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Foreword

Welcome to the Solar Sustainability Best Practices Benchmark of SolarPower Europe.

This report, stemming from the collaboration of industry experts in the SolarPower Europe Sustainability Workstream, presents the results of sustainability case studies and best practices along the solar value chain. Following the publication of the industry's first sustainability leadership standard for photovoltaic modules and inverters in 2019 and its inclusion into the EPEAT registry for sustainable electronics, as well as the ongoing regulatory discussions around Ecodesign and Energy Labeling in the European Union, the report takes a closer look at material sustainability and ESG topics in the PV value chain and how the European and international PV industry is addressing them.

This study aims to provide an overview on sectorial best practices, which fill the sometimes abstract frameworks of standards with life and demonstrate that the industry is continuously evaluating and improving approaches to sustainability. This work would not have been possible without the passionate support from the workstream members and other contributors over the last couple of months – starting off beginning of the year with a materiality evaluation and following through with a comprehensive portrayal of case studies and best practices, addressing those topics.

The industry is approaching a critical inflection point, growing into the role of being one of the major pillars of a renewable-based energy system, with Terawatt scale deployment over the next couple of years. With that role comes responsibility and accountability for responsible and sustainable approaches along the environmental, social and economic impacts of the technology. This report presents a first deeper view into currently established practices and should motivate value chain partners to benchmark themselves, with a view to improve and ensure responsibility, transparency and accountability for the sustainability performance of the technology.

Enjoy reading our Solar Sustainability Best Practices Benchmark, which we see as another milestone on the journey to a just and sustainable energy future.



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Sustainability considerations in the solar sector

In 2021, solar energy became the most cost-competitive and versatile energy source globally, and is now positioned in line with the Paris Agreement and objectives of the European Green Deal, to play a leading role in making Europe the world's first climate-neutral continent. According to SolarPower Europe's 100% renewable [study](#), solar electricity could deliver more than 60% of Europe's electricity generation by 2050.

Solar's impressive growth over the past years was also driven by the competitive sustainability profile of solar with high socio-economic benefits, which are inextricably linked to its sustainability attributes.

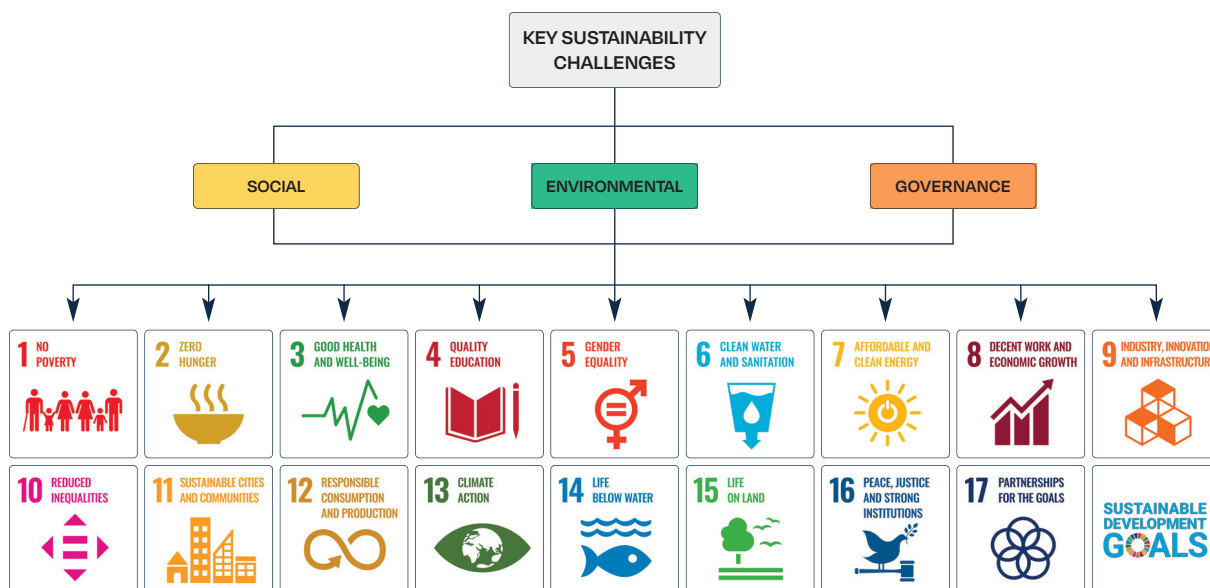
Sustainability is a complex concept. An often-quoted definition comes from the UN World Commission on Environment and Development: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Renewable energies are an accurate response to this concept, because, contrarily to conventional energy generation sources, the production of energy happens without depleting fuel resources. At the same time, renewable energy technologies, like any other product, need to be manufactured. It implies that energy and materials are utilised in the production process. Therefore, a straight-forward approach to improving the solar PV sector's sustainability performance is to minimise energy and material consumption during the manufacturing phase.

"Sustainable development is development that meets the needs of the **present** without **compromising** the **ability** of **future generations** to meet their own needs."

However, looking at the definition of sustainable development presented above, it is clear that the concept of sustainability goes much beyond addressing the sole issues of climate change and material consumption. This is well reflected in the [UN 2030 Agenda for Sustainable Development](#), which in 2015 outlined seventeen Sustainable Development Goals that provide a shared blueprint for advancing sustainability on all scales (Figure 1). The Goals show that sustainability is a multifaceted concept that considers different environmental, social and economic aspects.

For the solar sector, this implies that sustainability considerations need to be made at all levels of the value chain. Considerations must address a variety of areas, spanning from ecosystem preservation and biodiversity impacts, to evaluating decent working conditions, social inclusiveness, and gender equality levels.

FIGURE 1 SUSTAINABILITY CHALLENGES AND THE UN SUSTAINABLE DEVELOPMENT GOALS



"...sustainability is a multifaceted concept that considers different **environmental, social and economic** aspects. "

Throughout the previous decades solar had an exponential growth trajectory and in the coming years solar will conceivably continue this pathway towards multi-Terawatt scale deployment. Against this backdrop, material and energy supply chains, manufacturing capacities, PV project development and lifecycle management practices increasingly receive more attention from stakeholders in terms of sustainable performance details.

Indicators for this higher degree of attention include an increase in Environmental, Social and Governance (ESG) surveys that are deployed to technology manufacturers as part of technical and financial due diligence during procurement, and more generally, also includes an increase in transparency and benchmarking activities.

Additionally, regulatory initiatives, such as the European Commission [Preparatory study](#) for Eco-Design, Ecolabeling, Energy Labeling and Green Public Procurement, recommend introducing policy instruments to further improve the environmental, energy and socio-economic performance of photovoltaic modules, inverters and systems.

Acknowledging the importance of ESG considerations, over the last years, the industrial, financial, and scientific community involved in the solar value chain responded to these requirements, developing comprehensive frameworks to measure and report on the sustainability performance of PV systems on a lifecycle basis. The subsequent chapters in this report illustrate the standards that have been developed over the last years, providing a comprehensive overview as well as identifying potential gaps and improvement opportunities.

As the industry enters its next growth phase, propelled by the underlying economics of PV deployment as the most cost-effective electricity generation technology in most of the world's regions, a more granular focus on sustainability performance is necessary. It is an essential pillar for supporting the evolving regulatory

and non-regulatory framework conditions to decarbonise the economy further and attain the Sustainable Development Goals.

Methodology and scope

The objective of this report is to identify state-of-the-art sustainability practices in the solar PV industry and showcase them as benchmarks, to support the whole PV sector's sustainability performance and to drive overall sustainable change.

This objective is articulated in three sets of actions. The first objective is to identify key sustainability challenges in the solar industry; the second step is to collect good practices and approaches to address these challenges; the third step is to identify hands-on examples that apply such good practices, with the aim of encouraging other players to implement them too.

The chapters included in this report look at different sustainability areas associated with the solar PV sector. Following a brainstorming exercise, SolarPower Europe's Sustainability Workstream members indicated the top sustainability priorities in the industry, according to them. Thanks to this process, it was possible to identify which sustainability areas, industry players perceive as the most crucial and which areas require further action.

The sustainability areas addressed in this report are the following:

- Carbon footprint (Chapter 1)
- Circularity (Chapter 2)
- Sustainable supply chain (Chapter 3)
- Biodiversity in large-scale solar (Chapter 4)
- Planning and designing for public acceptance (Chapter 5)
- Human rights (Chapter 6)
- Supply chain transparency (Chapter 7)

Each chapter has a formalised structure. Firstly, we define the **Context and Background**, providing a description of the specific sustainability issue, explaining why it is relevant to the solar PV sector, and introducing the current state of knowledge. Secondly, **Approaches and best practices** are addressed, detailing the available sets of action and initiatives for this specific sustainability challenge. Thirdly, several **Case studies** are outlined, illustrating the implementation of best practices in current, real-world applications.

The full solar PV value chain is long and complex, with different actors throughout the lifecycle dealing with many different sustainability aspects. It spans from raw material extraction and processing at the upstream level, through manufacturing, transport and distribution, construction and installation, operation and maintenance during the use phase, all the way to end-of-life considerations during the termination of the product lifetime. Therefore, certain crucial sustainability aspects for certain players might be less relevant for other players. But some sustainability aspects are deemed important for the whole value chain. This report considers the entire value chain, at times highlighting specific lifecycle processes and on other occasions making more general conclusions.

With this first report ever on Solar Sustainability we hope to actively contribute to the position of the European solar sector as a sustainability leader, and to further transition our companies and businesses towards state-of-the-art sustainability best practices.

1

Carbon footprint

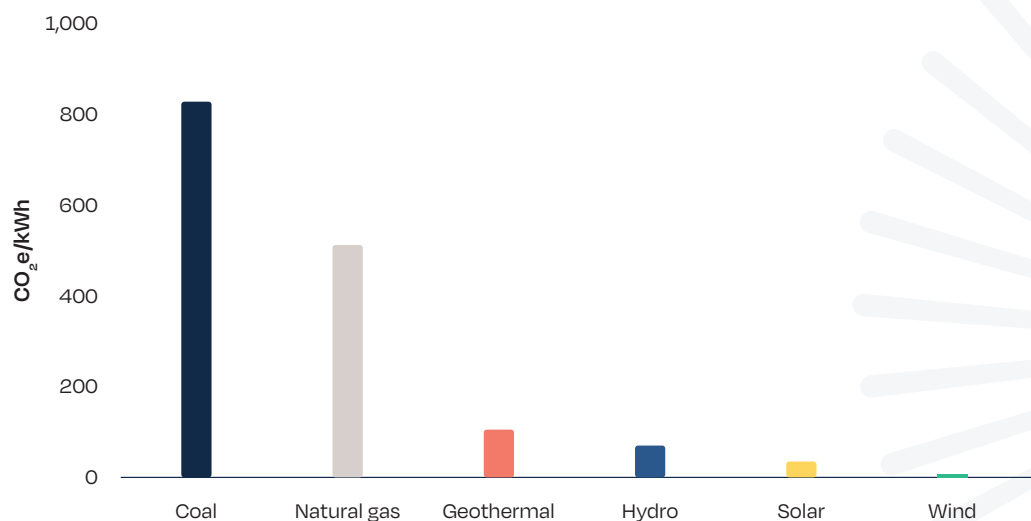
1.1. Context and background

Solar PV's main sustainability contribution is to decarbonise electricity generation and thus achieve the United Nation's Sustainable Development Goals (SDGs), particularly the Goal 13 on "Climate Action".

Considering the greenhouse gas emissions generated throughout its life cycle, solar produced about 96%

less GHG emissions than coal and 93% less than gas in 2010 (Figure 2). Solar PV is poised to become one of the main pillars of the world's future energy supply. Without solar, reaching the Paris climate goals is simply not possible. For this reason, PV technology must be rapidly deployed and solar will continue its global success story.

FIGURE 2 AVERAGE LIFECYCLE CARBON EMISSIONS OF ENERGY GENERATING TECHNOLOGIES IN 2010



Simple averages of 2010 values. Solar carbon emissions have further decreased ever since. SOURCE: UNEP (2016).

1 Carbon footprint / continued

However, although solar is one of the least carbon intensive and most cost-efficient alternatives to fossil fuel generation, solar does not come without a carbon footprint. With over 700 GW of cumulative capacity installed by the end of 2020 and future installed volumes that may reach the range of several hundreds of GW annually, it is essential to lower the carbon footprint of solar PV even further. Over the last decades the solar industry has already been very successful in reducing GHG emissions, and further progress is anticipated.

Recently, various stakeholders focused their attention and effort on further reducing solar's footprint. Some jurisdictions have already imposed reporting requirements or rating systems that reward low carbon solar. Several more stakeholders are considering doing the same. The different measures focus primarily on modules, as these account for most of the PV carbon footprint.

France requires a carbon footprint calculation for modules participating in public tenders for several years. Modules with low footprints can collect bonus points and thus afford higher electricity price bids. In 2020, South Korea introduced a similar system.

The European Union is also preparing for the introduction of Ecodesign and Energy Label for PV modules, inverters and systems, which will include carbon footprint information requirements. Consequently, carbon footprint reporting will most likely become mandatory for all modules and inverters placed on the European market. SolarPower Europe is actively engaged in finding solutions that help solar achieve its sustainability goals. In addition to this, a number of front-runners such as the Netherlands and Norway have introduced environmental product declaration requirements (EPD) for PV modules, which include carbon footprint reporting.

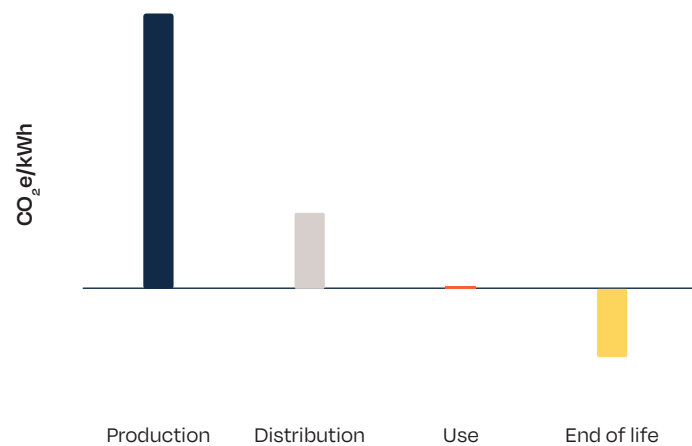
"...the **carbon footprint** per kWh of solar electricity is dominated by the GHG emissions at the **component manufacturing level**, including the manufacturing of the materials used in PV products."

Carbon footprint initiatives are not only coming from policymakers, but also very much driven by the industry itself. The Global Electronics Council recently [announced](#) the ongoing development of an Ultra-Low Carbon Solar designation, combined with the already existing EPEAT ecolabel.

Reducing a solar carbon footprint requires understanding the sources of GHG emissions over the whole solar value chain, identifying all hotspots. Several studies have shown that the carbon footprint per kWh of solar electricity is dominated by the GHG emissions at the component manufacturing level, including the manufacturing of the materials used in PV products. Emissions associated with the distribution phase, such as the transportation of PV products to their destination, are smaller, yet relevant, whereas emissions at the planning, construction, installation and operating stages are negligible. Dismantling end-of-life systems does not generate significant GHG emissions either. Rather, it offers the possibility to reduce the carbon footprint by recycling components and materials. An overview of the typical allocation of PV carbon emissions over the lifecycle of the product is shown in Figure 3.

"Carbon footprint initiatives are not only coming from policymakers, but also very much **driven by the industry** itself. "

FIGURE 3 ALLOCATION OF PV CARBON EMISSIONS OVER PRODUCT LIFECYCLE. BASE-CASE UTILITY-SCALE PV SYSTEM (DATA BASED ON 2014 VALUES)



Base-case utility-scale PV system. Data based on 2014 values. End-of-life emissions are negative thanks to the carbon credits granted by recycling the materials. SOURCE: JRC (2019).

