Chemical engineers	770	–	–	–	**770**
Total (as %)	**24,500** (49%)	**10,535** (21%)	**8,400** (17%)	**6,970** (14%)	**50,225**

The technical workforce forms the bulk of the labour requirements for the manufacturing of every component. More than 64 percent of the labour required (31,920 person-days) to manufacture components is factory labour and technicians with low to medium technical skills. Industrial engineers account for another 10 percent (5,180 person-days). Many of these workers can be sourced from similar industries, such as semiconductors, electrical equipment and automobiles. Technical education and training offered by dedicated institutions or as part of university curricula can also help equip the workforce with adequate skills. Non-technical experts in marketing and sales, administration, logistics and regulation play a small (each at around 5 percent of the total person-days) but important roles (see Figure 7).

Figure 7 **Distribution of human resources required to manufacture the main components of a 50 MW solar PV plant, by occupation**



Although building a domestic manufacturing capacity for solar has the potential to increase income and employment, realising its value creation potential requires the existence of, and access to, subcomponents (some highly specialised) and raw materials.

Maximising value creation from the development of a domestic PV industry relies on leveraging capacities in other industries, such as glass, aluminium, silicon and semiconductors, in order to provide expertise, raw materials and intermediary products for the manufacturing of components. The raw materials needed differ according to the PV technology. Two technologies dominate the market: crystalline silicon (c-Si) and thin film (see Box 4).

Box 4 **Types of solar cell technologies**

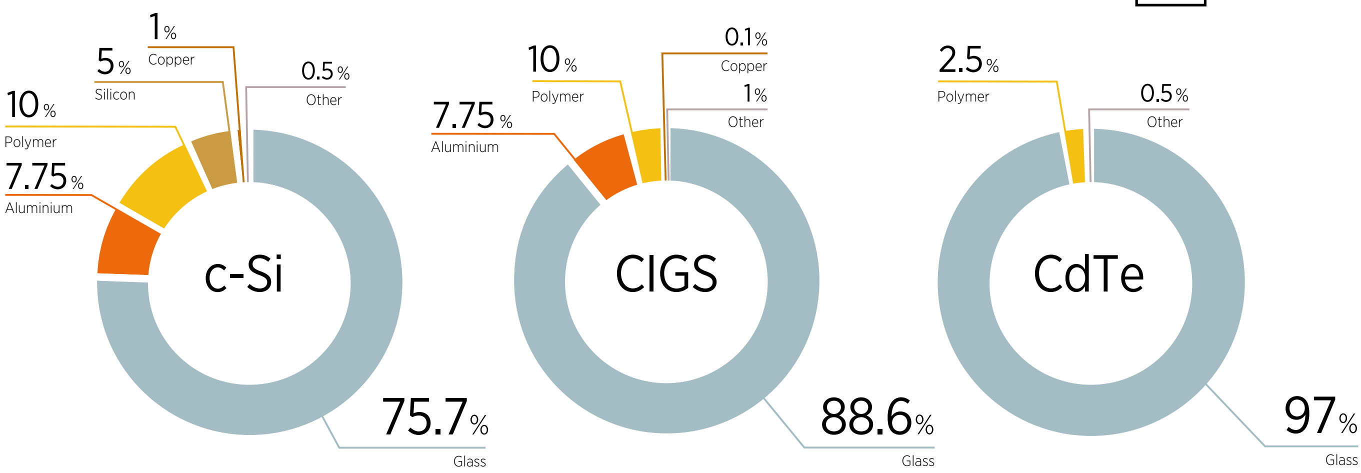
Crystalline silicon (c-Si) PV is the oldest PV technology. It accounts for 92 percent of the market, thanks to its high efficiency and low cost. C-Si PV consists of slices (or wafers) of solar-grade silicon made into cells and assembled into modules and electrically connected. C-Si cells are subdivided into mono-crystalline silicon (mono-c-Si) and multi-crystalline silicon (multi-c-Si). Mono-c-Si cells are more efficient but more expensive than multi-c-Si.

Thin-film technology consists of thin layers of semiconducting material deposited onto large-size substrates such as glass, polymer or metal. It is becoming competitive in utility-scale applications, where it has some advantages under certain operating conditions. Thin-film solar technology encompasses several technologies, including cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS).

Sources: IRENA and IEA-PVPS, 2016

Figure 8 shows the materials needed to manufacture the most commonly used PV panels as a percentage of total panel mass. Typical c-Si PV panels consist of about 76% glass (panel surface), with polymers, aluminium, silicon, copper and silver and other metals taking up much smaller shares of the panel mass. Thin film solar panels generally require higher shares of glass in their total mass: CIGS panels are composed of 89% glass and CdTe at 97%.

Figure 8 **Materials required to manufacture PV panels (percent of weight)**



Source: IRENA and IEA-PVPS, 2016

The materials required to produce inverters depend on their size, model and casing. A 500 W inverter can contain 682 grams (g) of aluminium, 216 g of polymers, and 78 g of steel (in the screws and clamps) (IEA-PVPS, 2015). The material needs to build the structures depend on the type of installation. Table 3 presents the materials needed to produce structures.

Table 3 **Materials required to manufacture mounting structures (per m² of solar panels)**

MATERIAL	Type of structure		
	Flat rooftop	Slanted rooftop	Ground-mounted
Aluminium and alloy	2.52 kg	2.84 kg	3.98 kg
Steel and alloy	0.267 kg	1.5 kg	7.457 kg
Concrete	0	0	0.00537 m3
Plastic	1.92 kg	1.40 g	0.909 g
Polymer	8.30 g	7.02 g	4.55 g
Corrugated board, mixed fibre, single wall	0.0183 kg	0.133 kg	0.0864 kg

Source: IEA-PVPS, 2015

Manufacturing the main components of a solar systems requires specialised equipment and other machinery (see Table 4). It also requires equipment which is commonly used in other industries such machines for cutting, welding, washing, bending, melting and joining. Electronic and information technology tools are also extensively used in manufacturing for monitoring and control of machinery.

Table 4 **Equipment needed to manufacture solar PV cells, modules and inverters**

PV cells	PV modules	Inverters
• Crystalline Ingot Growing machine • Diffusion equipment • Deposition machines • Semi- automatic laminator • Full automatic laminator • Solar cell tester • Framing machine • EVA, TPT cutting station • EVA, TPT transfer carrier • Laser cutting machine • Electrical iron • Pneumatic glue gun • Compressor • Quartz recipients, blowing gas machinery	• Systems able to automatically classify cells according to the electric current generated with a voltage: cell select tables, appearance inspection stations • Washing, joining machines, electric arc furnaces • Cutting machines (circular saw, muti-ware saw) • Serigraphy machinery • Welding equipment • Cell string shelves • Cooling systems • Laser beams • Laying up stations • Module transfer carrier	• Heavy cranes • Rolling machine • Welding machines (different technologies depending on process) • Shot peening machines • Material handling equipment • Automated Paint Machines • Inspection equipment

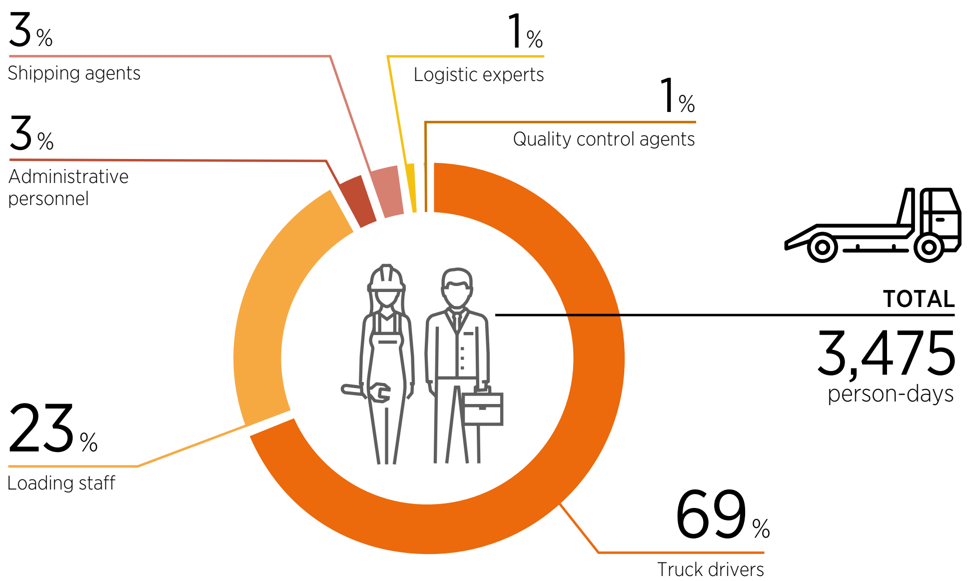
Given the high level of competition in the solar PV panel market, the decision to start local manufacturing should consider several factors including: the future market demand (domestic, regional and international) and the level of competitiveness of other leading countries. Moreover, decision makers may also consider that the transport of solar PV equipment is simpler than other technologies such as wind energy – as parts are less bulky.