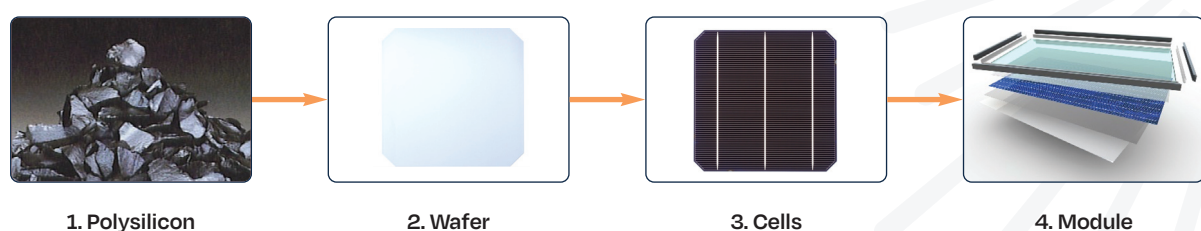
Considering all components of a whole PV system, module production clearly contributes the largest share of carbon emissions, while a smaller fraction is associated with inverter production. Therefore, this chapter will mainly focus on the manufacturing of silicon-based modules which constitute around 95% of the global solar market. An overview of the typical module production is shown in Figure 4.

The manufacturing of silicon-based modules starts with the production of high-quality polysilicon, the feedstock material used in solar cells (1). Producing the hyper-pure silicon needed for high efficiency cells is an energy intense production step and thus a major

contributor to the solar carbon footprint. It starts with mining quartz (SiO_2), converting quartz chunks into metallurgical grade silicon (MG-Si) – 98-99% pure silicon – and purifying the MG-Si into hyper pure polysilicon suitable for solar production. Highest purities are obtained with the so-called Siemens process, which has become the workhorse of the industry. Both MG-Si production and the Siemens process consume large amounts of electricity and generate the bulk of carbon emissions.

Polysilicon is used as a feedstock for growing solar ingots, which are then cut into wafers (2). Growing solar ingots is an energy intense process too, due to

FIGURE 4 OVERVIEW OF THE TYPICAL SOLAR PV PRODUCTION PROCESS



1 Carbon footprint / continued

the electricity demand for heating the crucibles. Again, the footprint of the electricity used has a major impact on the overall GHG emissions.

The next step processes wafers into individual solar cells (3). The industry put a strong focus on increasing cell efficiency while maintaining or even decreasing carbon footprint.

Lastly, cells are assembled and packaged into solar modules (4), a multi-layered structure that comprises a front glass cover and a polymer backsheet or a back glass cover, two polymer-based encapsulant layers, and the interconnected solar cells matrix in the middle. Aluminium frames are generally used to support the module structure. In addition to the carbon footprint embedded in the cells that has been described so far, significant GHG emissions are associated with the most energy intensive materials that are used as components, such as aluminium and glass.

1.2. Approaches and Best Practices

Solar PV carbon emissions can be reduced primarily through the following approaches:

- 1. Consume as little energy as possible in the manufacturing process.** Provided that the largest share of emissions take place at the production phase, reducing the electricity consumption in the production of polysilicon has the largest impact on the whole lifecycle emissions. Overall good practices include a well-designed reactor, optimised processes, and closed loop operations, such as internal recycling of all materials and energy reuse.
- 2. Use low carbon electricity in the manufacturing process.** Similar to the considerations on energy efficiency, using low carbon electricity (optimally renewable energy) significantly reduces the carbon footprint of manufacturing. One way to use low carbon electricity is to establish production facilities in countries with low carbon energy mixes. Against this background, several European countries have a great advantage compared to the rest of the world in terms of their electricity mixes. Another viable and increasingly successful approach is the procurement of renewable electricity for the manufacturing process. A number of vertically integrated solar module manufacturers have already [committed to sourcing 100% renewable electricity](#) over the next

decade to effectively address this hotspot, including LONGi Solar, Jinko Solar and First Solar.

- 3. Minimise the use of carbon-intensive materials.** Components such as aluminium, glass, and silicon have high carbon intensity. Reducing the amounts of these components used in PV products can reap large benefits in terms of carbon emissions. Good practices include increasing module efficiency to reduce specific consumption per Watt, reducing solar wafer thickness and promoting internal recycling of materials such as silicon. At the same time, these components should be manufactured in so that their embedded carbon emissions are as low as possible.
- 4. Minimise emissions from transportation.** The shipping of PV products globally causes relevant carbon emissions. On the one hand, these impacts can be minimised through the use of low carbon means of transportation, such as rail transport, and optimised logistics. On the other hand, avoiding long-haul transportation of PV products altogether is also an effective measure to reduce the carbon footprint. For Europe, this would mean building up a strong local PV manufacturing base along the full value chain from polysilicon, through ingots, wafers and cells, to modules and balance-of-system components.
- 5. Prioritise PV system locations where it enables the highest emission reductions.** Solar PV electricity replaces the electricity that would come from the national grid. In this sense, the net benefit of using solar electricity is higher when it substitutes carbon intensive electricity. By extension, installing a PV power plant in a country with a carbon intensive energy mix provides a larger reduction of emissions, compared to installing the PV power plant in a country whose carbon intensity is already low. Using the same reasoning, selecting PV products with the lowest carbon footprint grants the largest net carbon reductions. A 2020 study by [Watttime](#) explores how these two factors can determine the impacts of solar projects.
- 6. Maximise recycled content.** PV products contain energy intensive materials like silicon, glass and aluminium. High quality recycling of solar glass, aluminium frames and silicon from end-of-life modules enables the recovery of these materials, which do not have to be sourced through carbon intensive production processes. Generally, enhancing

product circularity at all levels (see Chapter 2) contributes to better carbon footprint performance.

7. **Extend product lifetime and increase energy yield.** Considering that carbon emissions stemming from the use phase are close to zero, the longer a PV product will last, the more the carbon footprint from the manufacturing phase can be diluted throughout its total lifetime. Similarly, improving PV efficiency and the resulting energy yield implies that more electricity is produced with the same carbon footprint. Therefore, extending product lifetime beyond thirty years and achieving higher efficiency enables an even lower CO₂e/kWh ratio.
8. **Consider carbon emissions from non-module components.** Even though modules are responsible for the largest share of solar's carbon footprint, it is important to look at the performance of PV elements such as inverters and other balance-of-system components.

1.3. Case studies

1.3.1. Polysilicon

Reducing emissions from high-quality polysilicon production

As explained above, large amounts of electricity are consumed in the MG-Si production and the Siemens process. The reduction of GHG emissions associated with this production step can be achieved through the reduction of specific electricity consumption and by using greener electricity. **WACKER**, the largest European polysilicon manufacturer, produces MG-Si in Norway deploying low carbon footprint hydropower. **WACKER** has reduced the specific energy consumption of polysilicon production by about 50% over the last 15 years and is leading in specific energy consumption for Siemens worldwide with its integrated polysilicon production sites in Burghausen, Nünchritz (both Germany) and Charleston (TN, United States).

Reducing emission from alternative approaches to low carbon footprint polysilicon

WACKER has the leading quality feedstock and best in class carbon footprint as far as Siemens material is concerned. At the same time, in the past few decades some industry players developed alternative routes to solar grade silicon.

REC Silicon in the US and **GCL** in China use the so-called Fluidised Bed Reactor (FBR) process to produce granular polysilicon. This technology reduces energy consumption to about 50% of the typical Siemens process.

REC Solar Norway purifies MG-Si with an alternative process to the typical Siemens process, which reduces the energy consumption up to 75%. This polysilicon is used in the production of high performance multi-crystalline ingots at 100% blend-in ratio. In recent years, the product has been adapted to also be compatible with high quality mono-crystalline ingot production at high blend-in ratios. From 2021, the company has replaced MG-Si with wafering fines and other recycled material from the PV value chain as silicon feedstock, further reducing the energy consumption of the process by a factor of 2-3. This leads to the lowest footprint for solar-grade silicon production. It is also the most significant step in making the PV industry circular in the history of PV. The many possible entry points of recycled content of different quality makes the **REC Solar Norway** process unique in this regard. Introducing recycled content from high-purity silicon from the PV value chain also allows one to develop products for advanced mono-crystalline solar cell production.

1.3.2. Wafers

Optimising solar ingot growing and wafering

Regardless of the specific module technology (multi-crystalline or mono-crystalline), growing solar ingots requires large amounts of electricity to heat the crucibles to melt and solidify polysilicon. The leading ingot growers, now mostly located in China, have reduced the energy intensity of the process by growing the ingots faster and by applying "multipulling", i.e., refilling the hot crucible and growing several ingots without cooling down the crucible in between. To reduce the carbon footprint associated with the large electricity consumption, the biggest European mono-crystalline wafer manufacturers **Norwegian Crystals** and **Norsun** both produce in Norway using hydropower and thus achieve a very low carbon footprint for their products.

Solar ingots are subsequently cut into wafers by wire sawing. The industry has significantly reduced the carbon footprint of solar wafers over the last two decades by reducing the standard wafer thickness from around 400 µm to about 170 – 180 µm. During

1 Carbon footprint / continued

this process, over 30% of silicon is typically lost (the so-called “kerf”). For the sawing of the wafers, switching from slurry-based to diamond-based wire sawing reduces the kerf loss by 30%.

Internal recycling of silicon has now become standard for solar ingot manufacturers. Non-usable parts of the solar ingots and other silicon residues are mostly used to grow new ingots. However, the next step for reducing the carbon footprint further is replacing a part of the virgin silicon feedstock with recycled silicon waste from manufacturing steps further down the value chain. REC Group subsidiary **REC Solar Norway** recently reported a significant silicon feedstock footprint reduction by using recycled silicon kerf (see more details in Chapter 2).

The sum of above-mentioned activities together with the continuous increase in solar cell efficiency has dramatically reduced the industry's specific silicon feedstock consumption from 15 grams of silicon per Watt of module power about 15 years ago to less than 3 grams per Watt today.

Kerf-free wafering technologies

Directly solidifying liquid silicon as wafers, skipping the process of ingot growing, offers the potential to further reduce silicon consumption and energy, thus reducing the carbon footprint. **1366** in the US has invented a process that directly creates multi-crystalline wafers from molten polysilicon. **NexWafe** in Germany is going one step further: mono-crystalline wafers are directly deposited from a mixture of chlorosilane and hydrogen in a process that grants additional savings in the energy intense polysilicon deposition step. However, both companies are in a start-up phase, and large-scale feasibility and competitiveness still need to be proven.

1.3.3. Cells

Increasing solar cell efficiency while reducing electricity consumption

Increasing the efficiency of a solar cell while maintaining or even decreasing the carbon footprint of the cell and all other components is a universal approach to lower solar emissions. Increasing the cell efficiency while maintaining the same electricity consumption reduces the carbon footprint per power unit.

There are several cell technologies currently available on the international market offering very high efficiency while maintaining or even reducing the electricity consumption during the production processes. For example, heterojunction cell technology (HJT) is foreseen to become one of the most promising cell technologies in the short-term. HJT cells are a highly advanced hybrid cell design structure that combines the advantages of crystalline silicon cells and thin-film technology for high efficiency and power density. The advanced production processes mean there are fewer production steps and no high temperature (800°C) firing of cells is required, saving a huge amount of energy and reducing the overall environmental impact. HJT based modules are offered by European PV players like **REC Group**, **Meyer Burger** and **Enel Green Power – 3 SUN**.

Other high efficiency technologies are under development, like perovskite technology or multi-junction cells. But these are not yet ready for commercialisation. The mass market entry is likely still some years out. All mentioned innovative cell technologies hold the potential to further reduce the carbon footprint of solar cells.

1.3.4. Modules

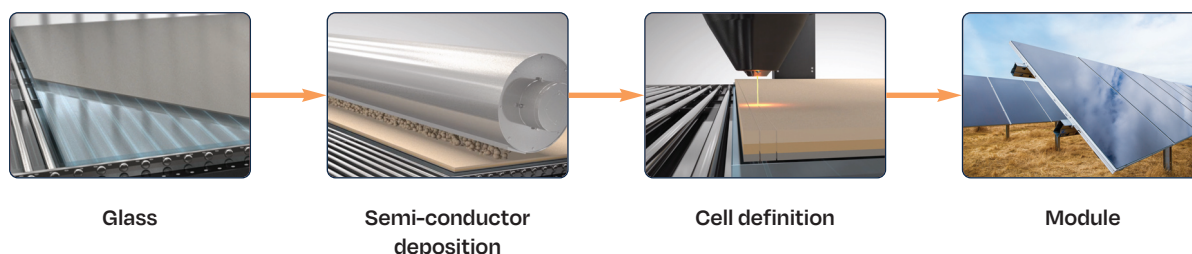
Optimising solar module production

New technological developments at the module production level enable a substantial carbon footprint reduction of the final PV product. One trend are larger wafers to produce higher efficient solar modules, or using half cells to improve the power output of panels. Another example is the removal of the soldering process used to connect the cells together. A technology used by **REC Group** eliminates the soldering points to connect the cells, and instead utilises a transparent foil that includes thin wires allowing the electrical connection between the cells. This reduces the temperature level of the production process and decreases the electricity consumption and, in turn, the carbon footprint. Another advanced module technology, shingling, also foregoes ribbon as the cells are laid in a module like shingles on a roof, and connected using electrically conductive adhesives.

Low carbon thin-film solar

In parallel to typical silicon-based PV products, an example of low carbon PV solutions are thin-film solar

FIGURE 5 OVERVIEW OF THIN-FILM PV SUPPLY CHAIN



SOURCE: First Solar.

technologies, which provide around 5% of today's global module market. Thin-film PV uses alternative semiconductor layers directly deposited on the glass substrate in extremely thin layers (Figure 5). Due to integrated high energy and material-efficient manufacturing technologies, only a fraction of the semiconductor material is required to produce solar modules at the same conversion efficiencies. Furthermore, a much lower amount of energy is needed for the upstream processing of the raw materials.

Thanks to these features, thin-film PV lifecycle emissions are significantly lower than in silicon-based PV products.

1.3.5. Transport

Promoting local PV manufacturing

How large solar component manufacturing can be re-established in Europe is a complex topic that has been discussed at national and EU levels for a long time. Despite an absence of major large PV wafer, cell and module manufacturers in Europe, the continent still leads in terms of quality and innovative technologies (polysilicon, wafers, cells) that will make the future of solar PV, thanks to a dynamic research and development ecosystem. The technological advance of Europe, coupled with important domestic solar PV market perspectives, has led to renewed investments into new industrial projects across Europe. This is probably one of the next steps towards an even lower carbon footprint on PV products in Europe, to use more products that are made close to their final place of deployment.

Against this background, SolarPower Europe and other partner associations launched in 2021 the [European Solar Initiative](#), which aims at scaling up the solar PV industrial ecosystem in Europe by 2025. This initiative, anchored to the Industrial Strategy presented by the European Commission, has the objective of reaching a 20 GW annual cell production capacity by 2025, from a few hundred MW today. Creating a local industrial ecosystem would generate benefits not only in terms of reduced transport, but also in terms of circularity (see Chapter 2).

1.3.6. Inverters

Improving inverter carbon footprint and extending lifetime

In parallel to the considerations at module level, another component that should be considered for its carbon footprint is the PV inverter. Even though the inverter causes only a small share of total PV carbon emissions, it is nevertheless an essential element with its own challenges, especially at the end-of-life stage. Scientific environmental analyses highlight various measures to decrease the carbon footprint of the inverter even further.

First, certain inverter components – such as some plastic elements, electronics, or aluminium if it is used – can come from energy-intensive processes. A better understanding of the supply chain, with more data, traceability and guarantees may provide opportunities to decrease the carbon footprint.

1 Carbon footprint / continued

Second, repair processes or on-site exchanges of components can extend the lifetime of the inverter or decrease the need to replace the whole device. In this regard, the inverter should be designed to facilitate repair or exchange thereby limiting the need for new materials and lowering the carbon footprint.