2.3 Transport

Transporting solar energy equipment is less cumbersome than transporting wind energy components. Components can be conveyed by truck, plane, train or boat, with no special handling apart from proper packaging to avoid breakage or scratching. Transporting solar components costs an average of about USD 0.10-0.20 per tonne-mile. Prices vary significantly across countries and also depend on the price of fuel.

It takes about 3,475 person-days to transport the main components of a 50 MW solar plant by truck over 1,000 miles (see Figure 9). Most of the work is done by local truck drivers (69 percent of the person-days) and loading staff (23 percent of the person-days), with smaller contributions from experts in administration, shipping, logistics and quality control.

Figure 9 **Distribution of human resources required to transport the components of a 50MW solar PV plant by truck over 1,000 miles, by occupation**



Source: IRENA and IEA-PVPS, 2016

Equipment needed for this activity is the same as that needed for transporting any shipment (trucks, trains or vessels for transporting the equipment and cranes for loading and unloading). The installation phase can start in parallel to the transport of equipment.

2.4 Installation and grid connection

The installation and grid connection phases last 6-12 months for facilities up to 50 MW. They offer good opportunities for value creation, particularly where existing resources (equipment, labour and expertise can be leveraged.

Installing and connecting a 50 MW solar plant takes about 39,380 person-days of labour. The most labour-intensive activity is site preparation and civil works, which accounts for more than half of the total (16,600 person-days). This activity is always sourced domestically, creating many opportunities for employment, especially for low- to medium-skilled workers. Assembling equipment account for a 24% of the total labour needed, followed by cabling and grid connection (16% of the total) and commissioning site selection (4%) (see Table 5).


Site preparation and civil works


Assembling equipment


Cabling and grid connection

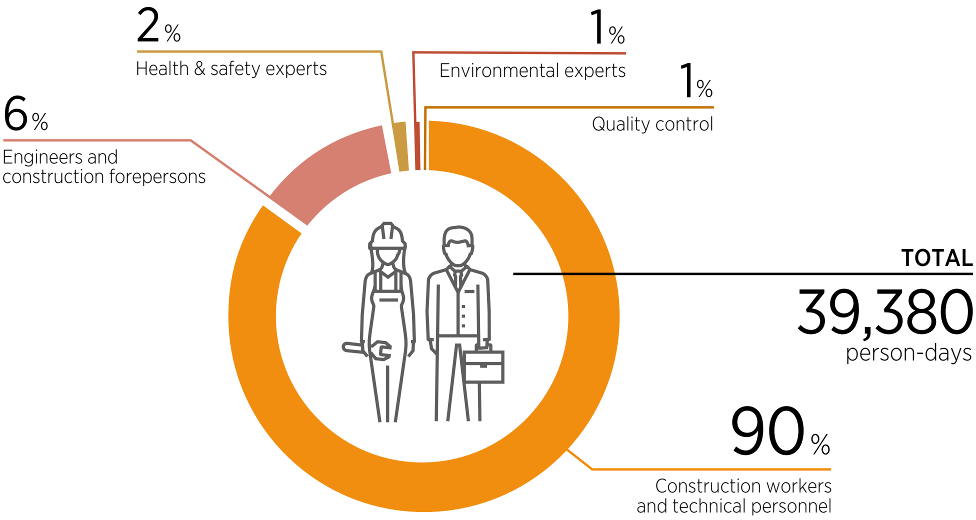

Commissioning

Table 5 **Human resources required to install and connect a 50 MW solar PV plant (person-days) and breakdown by activity**

TYPE OF HUMAN RESOURCES	Site preparation and civil works	Assembling equipment	Cabling and grid connection	Commissioning	Total by occupation
Construction workers and technical personnel	20,000	8,500	6,000	1,000	**35,500**
Civil engineers and foremen	1,400	900	–	–	**2,300**
Health and safety experts	450	150	100	100	**800**
Electrical and mechanical engineers	–	–	180	200	**380**
Environmental experts	300	–	–	–	**300**
Quality-control experts	–	–	100	–	**100**
Total (as %)	**22,150** (56%)	**9,550** (24%)	**6,380** (16%)	**1,300** (4%)	**39,380**

About 90 percent of the person-days require construction workers and technical personnel, most of whom are available domestically. The second-most prevalent occupations for the phase are civil engineers and forepersons, which account for about 6 percent of the total work (see Figure 10).

Figure 10 **Distribution of human resources required to install and connect a 50MW solar PV plant, by occupation**



Materials and equipment needed for the installation phase are usually available in most countries. Materials mainly include glass, steel, aluminium, concrete and other key materials such as silicon, copper and plastic (see Figure 5). Equipment includes loaders, cranes, high-tonnage trucks and excavators as well as supervisory control and data acquisition (SCADA) equipment, electrical and electronic instrumentation and control systems used for grid connection.

2.5 Operation and maintenance

The operation and maintenance phase of a PV plant covers its operation for the expected lifetime of about 25 to 30 years. This plants do not require complex maintenance, but a failing component should be rapidly repaired or changed. O&M activities can be undertaken by the project developer or subcontractors. Modern PV plants are automated and controlled by SCADA. Their operation is normally monitored remotely, by operators who reset the systems after line or grid outages.

Preventive and corrective maintenance, such as cleaning the panels, is required. It represents a large share of the total O&M costs of the companies surveyed for this report (see Table 6), followed by land rental (about 30 percent of the total cost), as the cost of leasing land can be significant in densely populated locations.

In 2015, the annual cost of O&M for selected solar plants was estimated at USD 24,500 – 43,000/MW (see Table 6). The cost depends on the cost of labour, the remoteness of the plant (the distance workers must travel), weather conditions and the levels of dust and sand in the atmosphere.

Operating and maintaining a 50 MW solar PV plant requires an average of 13,560 person-days for every year of the lifetime of the facility. Close to 86 percent for maintenance (between 9,950 and 13,300 person-days per year) and 14 percent of the labour is needed for operations (over 1,900 person-days per year) (see Table 7).

A skilled workforce with solid knowledge about solar PV plant operations make up the majority of the human resources needed. Maintenance requires construction workers for about 5,300 person-days per year (a 48 percent of the total O&M). Out of the over 1,900 person-days per year required for operation, more than 1,100 are high-skilled operators with specific skills. Similarly, about 19 percent of occupations needed for solar plant operation and maintenance consists of technical personnel (between 9,950 and 13,300 person-days per year); another 15 percent are highly skilled engineers (1,974 person-days per year) (see Figure 11).

Table 6 **Annual operation and maintenance costs of a typical solar PV plant (USD/MW) and breakdown by cost component**

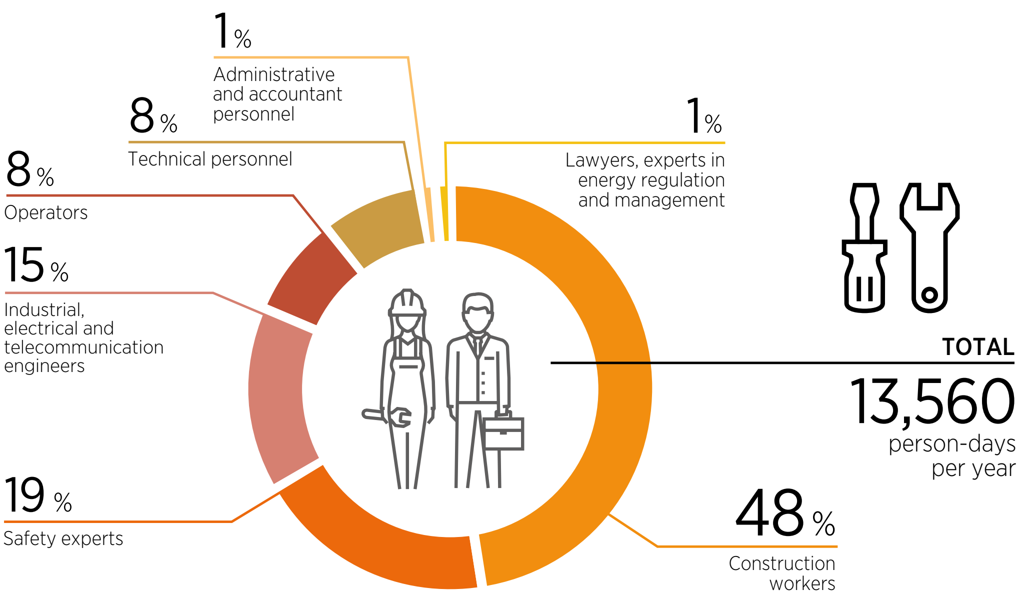
Solar PV plant operation and maintenance cost breakdown		
Cost component	**Annual cost (USD/MW)**	**Percent of total**
Maintenance	10,000 – 22,000	**41 – 52**
Land rental	8,000 – 12,000	**28 – 33**
Insurance	4,000 – 6,400	**15 – 16**
Management and administration	2,500 – 3,000	**7 – 10**
Total	**24,500 – 43,400**	**100**