Third, recycling strategies should also be considered. In some cases, inverters are already covered by existing norms, but differentiations may occur based on the power-capacity/size of the inverter. Furthermore, as the inverter is a complex electronic device, there are opportunities for material recovery that should be more developed or implemented (see Chapter 2).

Austrian inverter manufacturer Fronius conducted a reviewed lifecycle assessment on its product family Fronius GEN24 Plus that showed the important role of the supply chain in embodied emissions. In order to decrease its carbon footprint, more than 90% of recycled aluminium is being used in the main metallic component of the inverter.

Besides, Fronius offers repair options for its inverters. With the GEN24 Plus, it is possible to exchange the fan, the data communication unit (both on-site), 4 varistors on the power stage set and/or the replacement of the complete power stage set (both at the Fronius International Repair Center). These repairs avoid replacing the whole inverter, thus decreasing the need for new raw materials, and can even extend the life service of the product.

Finally, some discussions are currently underway to improve the end-of-life management process of the inverters. The life cycle assessment results will be further reused in the Fronius product development process to develop solutions that will benefit not only customers but also the environment.



2

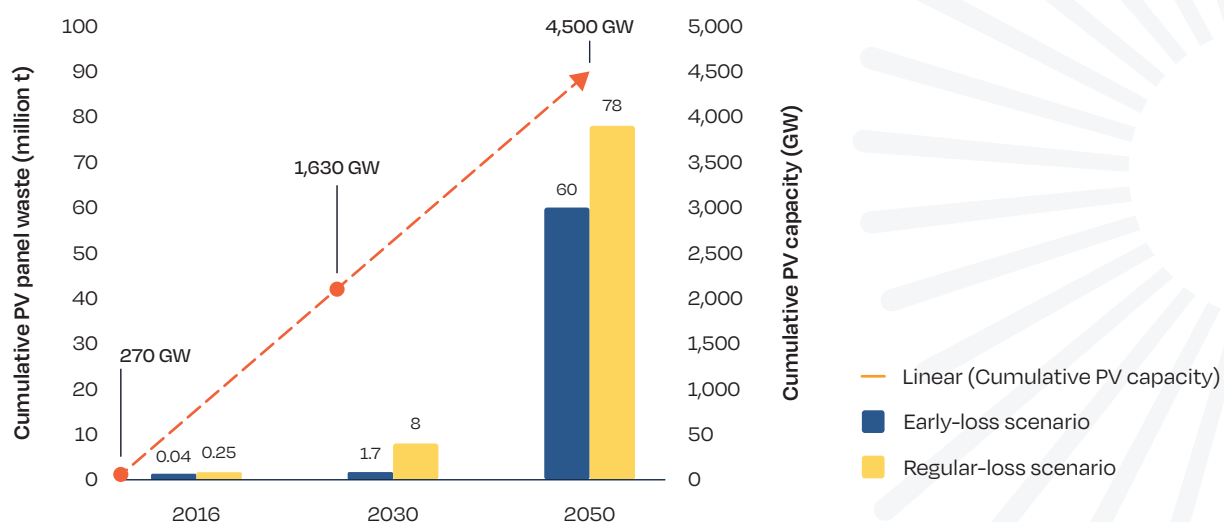
Circularity

2.1. Context and background

The rapid growth of the solar industry is an exemplary case study for the potential of renewable energy and was significantly enabled by innovative industrial solutions to reduce cost and increase product performance. With average product lifetimes of about thirty years, the solar industry in Europe – which is a young industry – has not yet been facing waste streams justifying a proactive integration of circular economy requirements. Nevertheless, solar product and component manufacturers have been constantly looking into ways to increase the recyclability or end-of-life management of their products.

Thanks to the long lifetime of PV products, today the ratio between modules reaching their end of life and modules annually installed is lower than 1%. However, this challenge is set to arise in the medium and long term, with the PV waste stream growing considerably after 2030 and eventually reaching installation levels. Some estimates suggest that cumulative PV waste could amount to as much as 8 million metric tonnes by 2030 and 60-70 million tonnes by 2050, equivalent to 3-16% of total e-waste produced annually today (Figure 6). To match the growing volume of PV module waste in Europe, even before it accelerates around 2030, expansion of dedicated PV recycling capacity will be needed.

FIGURE 6 OVERVIEW OF GLOBAL PV WASTE PROJECTIONS (DATA FROM 2016)



SOURCE: IEA-PVPS and IRENA (2016).

"Thanks to the long lifetime of PV products, today the ratio between modules reaching their end of life and modules annually installed **is lower than 1%.**"

The traditional "take-make-use-dispose" model is in a transitional phase towards a circular model. Yet, the EU has been a global front-runner to ensure that the solar sector abides by high circularity standards. Legislative measures in the form of Extended Producer Responsibility, Ecodesign, Design for recycling requirements promote this transition. In the EU, PV modules are under the scope of the Waste Electrical and Electronic Equipment (WEEE) Directive (2012/19/EU) and out of scope of the RoHs Directive 2011/65/EU. Inverters are also under the scope of the WEEE legislation.

Most of the materials contained in a PV module are common materials, such as glass, aluminium and plastic. Currently, solar modules at their end-of-life stage are processed in existing recycling plants for glass or metals. Mechanical processes are typically used to separate the materials. Technical recycling yields of up to 90% by weight are obtained, mostly comprising of aluminium frames and glass. Energy is also recovered from the incineration of the plastic fraction.

Therefore, while the largest bulk of materials present in a PV module are already undergoing treatment and recycling, solar's key circularity challenge involves recovering the small fractions of valuable materials.

"...while the largest bulk of materials present in a PV module are already undergoing treatment and recycling, solar's key circularity challenge involves **recovering the small fractions** of valuable materials"

Thanks to the existence of various solar technologies, solar power can be generated economically using different natural resources and materials. However, PV technologies make use of different types of limited resources, among which silver, zinc, tellurium, indium and gallium, and the recovery and reuse of these materials (particularly silver and indium) is critical for producing the desired quantity of solar cells in the coming years.

Although there is undoubtedly more to do for transitioning to circular product design and service models, there are numerous cases where the solar industry is addressing the challenges head on and in many cases where Europe leads the world in the adoption of these initiatives.

2.2. Approaches and Best Practices

With limited supplies of end-of-life modules, fluctuating raw material prices and high cost of transportation, the business case for large scale module recycling has not been clear-cut. The main factor challenging the development of a full-fledged solar recycling industry is the long lifetime of the product itself. With an expected lifetime of thirty years, solar products prevent post-consumer waste for a prolonged period. In this perspective, extending product lifetime would enable further waste prevention on top of the carbon footprint benefits described in Chapter 1.

In the European Waste Hierarchy, prevention of waste is the preferred circular activity, followed by re-use, product recycling, material recycling, incineration with energy recovery and disposal in landfills as the least preferred option. In this chapter, possible approaches have been clustered into three main categories:

1. **Circular practices at the manufacturing phase.** At the module and inverter production level, overall good practices include considerations in terms of design for recycling, repairability, dismantlability, and disclosure of materials contained in the product. At the design phase, it is worth exploring the viability of choosing materials that are easier to treat and recycle compared to their alternatives, and that do not contain hazardous substances. Intuitively, many practices aiming to reduce carbon footprint at the manufacturing stage, presented in Chapter 1, also have positive impacts on circularity.

2. **Optimised collection and recycling practices.** While end-of-life management of PV products already attains good yields, industry forerunners are exploring practices to achieve even higher yields, with special efforts to recover the most valuable materials contained in PV products. Regarding collection of end-of-life products, while in most EU countries the process already runs effectively, in a few Member States the situation can be improved. To this end, as highlighted in a recent [white paper](#) from the German environmental NGO DUH, PV module manufacturers should provide clear and concise information on the collection of end-of-life modules. When municipal collection points are used for gathering solar modules, one might consider standardising the collection process across collection points, as well as training on-site workers on handling PV modules correctly. For modules coming from large-scale PV systems, the provision of take-back services in proximity to the end-of-life installations should be made possible in accordance with the provisions of the WEEE Directive – collection and proper treatment and recycling could be incentivised through standardised approaches on decommissioning cost bonds and solid financial guarantees for utility and commercial installations.
3. **Reuse and repair practices.** Reusing, retrofitting, and repairing PV products can reduce costs, improve energy output, and extend lifetime, thus lowering the overall environmental footprint. The preparation for reuse and reuse market for second life PV panels shows interesting potential. But at present it is largely unregulated and requires guidelines and standards detailing the minimum requirements to classify PV products for potential reuse, sorting, testing and technical and safety requirements.

With regard to circularity, significant progress has been made across the EU market although it is clear that more needs to be done and support is needed from policy and inspection bodies to aid these advances. The European Commission is currently working to implement a combination of mandatory and voluntary policy instruments – such as Ecodesign measures for PV modules, inverters and systems – to improve the quality, durability and circularity for PV products in Europe and beyond. The proposed policies focus on issues such as the reparability and dismantlability of modules as well as calling for clearer

The European Commission is currently working to implement a combination of **mandatory** and **voluntary** policy instruments – such as Ecodesign measures for PV modules, inverters and systems – to improve the **quality**, **durability** and **circularity** for PV products in Europe and beyond.

disclosure of hazardous materials to aid future re-use and recycling processes. These developments are widely welcomed by the solar industry.

2.3. Case studies

SolarPower Europe supports the European Commission's recently launched Circular Economy Action Plan (CEAP). The CEAP announced initiatives along the entire life cycle of products, targeting for example their design, promoting circular economy processes, fostering sustainable consumption, and to ensure the resources used remain in the EU economy for as long as possible. The following case studies show some of the best-in-class examples from the European solar industry, focusing on delivery of the sustainability principles laid out in the CEAP and highlighting what can be achieved when the industry comes together to reach common goals.

2.3.1. Circular practices at manufacturing phase

Halogen-free backsheets addressing the presence of hazardous chemicals

Backsheets are a critical part of module design, playing an important role in protecting the module throughout its lifetime. Solar backsheets can make up to 10% of the total module weight. The first solar modules used fluorinated materials in the composition of the backsheet, and today this remains the most common solution globally. Fluorinated substances are hazardous materials that create a risk of leakage into the wider environment and have significant financial and safety consequences for the scalability of module recycling.

The European market has led the transition to halogen-free backsheets, using full PET or polyolefinic backsheets that contain no fluorinated substances. A vibrant European manufacturing base of material producers, film converters and module manufacturers such as **Coveme**, **DuPont Teijin Films** and **DSM Advanced Solar** now leads the way globally in the use of these technologies, in line with the EU's vision of "safe-by-design chemicals" being used as substitutes for hazardous substances. Halogen-free backsheets significantly reduce the amount of hazardous materials in PV modules, offer a significantly lower carbon footprint, reduce end-of-life waste-to-energy incineration costs and enable closed loop recycling of both industrial as well as post-consumer waste. With most of EU module manufacturers using halogen-free backsheets, this makes an excellent case study for how the right product selection can help deliver the EU's sustainability principles.

However, with over 80% of module demand in Europe being supplied by imports, most modules installed still contain halogenated backsheets. In 2017 Fraunhofer UMSICHT published a [report](#) which carried out a lifecycle assessment of end-of-life treatment pathways for PV backsheet. The report concluded that the use of fluoropolymers or halogenated polymers in PV modules should be avoided, and if halogenated backsheets are used, they must be properly marked or labelled.

Lead-free PV modules

Even today, a solar module typically contains a small amount of lead in relation to its total weight. Lead is a toxic material found within the ribbon coating and the soldering paste that connects cells together. Given the fact that lead is entirely sealed within the module materials, it is unlikely to become a relevant source of pollution, even considering a worst-case scenario in which end-of-life modules are landfilled. In spite of these low risks, industry forerunners have developed lead-free alternatives that eliminate challenges of recycling the material when modules reach the end of their service life. In its latest module series, **REC Group** has eliminated lead from all module components, including cell connections, cross connectors, and junction box soldering. Eliminating lead from all components not only enhances the circularity of the product, it also enables a minimal environmental footprint.

Recycled content for silicon wafers

In 2020, **REC Solar Norway**, a subsidiary of REC Group, started a silicon kerf recycling process, which constitutes the first full scale production of wafers based on 100% recycled kerf. This approach combines new innovative kerf processing steps with parts of the existing metallurgical route. According to REC Solar Norway, the energy consumption is less than 25% of the conventional process and the environmental impact is less than 7% of the conventional process.

2.3.2. Optimised recycling

Advancements in PV waste separation, purification, and recycling

CABRISS is a joint initiative of 16 European companies and research institutes and has received approval from EU's Horizon 2020 Research and Innovation Framework Programme. The aim of the project is to develop a circular economy for photovoltaic, electronic and glass industries from materials obtained from solar modules.

Since 2015, CABRISS have developed methods to separate, purify and recycle PV waste from manufacturing and end-of-life modules. The project has demonstrated that over 95% of materials like silicon, aluminium, silver, indium and ethylene vinyl acetate (EVA) from both silicon-based and thin-film modules can be recovered.

Research from the project has been used by CABRISS partners to use recycled silicon to produce modules with efficiencies up to 18.5%. The project partners have also suggested uses of recycled silicon in markets such as batteries, silicon-based alloys, and hydrogen production. Partners have also developed technologies to obtain silicon substrates and ingots from the hot-pressing of kerf, and research has been completed into the development of conductive inks and pastes using recycled silver.

Europe's flagship crystalline silicon recycling facility

In March 2017, **Veolia**, in partnership with **PV CYCLE France**, launched the first dedicated PV module recycling line. The recycling line, based on the technology developed in the R&D Project PV MOREDE, treats crystalline silicon modules, and is located in Rousset, in the Bouches-du-Rhône region.

The initial capacity of this line was 1,800 tonnes per year, growing up to 4,000 tonnes per year by 2022, with a reported 95% recovery rate. Waste streams are separated into fractions and sold to end-markets, with glass, aluminium, silicon, ferro and non-ferro metals all finding a new life in new materials and products.

Thin-film state-of-the-art recycling

In 2005, **First Solar** established the industry's first voluntary global module recycling programme for thin-film modules, and has been proactively investing in recycling technology improvements and driving down recycling costs ever since. First Solar's state-of-the-art PV recycling process recovers more than 90% of the semiconductor material and approximately 90% of glass. In many cases the materials are suitable to be reused in new First Solar modules or in new glass or rubber products.

In 2015, First Solar developed its third-generation recycling technology, which achieves superior glass and semiconductor purity with reduced capital and operating (chemicals, waste, and labour) costs. The continuous-flow process improves the recycling efficiency and increases the plant's daily recycling capacity from 30 metric tons to 150 metric tons.

High purity recovery of PV metals and glass

Due to the limited waste stream volumes and the volatile value of recovered materials, PV waste treatment and recycling remains very costly today. The most valuable materials, such as silicon, silver and copper, are only present in small quantities and difficult to separate from the laminated flat glass product.

ROSI Solar is developing technologies that enable the treatment of waste PV modules focusing on a thermal delamination process, which maximises the purity of the different recovered waste fractions. Combined with a soft chemistry process that separates the silver fingers from the silicon wafers, the company can recover silver and silicon with high purity levels. The value of these recovered materials can cover the costs of the treatment process and make the process cost competitive.

TIALPI is building a module recycling plant targeting full recovery of PV module materials, at high purity levels. The company has optimised a recycling

technology developed in the **FRELP** project (Full Recovery End of Life Photovoltaic) and its facility will be powered by an integrated PV rooftop system. In a first phase, TIALPI focuses on automated detachment and recovery of the aluminium frame and separating the glass over the sheet from the module stack to extract high purity ultra-white glass. In a next phase, high purity silicon and metals will be targeted to achieve 100% recyclability of PV panels in an economically viable way.