Source: Based on data provided by European, Canadian and American renewable energy project developers with solar PV installed capacity worldwide

Table 7 ■ **Human resources required to operate and maintain a 50 MW solar PV plant (person-days per year)**

TYPE OF HUMAN RESOURCES	Operation	Maintenance	Total by occupation
Construction workers	-	5,313-7,650	**5,313-7,650**
Safety experts	-	2,253-2,975	**2,253-2,975**
Industrial, electrical and telecommunication engineers	486	1,488	**1,974**
Operators	1,100	-	**1,100**
Technical personnel	-	893-1,190	**893-1,190**
Administrative and accountant personnel	179	-	**179**
Lawyers, experts in energy regulation	114	-	**114**
Management	57	-	**57**
Total (as %)	**1,770** (~14%)	**9,946-13,302** (~86%)	**11,882 - 15,239** (13,560 average)

Figure 11 ■ **Distribution of human resources required to operate and maintain a 50 MW solar PV plant, by occupation**



2.6 Decommissioning

Finally, decommissioning a PV plant involves planning the activity, dismantling the project, recycling/ disposing of the equipment and clearing the site. These activities can usually be handled locally.

It takes about 5,150 person-days to decommission a 50 MW solar PV plant. The most labour-intensive activity is dismantling the project, which requires 3,060 person-days (60 percent of the total). Disposing of equipment and clearing the site require 1,220 and 890 person-days, respectively (21 and 17 percent of the total) (see Table 8). Those activities can commonly be handled locally.

Planning the decommissioning

Dismantling the project

Disposing/recycling the equipment

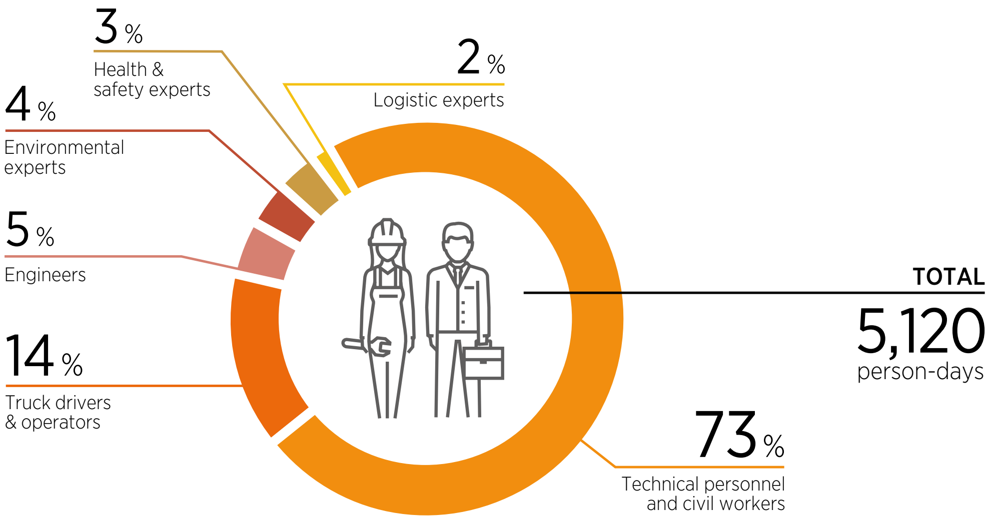
Clearing the site

Table 8 **Human resources required to decommission a 50 MW solar PV plant (person-days) and breakdown by activity**