LuxChemtech set up an innovative recycling location in which the input streams include both post-industrial waste such as broken cells and wafers or ingot with side cuts, as well as post-consumer waste such as solar modules. A combination of physical (light, water) decomposition and chemical (biodegradable substances) decomposition and purification methods resulted in an ecologically interesting, environmentally friendly process for high purity extraction of valuable metals and silicon, from the most common types of PV modules.

Recycling kerf

As illustrated in Chapter 1, PV silicon wafers are produced by sawing silicon ingots into very thin slices. During this process, over 30% of all silicon used in the PV industry is typically lost. Although the kerf is composed of ultra-pure silicon, it has historically been regarded as a waste stream. **ROSI Solar** has developed a recovery processes that fully separates and recovers the fine silicon particles and the sawing liquid. The sawing liquid can be reused for ingot slicing instead of being treated as wastewater and released in the environment, and the silicon particles are cleaned and then reconditioned as ultra-pure silicon granules. The company demonstrated that this silicon can then be reintroduced into the purification process for photovoltaic grade silicon production and increase efficiency by 15% in current plants.

2.3.3. Re-use and repair

Retrofitting existing solar parks with anti-reflective coatings

Repairing or re-powering modules in the field, without dismantling them, can be a viable option to use materials at the highest value, for a longer period of time. By extending the economic lifetime of solar parks,

FIGURE 7 RETROFIT ANTI-REFLECTIVE COATING



© Covestro

decommissioning is postponed. Repairing inverter or by-pass diode failures is already common practise, but new refurbishment options have emerged.

Many of the older solar parks in Europe (especially pre-2013) have been installed using modules without anti-reflective coating on the cover glass. Covestro's Solar Coatings Solutions BV (formerly DSM Advanced Solar) has tweaked the chemistry of its anti-reflective coating, which is widely used in PV glass manufacturing, so that it can be applied at ambient conditions in the field. Using a proprietary automated application tool, the retrofit anti-reflective coating can be spray-coated on arrays of modules in the field at a speed of several Megawatts per day (see Figure 7). The coating instantly increases the energy yield of the modules (~3%) without having to dismount them or disconnect the park from the grid. As a result, solar park owners increase the returns on their investments in a profitable way, while still benefitting from the original feed-in tariffs.

Marketplace for second-life PV modules

A certain percentage of modules in the waste stream are not necessarily damaged. Rather, they have only reached the end of their economic life or can, with a simple repair activity, be prepared for re-use. Due to decreasing module prices and the lack of quality and safety standards for second-hand PV modules, the second-hand PV module market is primarily in low-income countries, or in countries where there is no sound waste management infrastructure. In Europe, due to strict regulations, there is a small module replacement market for existing PV installations under Feed-In Tariff programmes when one or a more modules have a failure. However, this market will fade out as soon as the Feed-in Tariff period expires.

Market platforms such as **SecondSol** and **pvXchange** are operating with these Feed-in Tariff clients in Europe, but they are also gradually increasing their shipments outside of Europe. A major risk in exporting second-hand PV modules is that there are no standards, norms or guidelines on the definition of a second-hand PV module, nor inspections on the shipment of these products to countries with political instability or without waste management infrastructure. The leading destinations for second-hand PV modules sales are Afghanistan, Niger, Chad and Somalia.



Sustainable supply chain

3.1. Context and background

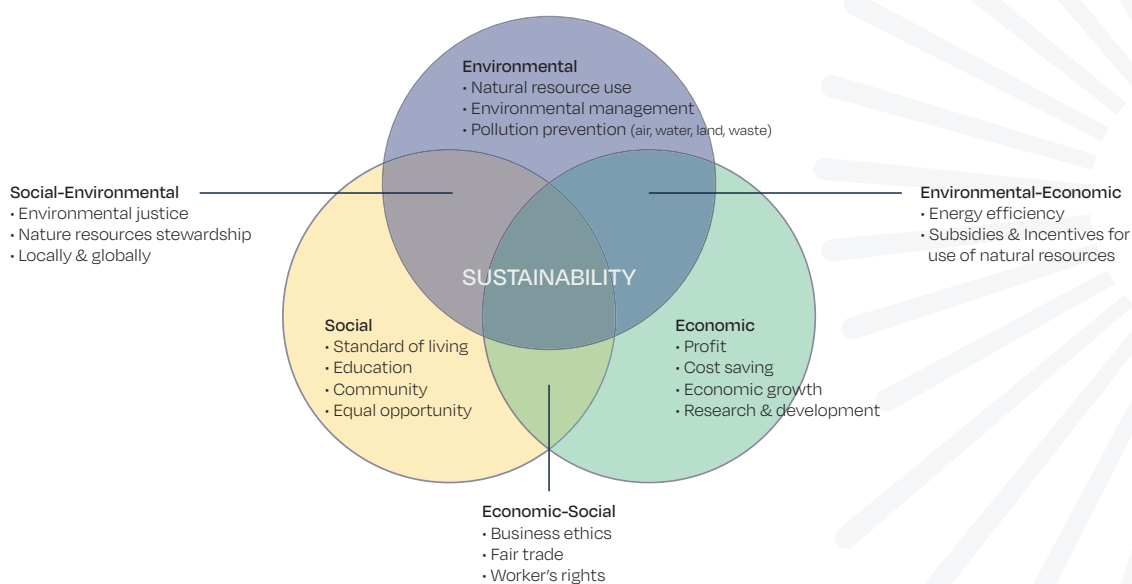
In the last decade, the growing focus on sustainability by citizens has pushed both public and private sector to accelerate the transition towards a sustainable world. To create shared value and promote the production of sustainable energy, sustainability considerations should be not limited to a company's internal value chain, but should also be implemented to external supply chain actors, considering the extended value chain of the product.

The integration of sustainability principles in the business-case of private companies is an ongoing, unstoppable process. Environmental sustainability is one of the bigger focus points, considering the

attention that climate change has gained and the importance of GHG emission reductions to avoid the planet's temperature increase. Nevertheless, social sustainability has also gained more and more attention, especially topics related to respect of Human Rights. Taking into account the rights of communities and people is key, for example by guaranteeing just and favourable working conditions but also the rejection of forced or compulsory labour and child labour.

Moreover, to speed up the transition to a sustainable world, the current way of manufacturing goods is going to be rethought. This means passing from a Linear to a Circular Economy model, based on the

FIGURE 8 SPHERES OF SUSTAINABLE PROCUREMENT



SOURCE: Dragon Sourcing.

principles of redesign by avoiding waste and pollution and keeping products and materials in use and regenerating natural systems.

The solar PV value chain is very diversified and encompasses a variety of actors along the production process. An overview of the production process for typical PV products is provided in Chapter 1. The structure of the value chain has several different configurations, due to the coexistence of highly vertically integrated players and other actors that rather focus on only one of few steps of the production process. Such variety makes the supply chain analysis somewhat complicated, given that no overall structure can be identified. Nevertheless, one general challenge that often arises is the presence of supply chain players beyond the first tier. This means that procurement policies need to look at the “supplier of the supplier” in order to increase their effectiveness. The global scale of solar PV production makes these activities more challenging, since they need to deal with different jurisdictions, regulations, norms and standards.

Managing sustainability along the solar supply chain is relevant for several dimensions. Firstly, the exchange of information between suppliers is a precondition for a product lifecycle assessment. Without a transparent understanding of each step of the production process, granular and accurate data on embedded carbon emissions cannot be collected.

Such considerations are similarly applicable to the dimension of circularity. End-consumers might require from wholesalers information on the environmental characteristics of the products purchased, such as the absence of hazardous substances, information on material content, but also information on circularity features such as repairability, dismantlability and recyclability. Additional reflections on these topics are provided in Chapter 2.

Additionally, end-customers and other stakeholders are looking with increasing attention at the social aspects in the PV value chain, including topics like human rights, transparency and reporting. These aspects are further analysed in Chapters 6 and 7.

These considerations are set to become more and more relevant as a wider range of stakeholders integrates sustainability considerations in their decision-making processes. Particularly public procurement processes often require products with higher socio-environmental

“...end-customers and other stakeholders are looking with increasing attention at the **social aspects** in the PV value chain, including topics like human rights, transparency and reporting.”

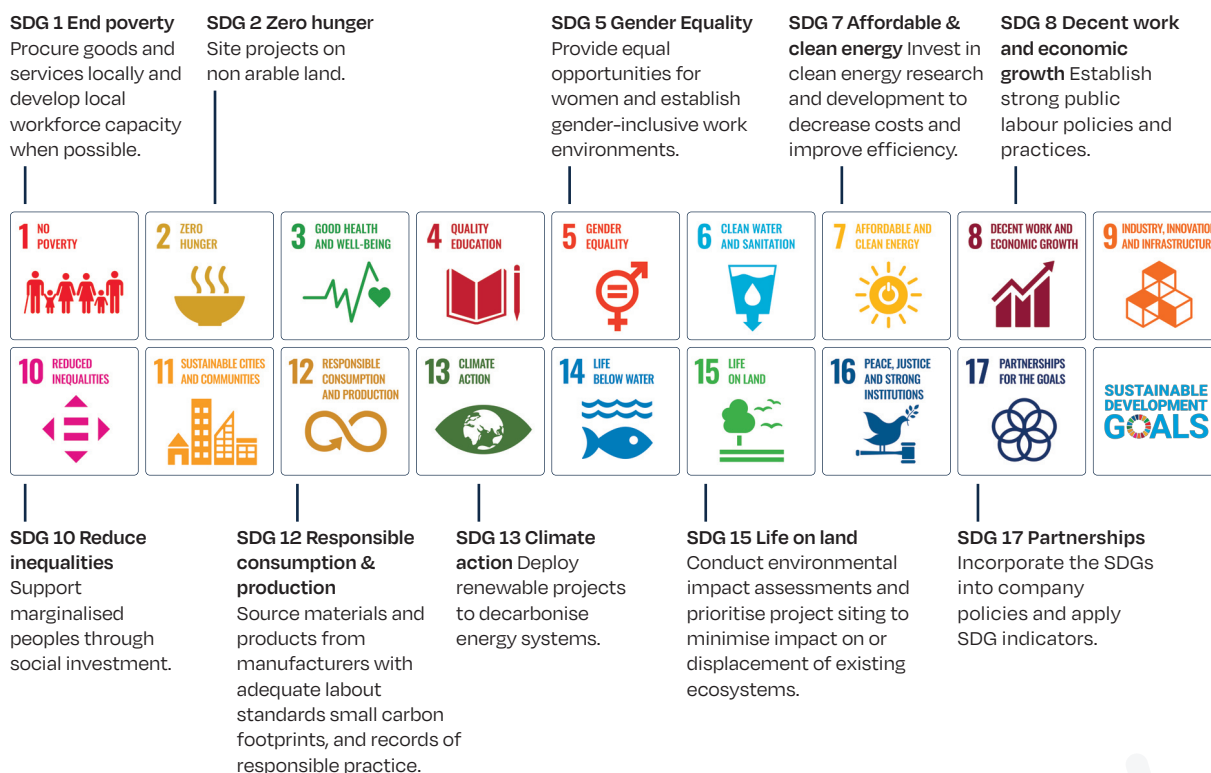
standards. This appears to be the case in the EU context, where a Green Public Procurement label for PV products is set to be developed in the coming years. Such a label, which awards best performers among a product category group, could be used not only in direct purchase of PV products by public entities such as local municipalities, but also in public tenders, and ultimately as a global industry benchmark.

3.2. Approaches and Best Practices

As discussed, sustainable supply chain management is a broad and encompassing topic, which relates to several of the sustainability areas addressed in this study. In terms of identification of best practices, this section contains key actions that companies can take to enhance their supply chain management. The following approaches are recommended:

1. **Map out and integrate ESG considerations at procurement level.** Power purchasers, project developers and renewable asset owners around the world have taken proactive steps to integrate sustainability and ESG criteria into the procurement processes to create a market pull effect along the supply chain. The most prominent example of a sustainability and ESG focused [Procurement Matrix](#) has recently been published by the Renewable Energy Buyers Alliance (REBA). Referencing a variety of international sustainability and ESG reporting standards and latest research, this procurement matrix provides a template for structuring a more sustainable supply chain for PV projects along the framework of the UN Sustainable Development Goals. An overview of the areas addressed by this procurement matrix in relation to the SDGs is provided in Figure 9 on the following page.

FIGURE 9 REBA PROCUREMENT MATRIX SUSTAINABILITY AREAS



SOURCE: REBA (2020).

2. Set requirements in procurement processes.

Developing sustainability requirements along the procurement process, including in pre-qualification and at tender stage, is a good first step. For pre-qualification, the first selection of suppliers is usually carried out through a negative screening, i.e. ruling out those who do not abide by the minimum standards. Therefore, the criteria for consideration at this stage are those in which hard thresholds are set. At tender stage, good performance on the sustainability aspects considered can be additionally rewarded through bonus points in the project evaluation, alongside price and technical considerations.

3. Monitor performance and engage with suppliers.

An essential step is the set-up of a continuous dialogue with suppliers to ensure that the minimum requirements in the areas under scrutiny are always met. To verify this, it is important to set appropriate Key Performance Indicators (KPIs). These KPIs should be monitored

on a regular basis, in order to detect any performance that falls below the required standards. Moreover, engaging with suppliers and involving them in the monitoring activities facilitates this process. Suppliers should be considered as partners. By working jointly on sustainability challenges, it is easier to understand the challenges faced by suppliers and to support them in improving their practices.

3.3. Case studies

3.3.1. Integrating sustainability in the procurement process

In Enel Green Power's procurement policy, sustainable procurement processes are not a top down activity that impacts suppliers, but it is a path where the company supports its suppliers and potential ones in increasing their sustainability performance. The sustainability integration covers all the main supply chain process, as:

"...sustainable procurement processes are not a top down activity that impacts suppliers, but it is a path where **the company supports its suppliers** and potential ones in increasing their sustainability performance."

1. Qualification. Enel Green Power has set up a supplier qualification system for the careful selection and evaluation of companies wishing to participate in procurement procedures. The system assesses the technical, financial, legal, environmental, health and safety requirements, human rights and ethical integrity to ensure the proper level of quality and reliability of any awarded contracts. More information on the compliance documents is provided in the case study in Chapter 6. There are three main areas of analysis:

- **Health and Safety:** thanks to the "Safety Self-Assessment" tool Enel Green Power can easily send to its suppliers the key requirements to grow together and improve their performances. In July 2018 it became an integral part of the sustainability requirements for assessing Merchandise Categories with a Health and Safety risks;
- **Environment:** environmental assessment criteria vary depending on the Merchandise Category and on its associated level of risk. As part of the qualification process, Enel Green Power has introduced a specific assessment of environmental requirements, in addition to the usual checks, for suppliers to be placed on the Supplier Register;
- **Human Rights:** taking a prudential approach, Enel Green Power assesses suppliers in relation to human rights, regardless of the level of risk, through a dedicated questionnaire. This questionnaire analyses the characteristics of potential suppliers in terms of inclusion and diversity, protection of workers' privacy, verification of their supply chain, forced or child labour, freedom of association and collective

bargaining and fair working conditions (including fair wages and hours worked). In 2019, the questionnaire was optimised with further verification questions for a more accurate assessment of the potential supplier.

2. Tender requirements. During tender, suppliers are chosen not only considering their technical performance and economical bids, but also depending on their sustainability performance. The latter assesses the application of (1) sustainability requirements in technical specifications, as a mandatory requirement; and (2) a Sustainability K Factor, as incentive/rewarding method to push sustainability performance above the minimum requirement. Sustainability K Factors are listed and cataloged in a so-called "Library" used in tender processes by the different purchasing units in line with the various Merchandise Categories. There are three main categories in particular:

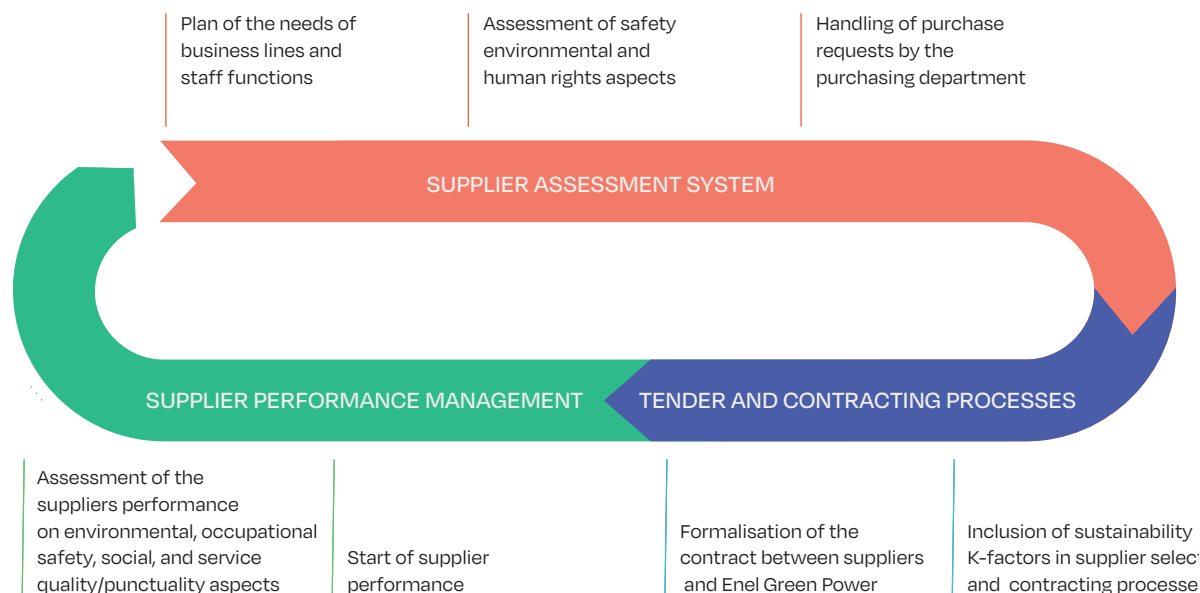
- **environmental Ks:** for example, with the ISO 14001 certification, waste management, carbon footprint assessment according to UNI EN ISO 14067:2018; circular economy projects;
- **safety Ks:** for example, having the OHSAS 18001 certification, monitoring the main safety indexes;
- **social Ks:** for example, hiring staff in a state of unemployment/redundancy/mobility or young first-time jobseekers, or conducting social projects.

3. Supplier performance management. Suppliers' performances are measured on various topics, one of which is sustainability, focusing on Environment, Human Rights and Innovability (Innovation & Sustainability including circular economy aspects). Low performances can lead to penalties, cancelled contracts or exclusion from future tenders.

Aiming at further developing its supply chain, Enel Green Power engages with its suppliers as partners. Thanks to this approach, it is possible to develop sustainability projects together, connected to specific tenders. Acting in synergy with the company's sustainability activities in place, the positive impacts on local community and the environment are larger.

This approach is used in the context of the Environmental Product Declaration (EPD) method, a lifecycle assessment to quantify, interpret and evaluate the environmental impacts of a product or a

FIGURE 10 ENEL GREEN POWER SUSTAINABILITY INTEGRATION IN PROCUREMENT PROCESSES



SOURCE: Enel Green Power.

service. Since 2018, the company asks suppliers to share, on a voluntary basis, the EPD data related to environmental footprint of their equipment. Starting from 2021, the EPD certification will be linked to qualification requirement, so it will be mandatory to have equipment certified in order to participate in the company's tenders.

3.3.2. Environmental and social considerations in supply chain practices

Fronius actively promotes sustainability within its supply chain, above and beyond the legal requirements. Due to a regional production and supply chain structure with a clear focus on Europe, Fronius can reduce logistics routes within the supply chain to a minimum. For the distribution of products to customers, transport volumes by rail and ship are increasing every year, thus measurably reducing the environmental impact. Lifecycle assessment studies

have further shown that a large part of the environmental impact of Fronius' products occurs in the upstream supply chain at supplier and sub-supplier level. For this reason, the company works closely with partners to continuously reduce the ecological impact along the supply chain.

For all business partners in the value network, requirements are summarised in a Code of Conduct for Business Partners as part of the contractual landscape. Such aspects are further described in the case study in Chapter 6.

In addition, the company promotes dialogue with customers and suppliers in order to identify and implement sustainability requirements within the value network at an early stage. To enable the most comprehensive monitoring possible of sustainability activities along the supply chain, Fronius also relies on external platforms, in particular to identify sustainability risks.

4

Biodiversity in large-scale solar

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4.1. Context and background

Large-scale solar PV plants provide the economies of the scale and volumes needed to accelerate the transition to clean, renewable energy sources and further the cost-competitiveness of solar compared to conventional energy sources. To reap these benefits in a fully sustainable manner, several aspects related to the impacts of large-scale solar on wildlife, biodiversity and land use need to be considered.

"...responsibly developed PV power plants put in appropriate locations can **create new habitats** and help **protect endangered animal and plant species...**"

Although construction projects involve some disturbance to existing land and wildlife habitats, responsibly developed PV power plants put in appropriate locations can create new habitats and help protect endangered animal and plant species by providing refuge from the continuous ground disturbance and predation that often occurs outside the project fences on agricultural properties.

Utility-scale PV plants can also support soil regeneration by avoiding disturbances such as annual tilling and the use of fertilisers, herbicides, and rodenticides. During the construction and operation of PV systems, vegetation management activities can include invasive species control, native plant revegetation and monitoring, and

re-planting protected plants. After the short-term construction disturbance period, vegetation within the project fencing can return to its native origins. In addition, in countries such as Germany most large-scale plants are built on degraded land, hence the potential for biodiversity improvement and soil regeneration is huge. So, in general, already in the planning phase, solar developers have a range of options to either preserve or regenerate biodiversity, for example by selecting the right site, choosing the best row distance etc.

A peer-reviewed study by [Armstrong et al.](#) observed that solar parks can have different impacts on microclimates, depending on their location. In sunnier regions, less solar radiation under panels can boost plant growth, whereas in other locations there is a risk that lower solar irradiance leads to a reduction in vegetation growth. The literature [suggests](#) that by employing good biodiversity practices, the solar plant's shading effect can create positive changes on microclimates, resulting in greater vegetation growth and higher species diversity. As a result of implementing industry best practices in responsible land use, appropriate location choice and PV power plant construction, utility-scale PV projects can in fact turn into

"As a result of implementing industry best practices in responsible land use, appropriate location choice and PV power plant construction, utility-scale PV projects can in fact turn into "solar reefs" and **provide sanctuaries for fauna and flora to thrive.**"

BOX 1 INNOVATIVE SOLAR BUSINESS MODELS ENHANCING SYNERGIES WITH LANDSCAPES AND BIODIVERSITY

Agrisolar refers to the integration of a solar photovoltaic project within an agricultural activity. It includes a variety of innovative solutions co-designed between the solar and the agricultural sectors such as Agrivoltaic (or Agri-PV) systems or the deployment of rooftop solar on agricultural buildings. The dual approach between agriculture and solar PV can generate several positive synergies, such as promoting the uptake of more sustainable agricultural practices that reduce the use of pesticides or reducing use of single-use plastics. To ensure effective operation both as agricultural infrastructure and as photovoltaic generation equipment, in addition to ensuring high levels of environmental and social sustainability, project developers should prepare a Sustainable Agriculture Concept. Details on this approach are available in SolarPower Europe's [Agrisolar Best Practices Guidelines](#).

"solar reefs" and provide sanctuaries for fauna and flora to thrive. Selecting the appropriate location may involve avoiding to implant PV module rows near sensitive wetland spots on a designated area, or avoiding the waterways, allowing for old-growth trees to remain or only reduce their height. Involving environmental experts at an early stage of the planning allows to weigh the different options and their impact on the PV capacity and yield.

Impact studies: a critical step to assess the sustainability of large-scale PV projects

From a traditionally restrictive approach to impact studies...

According to the [guidelines for impact studies](#) set forth by the French government, impact studies shall "prevent (...) environmental consequences" of large-scale solar projects. The same approach can be observed in other publications, for example the [Ademe review](#) of the impacts of renewable energy.

Although avoidable if properly designed, prevention of environmental consequences of a large-scale solar plant according to the methodology put forward by the French government can include the following:

- the protection of soil and water against pollution by carburants/oil of vehicles on the plant;
- the interdiction of use of herbicides in green maintenance practices;
- mitigating creation of barriers for fauna by demanding certain characteristics of fences.

...to the acknowledgement of broader environmental benefits

However, considering only the points highlighted above is traditionally a "negative" approach excluding the broader potentials of PV plant management. A [BSG literature review](#) of large-scale solar ecological impacts concludes that the majority of concerns are not well-founded. In fact, the study goes one step further by stating that many authors see the installations of solar PV as an opportunity for biodiversity enhancement. The notion of "environmental consequence" is here interpreted also through a positive lens.

This idea is not new. In 2007 [ARGE](#) discusses the "positive effects on environment, especially if sites with low importance for protection of species and biotopes, for example intensively used agricultural land or strongly impacted conversion sites" are used for implementation of PV. [Randle-Boggis et al.](#) adds that "the minimal land disturbance required during solar park operation, the anticipated 25–30 years life-time and the ability to stipulate land management within planning consents provide excellent conditions to enhance positive ecosystem impacts and minimise negative impacts, promoting net environmental gain". [Blaydes et al.](#) also highlights opportunities to enhance pollinator biodiversity in solar parks. A [BNE study](#) which analyses the data of 75 ground-mounted PV systems in Germany, comes to the same conclusion: "land use of PV plants can in general be seen positively, because besides contributing to climate protection by renewable energy production they can increase the value of the site by conserving biodiversity". Key findings of the study include the following:

- solar parks are also ideally suited as habitats for amphibians and reptiles, butterflies and breeding birds due to their design;

4 Biodiversity in large-scale solar / continued

"...land use of PV plants can in general be seen positively, because besides contributing to climate protection by renewable energy production they can **increase the value** of the site by **conserving biodiversity**."

- an essential cause for the potentially species- and individual-rich settlement of solar parks is the permanently extensive use or maintenance of grassland in the interspaces between the PV systems;
- accordingly, there is a difference between solar parks with wide and narrow row spacings. Wider sunny strips between the module rows increase the species and individual densities.

An analysis of [Enerplan et al.](#) scrutinizes 316 studies about 111 PV plants in Southern France concerning the impact on flora, butterflies, reptiles, and birds by differentiating between specific abundance, heritage value, and the abundance of certain specialists. For flora for example, the study found that specific abundance often increases, whereas the tendency of heritage value and abundance of specialists depend on the special context of the project. However, the study also makes it clear that biodiversity dynamics are often too complex to find simple general rules. A slight negative impact on reptiles is found and, though conversely, also a stabilisation of species with high heritage value, if certain zones which are favourable for these species were maintained. The study confirms that chances to improve biodiversity are highest when situating new PV plants on sites with degraded biodiversity.

4.2. Approaches and Best Practices

We can conclude from the former studies that biodiversity of a PV site is not automatically increased or impacted by the presence of such a project. Certain decisions during design, choice of location, construction, and operations of the site may impact biodiversity in a positive or negative way. The following approaches and practices increase the sustainable contribution of solar plants to their environment:

1. **Apply best practice guidelines.** An example here is the list of criteria of the [Triesdorf biodiversity strategy](#) for construction and operations of PV plants. This includes criteria such as the limitation of module cover to 50-60% of the used area, and the definition of a maximum density of sheep for grazing. The BNE study provides a list of recommendations, such as the need to respect a minimum distance between module rows and a standardisation of methods for biodiversity survey.
2. **Use decision frameworks and decision support tools (DSTs).** The Solar Park Impact on Ecosystem Services ([SPIES](#)) tool of Lancaster University is a free-access resource that uses 457 scientific articles ("evidence-based approach") in order to identify specific natural capital and ecosystem service benefits arising from different management interventions. For example, it highlights the consequences of replacing mowing with grazing by detailing positive and negative effects and directing the user to underlying scientific literature.
3. **Consult local experts and set management plans.** Even if these methods may be used for orientation and in order to avoid mistakes, PV plant managers should also seek advice from a professional, if possible, a local ecologist, before carrying out specific interventions. All this expertise should be condensed in management plans, which aim to reach clearly defined biodiversity objectives. Even if this sounds straightforward, several challenges need to be mastered. A first challenge is that the measurement of biodiversity goals needs a sound methodological approach. This is often the problem of ex-post evaluations: data sets are not complete or not comparable; important information gets lost; on-site staff for surveys fluctuates. A second challenge is that the measurement and fulfilment of biodiversity goals needs a certain budget: for experts, for surveys, for application of special practises, which can leverage benefits. In addition, there have been reports of accountability problems: planning is secured with good environmental plans, but they are not always implemented or maintained.
4. **Set up additional support schemes for projects enhancing biodiversity.** In addition to the traditional support schemes for solar, policymakers should consider the introduction of parallel support mechanisms that reward PV plants

that have a positive impact on biodiversity. The monetary value of supported activities should be reflected by effective biodiversity enhancement as compared to the original state of the site. This may lower offsetting costs for the project, but also finance better monitoring of biodiversity evolution or encourage further measures.

5. **Integrate solar plants into a European strategy for biodiversity.** The risk of permits focusing only on individual projects is that higher-level synergies are not thoroughly realised. Nation- or even Europe-wide implementation strategies can avoid this. For example, well managed PV plants may function as stepping-stones for species between areas that enjoy a higher protection level. Such a strategy could lead to green corridors, which allow exchanges between gene pools in the whole of Europe. This kind of reasoning should rationalise and complement current decision making, which is often based on structure of electrical grid, permitting chances or other criteria.

4.3. Case studies

4.3.1. Responsible utility-scale PV development in California

First Solar's Topaz solar farm, a 550 MW ground-mount project developed in California, provides a case study for responsible solar PV development. Throughout the development of the project and in the current solar farm management, a number of best practices have been employed in relation to biodiversity protection, vegetation management, land use considerations and so on. The development process also included the engagement of local and national stakeholders (more considerations on public acceptance are provided in Chapter 5.)

Topaz was largely constructed on active and fallowed dry-land used for barley farming. The project eliminated disturbances from annual tilling and use of fertilisers and rodenticides. Biological monitoring showed that the PV plant had greater live cover (land covered by living plants), less bare ground, and higher species diversity than surrounding Stewardship Lands. An overview of the best practices applied in the project is shown in Table 1.

TABLE 1 OVERVIEW OF BEST PRACTICES APPLIED IN THE TOPAZ SOLAR FARM

STAKEHOLDER ENGAGEMENT	<ul style="list-style-type: none"> • Consult local communities, state and federal resource agencies, and national and local environmental groups.
BIODIVERSITY PROTECTION	<ul style="list-style-type: none"> • Comprehensive training for onsite workers. • Regular biological monitoring to develop best conservation strategy. • Preserve conservation corridor between arrays for wildlife movement. • Protect endangered species with fencing designed to exclude predators. • Reseed site with native flora species for dust control and to create new habitats and food sources for wildlife.
RESPONSIBLE CONSTRUCTION	<ul style="list-style-type: none"> • Light-on-land site preparation methods, e.g. disk-and-roll or mowing, reduce ground disturbance by contouring the land without changing macro-level topography and drainage patterns. • Results in reduced emissions from heavy equipment, lower likelihood of fugitive dust emissions, and significantly lower water consumption dedicated to dust suppression. • Shifting from below-ground trenching of electrical cables to above-ground housing of cables in cable trays can further reduce ground disturbance and increase the project's end-of-life scrap metal revenues.
VEGETATION MANAGEMENT	<ul style="list-style-type: none"> • Periodic sheep grazing provides ongoing invasive weed control, manages vegetation height and limits fuel load for potential wildfires.
MITIGATION LAND	<ul style="list-style-type: none"> • Acquire conservation land to offset project impacts.
DECOMMISSIONING	<ul style="list-style-type: none"> • Restore site to original state (or better) and recycle panels and Balance of System products.