TYPE OF HUMAN RESOURCES	Planning the activity	Dismantling the project	Disposing of equipment	Clearing the site	Total by occupation
Technical personnel and construction workers	-	2,000	750	1,000	**3,750**
Truck drivers and crane operators	-	740	-	-	**740**
Industrial/mechanical/ electrical engineers	30	160	-	40	**230**
Environmental experts	25	80	40	40	**185**
Safety experts	-	80	40	40	**170**
Logistic experts	25	-	60	-	**85**
Total (as %)	**80** (2%)	**3,060** (60%)	**890** (17%)	**1,120** (21%)	**5,150**

Technical and construction workers perform 73 percent of all decommissioning work. The second most-needed occupations in this phase are truck drivers and crane operators, who account for 14 percent of the total work (see Figure 12).

Figure 12 **Distribution of human resources required to decommission a 50 MW solar PV plant, by occupation**



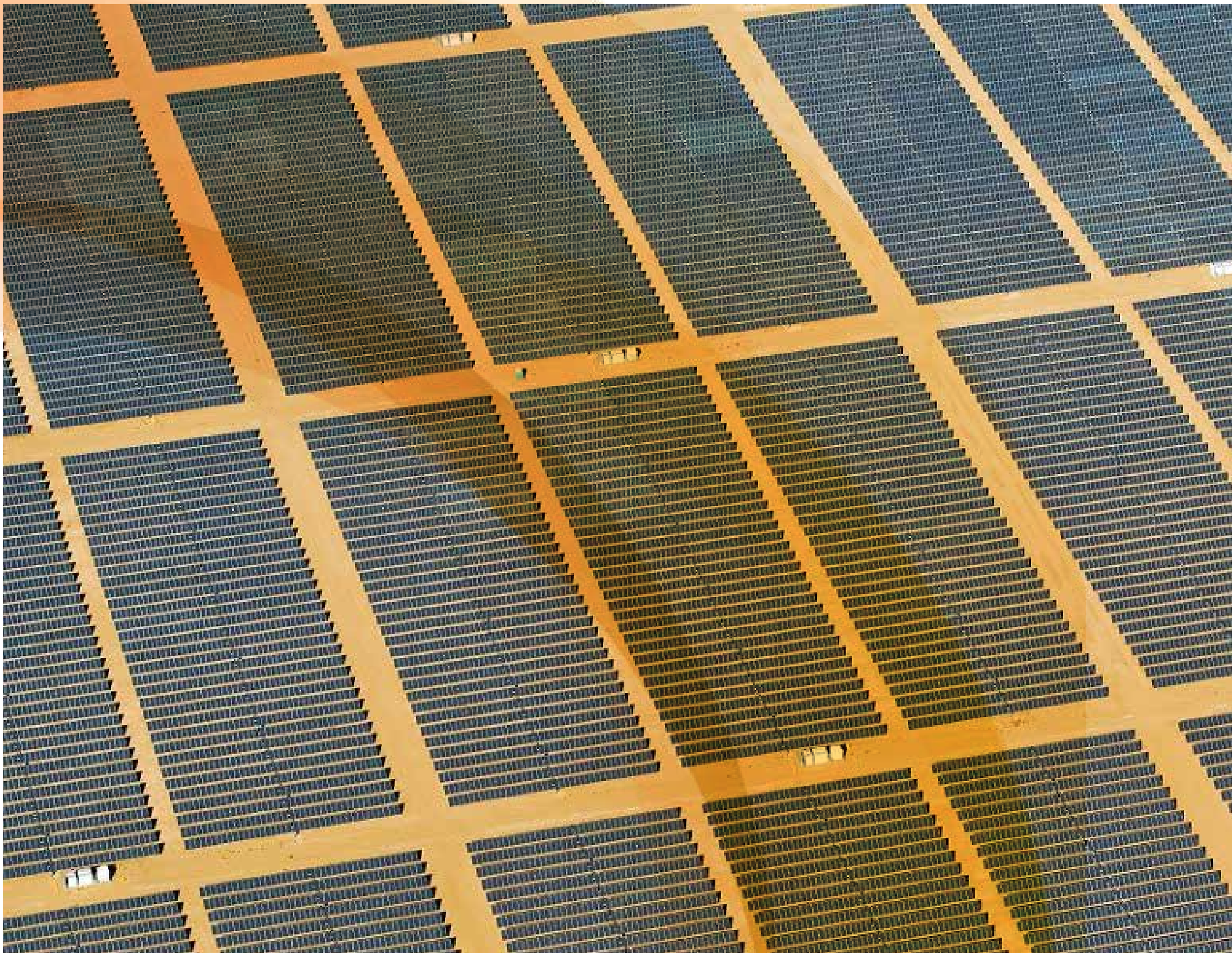
The equipment needed is the same as that required for construction and installation – all of it commonly available in countries with functioning construction sectors.