SOURCE: Sinha et al. (2018).

4 Biodiversity in large-scale solar / continued

FIGURE 11 TOPAZ SOLAR FARM



© Covestro

4.3.2 Responsible development, construction and operation in France

Solaquitaine built a sustainable PV project in the South-West of France, with a capacity of 4.5 MW. This site has been developed on a poor, overgrazed sheep pasture with low ecological interest. More interesting spots, such as a wild pond in the North-Eastern part of the plant, have been excluded from the fenced area, in order to maintain accessibility for every kind of animal.

During construction, the EPC company paid attention to the conservation of the top soil: the plant was built without terracing and with minimal earth work. DC cables run systematically within the support structure, which is anchored in the soil by piles without any supplementary foundation. Therefore, the terrain can be returned to its former state during the dismantling stage of it. A contract for module recycling was included in the module purchase.

Since the vegetation layer was barely impacted during the construction, sowing of herbs was not necessary. During the operations of the PV plant, green maintenance is limited to a minimum, especially in regard to the frequency of cuts. The use of herbicides is explicitly forbidden, and respect of this rule is controlled.

Cooperation with the local association ARPE47 aims to integrate the PV plant into the surrounding system of areas with high biodiversity: the plantation of 500 meters of bushes at the north of the plant, composed of local species is an example of such a measure. The overall idea is to create a “green corridor” in a region with intensive agricultural land use (Figure 12). Regular surveys monitor the evolution of biodiversity on these sites and have shown that 6 years after construction biodiversity of the terrain is considerably higher than before construction.

A summary of the biodiversity aspects considered is provided in Table 2 on the following page.

TABLE 2 SOLAQUITAINE PV PROJECT CHARACTERISTICS

DEVELOPMENT PHASE	<ul style="list-style-type: none"> • Site selection: overgrazed sheep pasture of low fertility and low biodiversity • Plant design: <ul style="list-style-type: none"> • Row distance is large enough, so that effective module cover remained under 50%. • No use of fundamentals for structure, but pile-driving. • No laying of DC cables in the earth until DC boxes (cables run in support structure). • Wetland and existing ponds have been conserved.
CONSTRUCTION PHASE	<ul style="list-style-type: none"> • No terracing. Topsoil and vegetation have remained largely intact. • Existing bushes in the periphery of the plant have been conserved. • Only one central lane has been built with gravel (no asphalt). • Spaces between fence and soil allow small fauna to enter and leave the plant without problems.
OPERATIONS PHASE	<ul style="list-style-type: none"> • Categorical interdiction of herbicides. • Herb cutting is minimised. Maximum is 3 cuts in front of the panels. Under and behind the structure two cuts are sufficient. In the periphery herbs are cut only once a year or once every second year. • Creation of an area where cut herbs are removed in order to stimulate growth of specialists. • In the north of the PV plant, a 500 meters long line of local bushes has been planted in order to create a green corridor and screen. • Studies about development of biodiversity on the site have been undertaken with Paris Diderot University and the association ARPE47. A partnership with the latter aims at integrating the PV plant into the super-structure of a regional green corridor.

FIGURE 12 INTEGRATION OF THE PV PLANT INTO A BIGGER GREEN CORRIDOR



4 Biodiversity in large-scale solar / continued

4.3.3. Agrisolar best practices in Germany

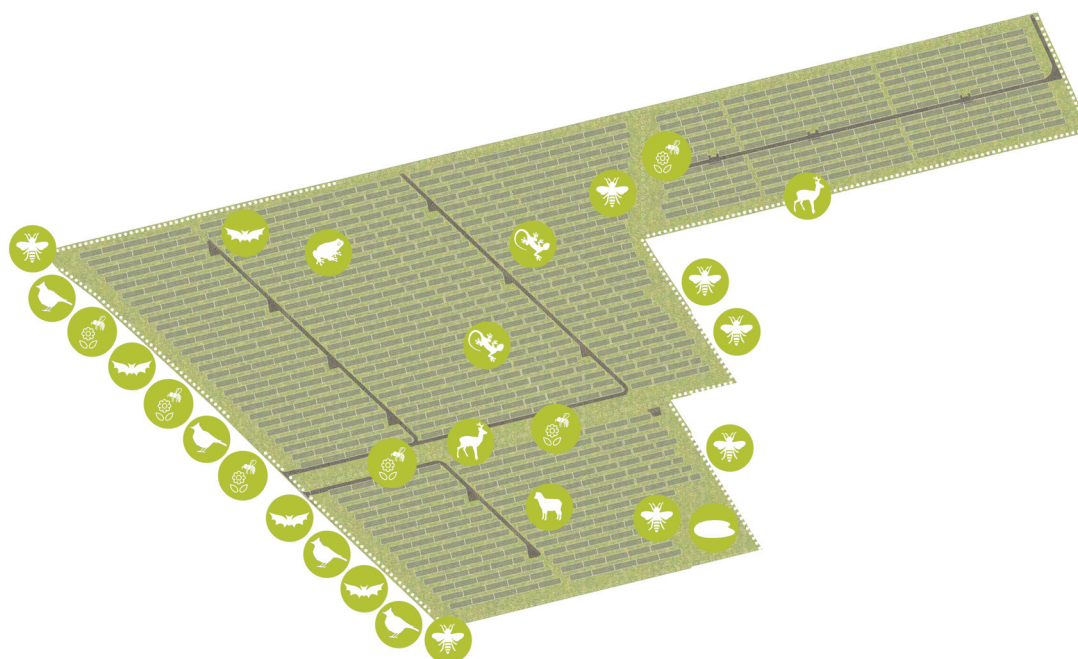
The Klein Rheide solar park in Germany has been developed looking at the nexus between renewable energy generation, biodiversity and agriculture. Wattmanufactur's subsidiary Osterhof built this 23 MW solar park on the fallow land created by previous gravel extraction, and created a habitat for 450 plants - including 17 on the Red List - as well as native wild animals, insects and amphibians. An overview of how the different types of species interact with the solar park is provided in Figure 13. The project also includes secure corridors for the safe passage of wildlife, 5 wild bee-hives, 5 bat nests, 15 bird houses, and grazing areas for local shepherds.

4.3.4. Going beyond impact studies

ENGIE Green teams take into account the environmental protection challenges of PV park development through impact studies and proactive actions. A tailored approach is used for each project, with a view to avoid, reduce, and if necessary, compensate the possible impacts of the installation on the environment.

Going beyond the regulatory requirements, ENGIE develops innovative methods and deploys protection measures that contribute to the preservation of local biodiversity. In its PV parks located in Istres (France), developed in 2020, reptile houses were built to protect the ocellated lizard, a rare and vulnerable species. That included the use of special materials to facilitate colonisation of the place by the reptiles. The locations of the reptile houses have been selected according to several criteria to better adapt to the reptiles' characteristics.

FIGURE 13 OVERVIEW OF THE BIODIVERSITY INTERACTIONS BETWEEN SPECIES AND THE KLEIN RHEIDE SOLAR PARK



SOURCE: Wattmanufactur.

© Covestro

4.3.5. Enhancing biodiversity in large-scale solar

With a total capacity of 500 MW, Iberdrola's Nuñez de Balboa PV plant is the largest solar park in Europe to date. Its construction shows how utility-scale solar projects can be sustainably integrated into the ecological contexts and the local cultures. The solar park is in a traditional and high ecological value habitat in the Iberian Peninsula, the ecosystem of the *dehesa*, which is formed by isolated oak trees and large areas of pasture. This is an ecosystem with high value biodiversity, with plant and animal species associated with it. This habitat depends on human action, which traditionally shaped it for use as feed for livestock.

The main challenge of this project was integrating the plant into the environment. To do so, Iberdrola carried out an environmental inventory which helped select a zone that would affect it as little as possible. In view of

the wealth of species in the zone, environmental monitoring was carried out during the construction phase. Sustainability actions throughout the project design and construction included a wide range of activities for the improvement of habitats and vegetation. The growth of native species was favoured and the impact of invasive species was reduced. Measures for birdlife conservation were also taken.

In addition, the project made a positive social, economic, and cultural contribution with sustainable and compatible activities, as the plant incorporated archaeological projects, and allowed local communities to integrate and continue working on the traditional activities like agricultural, beekeeping or sheep grazing. Further, the project injected life into the local industrial fabric and created a record number of jobs, mainly employing the local workforce.

FIGURE 14 IBERDROLA NUÑEZ DE BALBOA PV PLANT



© Iberdrola



Planning and designing for public acceptance

5.1. Context and background

The global transition to renewable energies combined with the growing urbanisation of European territories intensifies the competition for land. The situation becomes especially challenging for countries with high population densities and high electricity consumption per capita. On the one hand, the scarcity of land leads to conflicts with existing land use. On the other hand, people are developing resistance to new plants being developed in their area, despite fundamentally supporting renewable energies – the so called “NIMBYism” - Not In My Backyard opposition.

However, to achieve the EU-wide climate targets, a massive addition of renewable energy plants is necessary and was acknowledged as a no-regret option by the European Commission's 2050 long-term strategy. As the most versatile and cost-competitive energy source in history, ground-mounted solar should drive the bulk of this transition in the coming years. While rooftop solar is not exposed to public acceptance challenges, the development of large-scale PV plants can create concerns among local stakeholders, who want to ensure that the project will bring social, environmental, and economic benefits to their communities, or who are concerned about changes of the landscape in their neighbourhood.

Another common concern with PV projects is a competition for space, even if studies on the subject [show](#) that large solar parks have lower land use impacts than other energy generation technologies. Considering the complete project lifecycle – material

sourcing, manufacturing, distribution, use, and end-of-life management – large-scale solar PV plants use relatively little land compared to other renewable generation sources, such as bioenergy. Moreover, the literature [indicates](#) that large-scale PV plants in areas of high solar irradiance also use less land than some traditional energy sources such as coal, if land impacts from surface mining are considered.

If utility-scale PV installations are designed and built in a certain way, the competition for land could be reduced and win-win situations could be harvested. By implementing a few rules, a solar park becomes a biosphere habitat with a high degree of biodiversity and with very positive impacts for the surrounding agricultural land, or into a facility that the municipality identifies as part of it and not as a disturbing foreign object.

To this end, acceptance challenges for new solar projects require alternative approaches in the planning and designing phase. Ultimately, all ground-mounted solar plants should strive to be built in accordance with the neighbours, in harmony with nature and the local environment.

Clearly, these reflections are inherently interlinked with those illustrated in the previous Chapter. While in Chapter 4 the focus was on environmental considerations and ecological impacts, this chapter will primarily explore the social dimension, considering the practices that increase public acceptance of solar projects.

5.2. Approaches and Best Practices

The existing [guidelines](#) for ecological and social implementation of utility-scale PV outline that the following aspects of planning and designing ground-mounted solar projects can increase the public acceptance for new plants:

1. Enhance biodiversity through the design and the maintenance of the plants

While aspects of technical implementation and the impact on biodiversity are considered in Chapter 4, the focus here is on the social aspect and the impact on public acceptance.

- In an iterative process between planners/operators and local nature conservation experts, the best possible conditions could be targeted. Local nature conservation associations and other local experts know the local conditions and can provide helpful advice on which animals and plants occur locally. Together, measures should be discussed that best meet local biodiversity needs.
- The positive correlation between ground-mounted solar and flora, fauna and soils could be communicated in citizen events or in public media. Placing information boards on site is also useful. School classes can visit the plant. The topics of renewable energies and biodiversity can be vividly integrated into the teaching plan.
- It makes sense to have biodiversity measures implemented by experts and to measure their long-term effect. This would provide serious evidence that local biodiversity has improved after a few years. Follow-up projects would also benefit from this and the long-term relationship with nature conservation organizations can be strengthened.

2. Better integrate ground-mounted solar plants in the landscape.

PV plants need to be integrated appropriately into the scenery and should not catch the eye easily.

- Suitable visualizations should be created at the beginning of the planning process and communicated transparently to municipalities and citizens. There are modern visualization

tools or apps for this purpose that can be used on websites or on-site events.

- In flat terrain, ground-mounted solar plants should be implemented in such a way that they are barely visible or not visible at relevant edges, due to their low construction height compared to the horizon or accompanying plantings. However, to increase biodiversity under and around the solar plants, the plants should not be built too low either.
 - In topographies where suitable ground-mounted photovoltaic systems cannot be easily integrated into the landscape, e.g. due to hilly landscapes, the appearance should be discussed at an early stage with municipalities and citizens and should be optimised if necessary.
 - Visual relationships protecting historical monuments should be taken into account. This applies equally to ground-mounted and roof-mounted systems
 - Technologies such as Agri- and Floating-PV allow true dual-use of land and are embedded smoothly in the surrounding landscape. For example, Agri-PV over fruit plantations can permanently replace hail protection foils. Artificially created lakes, which are neither used for tourism nor under any kind of nature protection, are well-suited for floating PV systems.
- ### 3. Involving municipalities, the administration, and citizens.
- The implementation of renewable energy plants is often delayed or even hindered by lacking citizen consultation from corresponding municipalities, because they perceive alleged disadvantages or no direct advantages for themselves in building a renewable energy plant in their district. The following set of actions are recommended:
- Provide comprehensive information and ensure early engagement of local communities, administration, and population. This also includes transparent information about the plant's economic basis and the marketing of the generated power.

5 Planning and designing for public acceptance / continued

- Present and leverage economic benefits for the municipality. On the one hand by providing information on possible incomes through tax. On the other hand, by providing municipalities a financial contribution that complies with legal requirements, regulatory standards, and other ethical standards. Shares of the expected revenues from the plant could additionally be used to support municipal infrastructure such as the providing of PV systems on public buildings or the installation of e-mobility charging stations.
 - Create benefits for the local population. Local citizens will be more supportive of the project if they receive part of the positive impacts generated by the solar project. If the marketing concept permits, local citizens can purchase electricity from regional electricity producers at low cost or participate financially via crowdfunding or other approaches.
 - Link solar projects with regional cultural objects or activities. Through funds from the PV project, abandoned historic buildings or areas can be revalued and filled with life again, which adds value to the entire region. Land-leasing income and targeted sponsorship can also help to expand cultural diversity and help create new community spaces or cultural offerings.
 - As with any construction process, care should be taken where archaeological monuments or sites may be present. In this case, close cooperation with the archaeological authorities is important to obtain their consent.
4. **Going new ways in planning, implementation, and technology.** Acceptance can also be increased through other approaches in planning and implementation, as well as the type of technology used:
- Implement solutions to reduce CO₂ while constructing large-scale solar parks. The energy used to construct PV parks can largely be generated on site by the PV modules to be installed. The carbon footprint of construction sites can be successively reduced through mobile battery concepts, electricity-powered construction site vehicles and recycling concepts.
 - Overhead lines for grid connection should be avoided. A careful and cooperative construction of the necessary transmission lines is in the interest of acceptance.
 - PV plants of the “next generation” should be developed, such as PV plants in combination with storage systems. The integration of storage in the plant is well received by residents. This is because of the widespread common myth about fluctuating generation plants that regularly “congest the power grid” and do not supply sufficient electricity at other times.
 - The solar modules, inverter concepts and other technical components should also meet high efficiency standards. High technical efficiency leads to lower land use.
- Very rarely, solar modules cause some light reflection or glare. However, this issue can still be a fear among authorities and residents, which again has a negative impact on acceptance. Therefore, this topic could be addressed proactively. An assessment of the possible risk of glare could be conducted and measures must be implemented to avoid it. If glare can occur along highways, railroads, or airways, mostly when the sun is low, specific countermeasures should be taken, such as planting hedges, changing distances and angles of the modules, or, in an extreme case, leaving out individual modules.

5.3. Case studies

5.3.1. Community funds

Funds are an option to deal with municipalities and to let local people profit from a PV plant. In the Netherlands, GroenLeven B.V. provide “Area Funds” that are financed with revenues from the solar parks. The funds are managed by people from the municipality and people from the local community. They decide what the funds are used for. Usually, the funds are used for social and sustainable purposes, such as refurbishing a community center, making sport clubs more sustainable or strengthening the nature around the solar park.

FIGURE 15 FLOATING PV PROJECT IN NIJ BEETS, NETHERLANDS



Handover of a cheque for the local area fund for the Floating PV project Nij Beets.

© GroenLeven

5.3.2. Recovery of local rural heritage

Rural recovery and restoration of historical buildings that are related directly to a solar project can increase acceptance for it. In the San Severo project in Italy, BayWa r.e. developed a plan to recover the local rural heritage. Starting from the restoration of an ancient farmhouse nearby the plant, this expanded to the enhancement of local agricultural integrated activities like sheep herding,

cheese production and beekeeping. BayWa r.e. is financing the project, in close cooperation with the municipality. The measure allows to recover and connect three main elements of the typical agricultural landscape: the ancient farmhouse, the animal passage and a pasture area located in the PV plant. Side activities in the restored farmhouse will be a museum of the rural activities, an educational centre for school trips, and a production to sell cheese, herbs and honey.

FIGURE 16 FLOATING PV PROJECT IN EXLOO, NETHERLANDS



Toast on the successful cooperation with the local community.

© GroenLeven

5 Planning and designing for public acceptance / continued

FIGURE 17 PV PROJECT IN SAN SEVERO, ITALY



Air view on the ancient farmhouse, which will be restored in the San Severo project.

© BayWa r.e. AG

5.3.3. Cooperation with nature conservation associations

Decision-makers and nature conservation organizations were involved in a 7.2 MW PV and 2.9 MW BESS BayWa r.e. ground-mounted PV project in South Germany from the very beginning. At an initial on-site meeting, the landowner stated that increasing biodiversity on the previously intensively used field was an important concern. The representatives of the two local nature conservation associations, locally rooted and networked individuals, were initially critical. BayWa r.e. actively approached them. By means of discussions, meetings at the site, a joint exchange with the environmental planner, a level of trust was created. Subsequently, a joint catalogue of measures was developed, in which the local-specific knowledge of the nature conservation associations was substantially incorporated, and objections were taken into account. In the end, the representatives of the nature conservation associations contributed an article to the local newspaper on their own initiative, in which they endorsed the solar park. They also approached critics of the project on their own.

5.3.4. Bringing benefits to local communities

At 300 MW, Talayuela Solar is one of the biggest solar projects in Europe. When Solarcentury (now Statkraft) started planning the community engagement no plant of this size had been built in Spain and the team was keen to ensure that the project was not only accepted, but welcomed. The company therefore focused on three areas of benefit. First and foremost, local jobs: the team committed to creating jobs for local people. Beyond just achieving this, the construction also resulted in indirect jobs being created for the local hospitality sector, local suppliers, and more. Secondly, there were significant benefits to local community support. Besides sponsoring the local football team, the company supported the local community during the COVID-19 health crisis with foodbank donations. This is in addition to the substantial local taxes that arise from such a large project. Lastly, the project improved biodiversity: improvements to wildlife and nature are always important to creating local acceptance. At Talayuela, EUR 1 million has been spent on enhancing and protecting biodiversity, including 312 hectares of protected area, oak restoration, crane and wild rabbit restoration projects, and a nature classroom for children.

FIGURE 18 BOMHOFSPLAS FLOATING PV PARK AFTER COMPLETION OF CONSTRUCTION



© GroenLeven.

5.3.5. Carbon-free construction of solar parks

GroenLeven B.V. developed solutions to reduce CO₂ while constructing large-scale solar parks. All recently built Floating PV parks in the Netherlands, including the 27.4 MW Bomhofsplas park, were constructed with their own generated electricity. This means that the solar park is literally self-supplying its energy need during construction time. All tools and appliances as

well as vehicles on the construction site were electric. The power that was stored in the battery was enough to charge all tools and construction site facilities during nighttime. In addition, the solar battery system was put to the test by using it for rather harsh loads like electric heating. The workers' containers were kept warm, powered by the solar battery system. The battery storage system used at Bomhofsplas were loaned.



Human rights

6.1. Context and background

The nature of solar PV, as a global product with a complex value chain, means that the sector operates in regions with very different social, economic, political, and cultural contexts. Regardless of the diversity of geographies and conditions of companies' global operations, solar companies have a duty to ensure and promote the respect of fundamental human rights, specifically in regard to the rights of workers. These actions must be carried out within business relationships with contractors, suppliers, and any other partners, with a particular focus on conflict-affected and high-risk contexts.

In accordance with international legislation and agreements – such as the [Universal Declaration of Human Rights](#), the [International Covenant on Economic, Social and Cultural Rights](#) and the International Labour Organisation's [Declaration on Fundamental Principles and Rights at Work](#) – all companies must carefully monitor supply chain labour practices and relations with local communities at large. This involves a proactive stance towards actions including, but not limited to, rejection of forced labour and child labour, respect for diversity and non-discrimination, freedom of association and collective bargaining, health and safety, fair working conditions, respect for community rights, absence of corruption, and respect of privacy.

Awareness of these issues among companies across industries is at an all-time high, thanks to increased scrutiny and pressure from government regulators, non-governmental organisations, customers, institutional investors, and the media. It is well documented that consumers are increasingly in the spotlight for their ESG practices and stances: a 2018

survey by Accenture Strategy found that more than one third of consumers in the UK will walk away from a brand when disappointed with its social stances.

In the EU context, policymakers have announced legislative action concerning mandatory corporate sustainability reporting and due diligence requirements, with a focus on forced labour prevention. These actions are strongly connected with the topic of reporting and transparency, which is addressed in Chapter 7.

Companies have a moral and often legal imperative to act. It also makes business sense, because of the risks to their operations, reputations and in some cases, sales, if human rights violations occur in their supply chains. Even though multiple industries share recruitment actors and corridors, solutions are often implemented in parallel rather than working in conjunction with one another. While guiding principles on workers' rights are well-established, these solutions tend to be fragmented across industries and geographies, only addressing certain aspects of worker conditions.

For renewable energy, the issue is even more serious, as consumers do not want to materially support companies with perceived unethical business practices, and generally distrust companies that purport to have a role in green transitions while turning a blind eye to humanitarian or ecological abuses in their supply chains. For the renewable energy sector, the following considerations apply:

- Renewable energy is key for the transition to a low carbon economy, but companies' human rights policies and practices are not yet strong enough to ensure this transition is fast and fair.

- Evidence shows that a failure to respect human rights can result in project delays, legal procedures, and high costs for renewable energy companies, underlying the urgency to strengthen human rights due diligence; such delays would slow the critical transition to renewable energy.
- As renewable energy investments expand in countries with less developed frameworks for human rights protection, investors must step up their engagement to ensure projects meet international standards.

In September 2018, the Business & Human Rights Resource Centre published an [analysis](#) of renewable energy companies' human rights commitments. Key findings included insufficient human rights commitments in the biggest renewable energy markets, low level of commitment to consultation and engagement with affected communities, uneven commitment to labour rights, and supply chain monitoring that did not cover human rights.

In early 2021, the issue of forced labour in the solar sector, particularly related to polysilicon production in China's Xinjiang region, has been the subject of numerous reports and articles. At present, there is insufficient evidence to confirm these allegations, however, despite the lack of clarity as to the exposure of the sector, the European solar industry has taken these allegations very seriously.

Today, a relevant share of global polysilicon production comes from Xinjiang and this is an essential component for most PV modules (crystalline silicon). While EU PV manufacturing relies on EU-produced polysilicon to a certain extent, Chinese polysilicon is also used in EU manufacturing and, most importantly, a large share of modules sold in the EU are imported from China.

As a sector that strives for the highest standard of sustainability, the solar industry must remain vigilant across its supply chain in meeting global human rights standards. Considering the immense solar potential in the EU, and the necessity of scaling-up deployment in order to support the European Green Deal's ambitious energy targets, the EU solar sector cannot accept any such violations of human rights and must work to maintain its reputation as a champion of sustainability and corporate social responsibility.

6.2. Approaches and best practices

1. **Develop and implement a management system to address human rights within the organisation.** A management system is defined as an oversight mechanism that comprises a set of policies, processes, procedures, and objectives. There are different levels of maturity that can be achieved. Table 3 shows a simple rating spectrum of possible approaches an organisation or company can have regarding management systems, with 5 being the best approach.

TABLE 3 OVERVIEW OF APPROACHES FOR HUMAN RIGHTS MANAGEMENT SYSTEM

5	Developed and implemented mature management system with continual improvement of the system.
4	Developed management system, implemented consistently and regularly .
3	Developed management system, but not fully implemented .
2	Partially developed management system, but implementation is reactive, inconsistent and mostly ineffective .
1	No awareness of SA8000 or any system in place to manage social performance.

SOURCE: Social Accountability International.

2. **Request Environmental, Social and Governance (ESG) expert advice.** Companies should seek support from ESG experts on this topic, both at portfolio level (relevant for investors and lenders) and at project level (relevant for developers, investors, and lenders).
3. **Integrate human rights considerations into supply chain contracts and management.** As discussed in Chapter 3, sustainable supply chain practices can prove an effective means to enhance the sustainability performance of business partners and the entire value chain. Human rights considerations should be taken into account when setting minimum requirements in supply chain contracts, monitoring supplier performance through KPIs and engaging with them to improve their business practices. At procurement level, companies can leverage their contracting power towards their

6 Human rights / continued

suppliers to include “no modern slavery” clauses requiring no forced labour practices or any other human right breaching in supply contracts.

4. **Strengthen risk assessment related to human rights through an overarching framework.** Management system approaches, as described above, should align with recognised standards of

human rights – including the Universal Declaration of Human Rights, ILO conventions, and national laws – and should be continually improved rather than checklist-style auditing. Social Accountability International outlined in its SA8000 standard a list of elements of human rights standards that should be met. The list is presented in Table 4.

TABLE 4 ELEMENTS OF HUMAN RIGHTS STANDARDS

CHILD LABOUR	No use or support of child labour; policies and written procedures for remediation of children found to be working in situation; provide adequate financial and other support to enable such children to attend school; and employment of young workers conditional.
FORCED AND COMPULSORY LABOUR	No use or support for forced or compulsory labour; no required 'deposits' - financial or otherwise; no withholding salary, benefits, property or documents to force personnel to continue work; personnel right to leave premises after workday; personnel free to terminate their employment; and no use nor support for human trafficking.
HEALTH AND SAFETY	Provide a safe and healthy workplace; prevent potential occupational accidents; appoint senior manager to ensure OSH; instruction on OSH for all personnel; system to detect, avoid, respond to risks; record all accidents; provide personal protection equipment and medical attention in event of work-related injury; remove, reduce risks to new and expectant mothers; hygiene- toilet, potable water, sanitary food storage; decent dormitories- clean, safe, meet basic needs; and worker right to remove from imminent danger.
FREEDOM OF ASSOCIATION AND RIGHT TO COLLECTIVE BARGAINING	Respect the right to form and join trade unions and bargain collectively. All personnel are free to: organise trade unions of their choice; and bargain collectively with their employer. A company shall: respect right to organise unions & bargain collectively; not interfere in workers' organisations or collective bargaining; inform personnel of these rights & freedom from retaliation; where law restricts rights, allow workers freely elect representatives; ensure no discrimination against personnel engaged in worker organisations; and ensure representatives access to workers at the workplace.
DISCRIMINATION	No discrimination based on race, national or social origin, caste, birth, religion, disability, gender, sexual orientation, union membership, political opinions and age. No discrimination in hiring, remuneration, access to training, promotion, termination, and retirement. No interference with exercise of personnel tenets or practices; prohibition of threatening, abusive, exploitative, coercive behaviour at workplace or company facilities; no pregnancy or virginity tests under any circumstances.
DISCIPLINARY PRACTICES	Treat all personnel with dignity and respect; zero tolerance of corporal punishment, mental or physical abuse of personnel; no harsh or inhumane treatment.
WORKING HOURS	Compliance with laws & industry standards; normal workweek, not including overtime, shall not exceed 48 hours; 1 day off following every 6 consecutive work days, with some exceptions; overtime is voluntary, not regular, not more than 12 hours per week; required overtime only if negotiated in CBA.
REMUNERATION	Respect right of personnel to living wage; all workers paid at least legal minimum wage; wages sufficient to meet basic needs & provide discretionary income; deductions not for disciplinary purposes, with some exceptions; wages and benefits clearly communicated to workers; paid in convenient manner – cash or check form; overtime paid at premium rate; prohibited use of labour-only contracting, short-term contracts, false apprenticeship schemes to avoid legal obligations to personnel.

SOURCE: Social Accountability International.

6.3. Case studies

6.3.1. Developing a framework for human rights protection

Enel Green Power's purchasing processes are based on pre-contractual and contractual conduct geared towards loyalty, transparency, and collaboration. In addition to ensuring the necessary quality standards, supplier performance must go hand-in-hand with the commitment to adopt best practices in terms of human rights, working conditions, occupational health and safety, and environmental responsibility. The Code of Ethics, the Zero Tolerance of Corruption Plan, the Policy on Human Rights, the Model pursuant to Legislative Decree 231/01, and the Enel Global Compliance Program are the documents that underpin its purchasing activities and serve as a guide and code of conduct for suppliers.

The company has set up a supplier qualification system for the careful selection and evaluation of companies wishing to participate in procurement procedures. The system assesses the technical, financial, legal, environmental, health and safety requirements, human rights, and ethical integrity to ensure the proper level of quality and reliability of any awarded contracts.

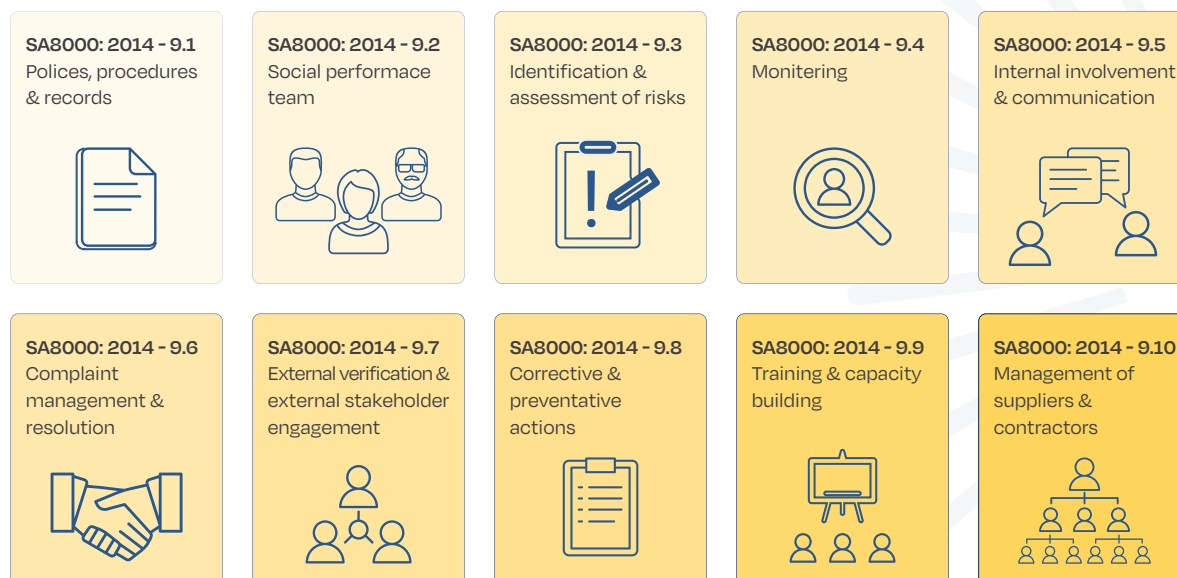
Suppliers are assessed in relation to human rights, regardless of the level of risk, through a dedicated questionnaire. The questionnaire analyses the characteristics of potential suppliers in terms of inclusion and diversity, protection of workers' privacy, verification of their supply chain, forced or child labour, freedom of association and collective bargaining and fair working conditions (including fair wages and hours worked). In 2019, the questionnaire was integrated with further verification questions for a more accurate assessment of the potential supplier.