3. CONCLUSION

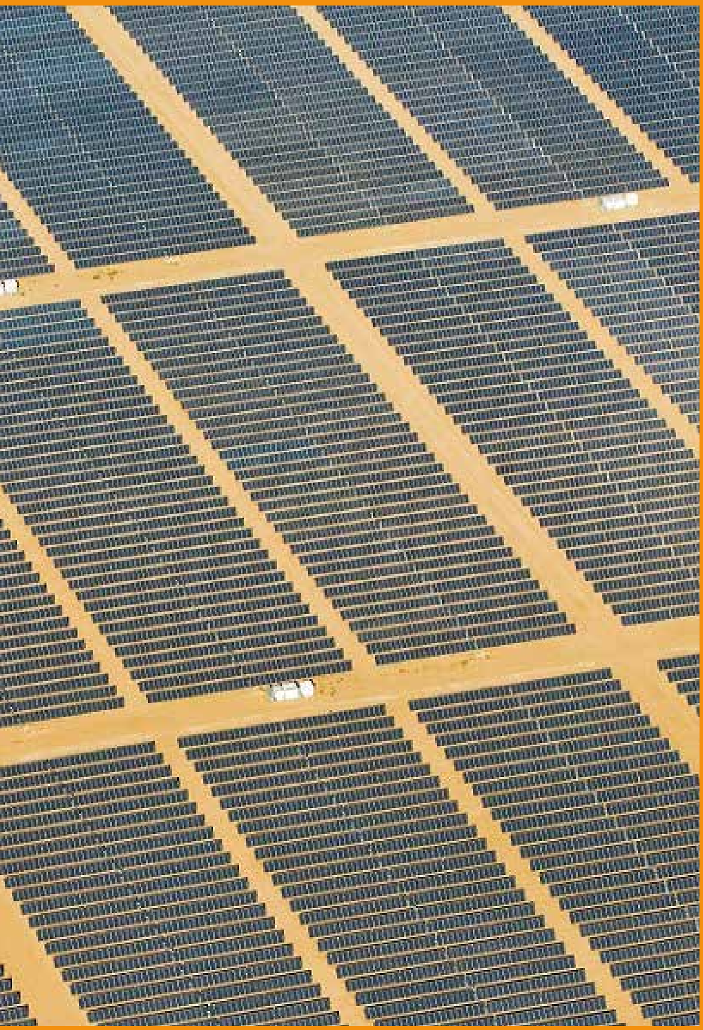
The socio-economic benefits of renewable energy have become a key consideration in building the case for its wide deployment. Increasingly, governments see the potential to fuel economic growth, create employment opportunities and enhance welfare by investing in renewable energy.

Opportunities for domestic value creation can be created at each segment of the value chain, in the form of jobs and income generation for enterprises operating in the country.

To assess the case for domestic industry participation in solar PV development, policy makers need to analyse the labour, materials and equipment requirements of each segment of the value chain. Based on such an analysis, opportunities for leveraging local labour markets and existing industries can be identified to maximise domestic value. Regional and global market dynamics also strongly influence the decision to pursue domestic industry development.



To realise the full range of socio-economic benefits from the development of renewable energy, a conducive environment needs to be established. Should countries choose to support the development of a local industry, a broad mix of policies are required, including those related to deployment and to other sectors of the economy:



- Setting clear targets for renewable energy development provides a long-term view of the market's development trajectory. These are effective when accompanied by suitable deployment policies which provide a stable and predictable environment for attracting investments into the sector.
- To meet the human resource requirements associated with deployment targets, education and training policies would need to consider the skills needs of the solar PV sector which would increase opportunities for local employment.
- To strengthen the industrial capability of domestic firms, policy measures and interventions are needed that contribute to increased competitiveness. Measures include industrial upgrading programmes, supplier development programmes, promotion of joint ventures, development of industrial clusters and investment promotion schemes.
- To ensure the full-fledged development of a nascent industry, policy support should be time-bound and include broader aspects beyond deployment, human resources and industrial development.

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