6.3.2. Certification standards for workers' rights

ISO/SA8000 Social Accountability Certification is an auditable certification standard that encourages organisations to develop, maintain, and apply socially acceptable practices in the workplace. It was developed in 1989 by Social Accountability International (formerly the Council on Economic Priorities), an advisory board consisting of trade unions, NGOs, civil society organisations, and companies.

Externally seeking SA8000 Social Accountability Certification from supplier sites and upstream as a part of pre-qualification due diligence is one of the

FIGURE 19 SA8000 CERTIFICATION AREAS



SOURCE: Social Accountability International.

6 Human rights / continued

most effective and reliable means of validation. The key areas that are accounted for within the SA8000 certification are presented in Figure 19.

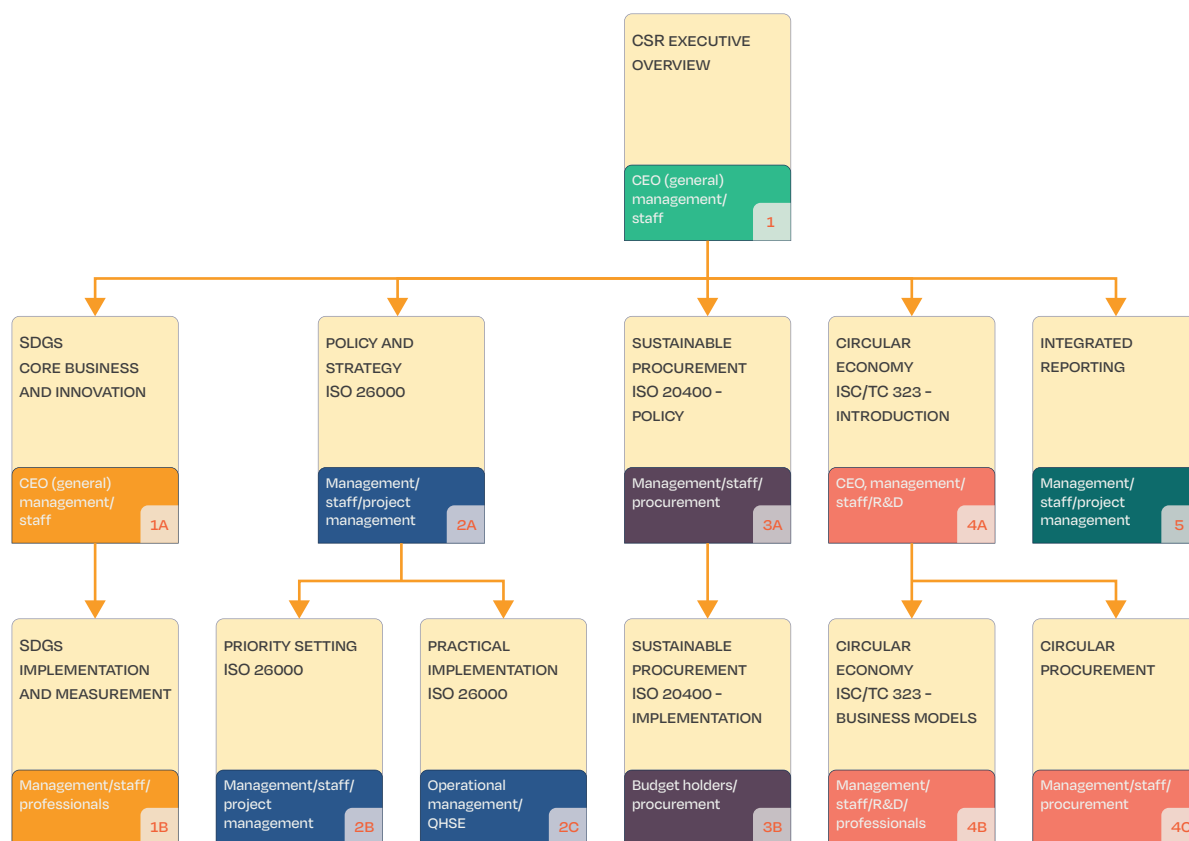
Internally stepping up procurement and supply chain activities to sustainably integrate all processes, implementing **ISO 20400 Sustainable Procurement** and getting certified by an external party such as an auditing firm are also considered to be best practices. This will help to manage the performance of all suppliers, ensuring social responsibility, sustainability, and ethical sourcing, which in turn serves to provide assurance to shareholders and stakeholders.

The ISO standard provides guidelines for integrating sustainability into an organisation's procurement processes. Aimed at top managers and directors of the

purchasing function, it covers the political and strategic aspects of the purchasing process, namely, how to align procurement with an organisation's goals and objectives, ultimately creating a culture of sustainability.

The standard defines the principles of sustainable procurement, including accountability, transparency, respect for human rights, and ethical behaviour; it highlights key considerations, such as risk management and priority setting. It also covers various stages of the procurement process, outlining the steps required to integrate social responsibility into the purchasing function. Figure 20 maps the aspects and steps of sustainable procurement practices, including the staff that would likely be responsible for each stage.

FIGURE 20 ISO 20400 SUSTAINABLE PROCUREMENT



SOURCE: ISO.

6.3.3. Audit process focusing on forced labour

The Responsible Business Alliance (RBA) has developed an assessment program for forced labour due diligence: the Supplemental Validated Audit Process (SVAP) on Forced Labour. The assessment is used to identify risks of forced labour at factory level or recruitment agency level. The SVAP protocol makes use of third-party auditors to maintain quality control, involving native language interviewers to improve the collection of information. The SVAP process is outlined in Figure 21.

6.3.4. Human rights due diligence practices

Fronius has developed a Code of Conduct (for employees within the company) and a Code of Conduct for Business Partners, which are used as a framework for addressing human rights within the company's activities.

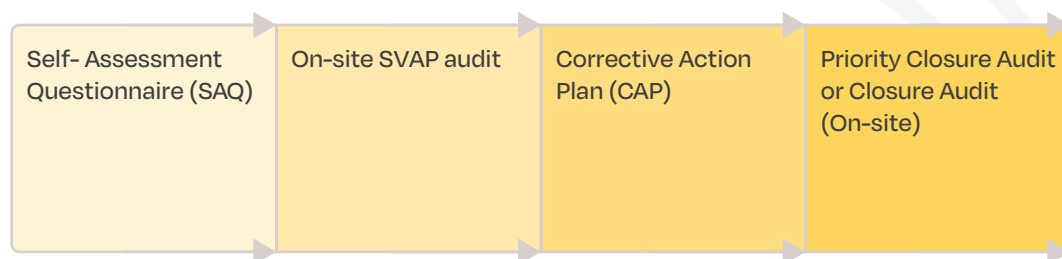
To ensure compliance with the Code of Conduct at all times and raise awareness, all employees must complete a mandatory e-learning course every year. If

employees identify human rights violations or violations of other concerns, they must report them immediately to the respective internal contact person.

The Code of Conduct for Business Partners is based on Fronius' Code of Conduct, the UN Global Compact, the ISO 26000 (Guidance on Social Responsibility), and the European Convention on Human Rights. By accepting the general terms and conditions of purchase, suppliers agree to comply with Fronius' Code of Conduct and the regulations regarding social sustainability in supply chains. To ensure compliance with human rights, new suppliers are screened against various social criteria. For the ongoing monitoring of existing suppliers, a tool has been set up to identify potential violations and risks.

By focusing on European markets and the associated stable political conditions, risks of social violations are reduced at an early stage. Social legislation along the supply chain (e.g., Modern Slavery Acts) is continuously reviewed and complied with through a reporting structure (e.g., Modern Slavery Statements) in line with the legal requirements.

FIGURE 21 SVAP PROCESS



SOURCE: RBA.



Supply chain transparency

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7.1. Context and background

The importance of responsible supply chain management, described in Chapter 3, reveals the corresponding need of understanding a product's geographic origin, its chain of custody (the various stages of the value chain), and the conditions of production at each of these stages. In order to have a full picture of the characteristics of the product and all of the sustainability dimensions connected to its production, companies should strive to enhance transparency in their supply chains.

However, while certain aspects can be tracked with comparatively lower efforts, other characteristics may prove more challenging. Certain physical characteristics of the product (e.g., solar PV module efficiency) can be detected without looking into detail at the supply chain; for other features, such as the product's carbon footprint, methodologies and approaches that require a full value chain analysis are required. The issue gets even more complicated with regard to the conditions of production along the value chain, in which social aspects, such as workers' rights in producing countries, are difficult to monitor without a strong transparency framework in place, or robust international cooperation. A detailed assessment of human rights dimensions to address in the supply chain is provided in Chapter 6.

"Ensuring a high level of transparency in the supply chain can ultimately become a **competitive advantage**, increasing trust with commercial partners and consumers."

Ensuring a high level of transparency in the supply chain can ultimately become a competitive advantage, increasing trust with commercial partners and consumers. It can also guarantee faster adaptation if EU or national regulators decide to intervene on this matter. In the EU, large corporations are already subject to certain non-financial and diversity reporting rules, which have been introduced by the Non-Financial Reporting Directive 2014. This legislation provides the foundations for sustainability reporting, yet a comprehensive approach on sustainable corporate governance that ensures strong supply chain transparency and a full exchange of information is missing. Against this background, some Member States have introduced laws with different levels of ambition on the topic, while others are in the process of considering action.

However, the policy landscape in the EU is set to markedly change. The European Commission recently announced work on corporate transparency on different fronts. In April 2021, the Commission unveiled plans for a Corporate Sustainability Reporting Directive, revising and strengthening the existing rules

introduced by the Non-Financial Reporting Directive, which will be applied to a broader number of companies. Within the context of sustainable finance, other initiatives such as the Sustainable Finance Disclosure Regulation and the EU Taxonomy also apply. Moreover, new legislation revising the framework for due diligence is due by 2023. These developments are strongly welcomed by the solar industry, with several solar companies already going well beyond existing standards and requirements to drive progress forward.

The importance of supply chain transparency for the solar industry has become apparent related to the recent allegations of forced labour associated with polysilicon production in China's Xinjiang region (see Chapter 6). In certain jurisdictions, the local solar industry has advanced work on transparency, such as in the [Solar Supply Chain Traceability Protocol](#), recently launched by the US solar association SEIA.

7.2. Approaches and Best Practices

A new [report](#) from the Center for Strategic and International Studies on supply chain traceability categorises current approaches into upstream or downstream, highlighting that even when both methods are used, full visibility of the supply chain remains difficult, especially in areas where access is restricted. The study argues that despite their limitations, some of the traditional approaches can support a company in establishing traceability, whereas new technologies enable a more streamlined methodology and verification of the findings.

In other industries, technological innovations have greatly improved the traceability potential. For example, radio frequency identification (RFID), wireless sensor networks, DNA barcoding, Internet of Things (IoT) systems, isotope tracing, and artificial intelligence (AI) are among the new technologies that the cotton industry is using for supply chain traceability. Many of these technologies are directly applicable to sectors such as the agrifood industry, but are not always suitable for the solar industry.

For the solar PV sector, two general approaches are recommended:

- 1. Collect and share supply chain data through joint supplier audits.** Due to the complexity of the value chain and the large number of players at the global level, collecting extensive supply chain data in an effective manner is a difficult task. One solution to this challenge is enhancing collaboration across the industry. Data sharing platforms facilitate the exchange of information about business partners, products, and production processes, reducing redundancies in data collection. This can be done, for example, by developing a system to jointly carry out audits of suppliers, as in the case of the [Joint Audit Cooperation \(JAC\) initiative](#) for the telecom industry. The JAC initiative is a coordinated on-site audit and development program based on a common verification, assessment and development methodology. Each member company is assigned a number of common suppliers and carries out a complete audit process on behalf of the whole group. Data sharing also prevents bad practices as it poses the risk for a non-compliant supplier to have industry-wide reputational damage.
- 2. Employ effective tracking technologies, such as blockchain.** Distributed ledger technologies (DLT) such as blockchain provide a decentralised, digitally synchronised, and immutable ledger of information. A blockchain is essentially a chain of digital records – at any new step of the value chain, additional data is added to the block of information, so that it is possible to trace back the entire origin of the product. The inherent DLT characteristics prevent any modification of historical data to falsify compliance with regulations. These technologies could prove useful to track supply chain data and share it among peers, although in order to achieve this integration, significant challenges, such as security and privacy concerns, need to first be addressed. In addition, one key challenge is ensuring that all data uploaded is accurate and comes from a trustworthy source.

7.3. Case studies

7.3.1. Tracking solar manufacturing processes

As previously mentioned in this report, the solar PV sector has a complex value chain and full vertical integration is a rare feature. Some suppliers make wafers, cells, and modules; some only assemble modules from purchased materials; few vertically integrate into polysilicon production and none vertically integrate into the production of metallurgical grade silicon. Consequently, module suppliers may not have ready access to data that generated during previous supply chain stages, thereby making full transparency very difficult or impractical.

Clean Energy Associates (CEA) evaluates the ability of module suppliers to capture important manufacturing data in their value chain, from beginning to end, and to then audit the suppliers' systems and records to verify consistent and accurate data collection and reporting. Provenance of key materials, including provenance of polysilicon, are essential elements of such reports.

The module supplier is requested to provide a map of their supply chain insofar as it relates to the modules destined for the buyer. Given the supply chain map, the module supplier is asked to provide the codes of conduct (or equivalent) from each of the links in the chain. The buyer can then consider and, subject to suppliers' agreement, take action to specify, or conversely disapprove, specific links in the supply chain. Vertically integrated suppliers are likely to have manufacturing execution systems (MES) that capture all the data about the product as it moves through the value chain. Suppliers who depend on other entities for parts and materials should demonstrate that the data from their upstream supplier is transferred to them along with the material.

Among the activities in the audit, the auditor seeks to confirm that the transaction records between entities are consistent and reflect, at a minimum, the product number/specification, production location and volume. Ultimately, the objective is to affirm that the data collected along the value chain is correct and accessible to the module assembler (the last link in the chain) and that the module assembler can then share that data with the buyer (or, as needed, authorities) under a framework of transparency.

7.3.2. Supply chain transparency requirements from carbon footprint declarations

France has set up a traceability system for solar modules in its industry aligned with its carbon footprint rating system. In the French calls for tenders, it is stated that the provenance of each material necessary for the manufacture of PV modules must be documented during production.

Therefore, each module manufacturer participating in a call for tenders must be able to justify the geographical origin of the materials and components used and the carbon content of these components. This documentation is then validated by CERTISOLIS, an independent certification body. The certification for crystalline silicon modules must at least contain information at module level and at wafer level, including the reference of the wafer manufacturing facility.

It is also specified that the administrative authority reserves the right to require from the module supplier a certificate by the producer proving the origins of the components covered by the simplified carbon assessment.

7.3.3. Blockchain based supply chain traceability

Lightsource BP is currently looking at means to support the creation of a more sustainable and transparent supply chain, with a specific focus on addressing human rights issues linked to the solar supply chain. The approach Lightsource BP is developing is split into three phases: (1) strategy setting; (2) assurance and assessment; (3) product traceability and claims. This approach includes an assessment of supply chain transparency, peer analysis of other industry leaders, full supply chain mapping, and assessment of sustainability risks. The supply chain solutions identified make use of various digital technologies, such as blockchain, AI, and IoT. Digital passports can be also used as a way to consolidate information about a particular asset, allowing for verification and tracing along the supply chain and throughout the entire lifecycle.



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