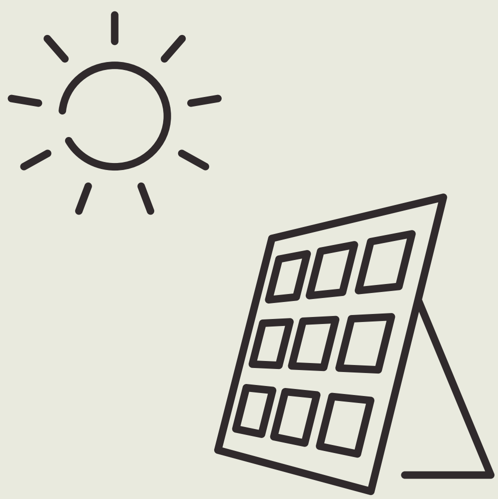
Global Innovation Needs Assessment

Solar power

November 1, 2021



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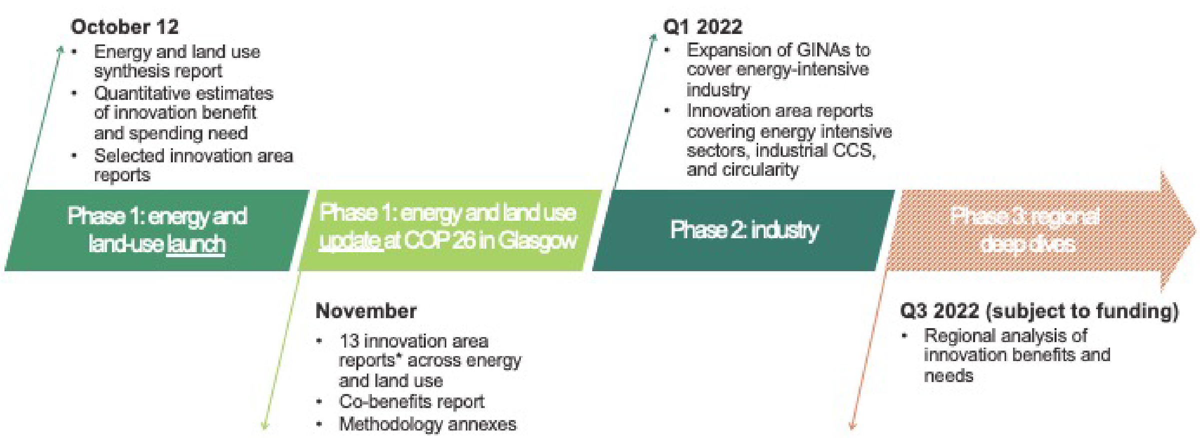
The Global Innovation Needs Assessments

The Global Innovation Needs Assessments (GINAs) is a first-of-its-kind platform for assessing the case for low-carbon innovation. The GINAs take a systemwide perspective, explicitly modeling the impact of innovations across the global economy. Uniquely, the analysis quantifies the economic benefits of low-carbon innovation and identifies the levels of public investment—from research and development to commercialization—needed to unlock these benefits. The analysis is divided into three phases: Phase 1, global energy and land use; Phase 2, global industry; and Phase 3, regional deep dives. This report is part of Phase 1's investigation of innovative technologies in the energy and land systems.

The analyses do not assess all relevant technologies, nor do they evaluate all relevant factors for policy judgments. Instead, the work is intended to provide a novel evidence base to better inform policy decisions. The Phase 1 analysis looks across a broad range of climate mitigation technologies in energy and land use, including demand response to protein diversification, to model the economic value of related innovation investment. Later phases expand the research. As with adoption of all technologies, including some controversial ones described in this report, there are risks and potential downsides. Technology investment is ultimately a policy judgment. This analysis provides no policy recommendations for that investment.

Phases of the Global Innovation Needs Assessments



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The findings and views expressed across here do not reflect the view of ClimateWorks, the Government of the United Kingdom, or Mission Innovation.

Phase 1 GINA outputs

The suite of reports across innovation areas, methodological annexes and a synthesis report for GINAs are available on the GINA website at https://www.climateworks.org/report/ginas/.

The suite of outputs for Phase 1 of the Global Innovation Needs Assessments

1. **Energy and land use synthesis report: slide-based summary for policymakers and executives**
   Synthesis of the findings across the innovations considered in energy and land use
2. **Innovation reports** – in depth quantitative analysis for industry and policy analysts

Energy

- **Wind power** – Offshore and onshore wind turbines
- **Low carbon hydrogen** – Electrolyzers and gas reforming with CCS
- **Solar power** – Utility-scale and distributed PV
- **Low carbon fuels** – 2nd generation biofuels, synthetic fuels ($H_2 + CO_2$)
- **Nuclear power** – Small modular and large-scale advanced reactors
- **System flexibility** – Battery storage, power-to-X, demand response
- **Buildings** – Heat pumps, building fabric
- **Power CCS** – CCS in power generation (coal, gas and biomass)
- **Zero-carbon road transport** – Battery electric vehicles, fuel cell electric vehicles

Land use & agriculture

- **Protein diversity** – Novel protein-rich food and feed
- **Decarbonizing agrochemical inputs** – Innovative fertilisers and pesticides
- **Yield enhancing technologies** – Digital agriculture and vertical farming
- **Irrigation** – Improved irrigation methods and systems

The selected innovation areas were selected for their potential for further innovation and the potential magnitude of the associated system benefits. Their selection here is because they could play a key role in a net zero pathway but does not imply that an optimal net zero pathway necessarily includes them. Further notes on the rationale behind their selection is provided in the methodology annex on the GINA website

3. **Co-benefits of innovation report** – qualitative analysis of the environmental and other non-economic benefits of net-zero innovation
4. **European case study** – analysis of jobs and growth benefits in Europe specifically
5. **Methodology annex** – description of the modeling approach

Executive summary

As electricity demand rapidly grows, large-scale solar photovoltaic (PV) will be key to decarbonizing the global energy system. Today, solar power accounts for roughly 2% of global electricity generated, with 707 GW of cumulative installed capacity in 2020. Modeling scenarios that limit warming to 1.5°C suggest that solar power generation needs to increase significantly to supply between 25% and 36% of global electricity by 2050, requiring installed capacity to increase to more than 8,000 GW. Given the required scale of solar PV deployment, even small reductions in the cost of the technology, which dropped substantially over the last decade, can have a large impact on energy system costs.

Increased innovation in and commercialization of solar technologies can reduce costs of utility-scale solar PV and distributed solar PV by 60% and 50%, respectively, by 2050. There are multiple ways to reduce capital and operating costs of solar PV, primarily through the application of advanced module materials, such as PERC cells and thin film, and innovative cell architectures, such as bifacial and half cells. In addition, new solar applications, including floating solar, and digitalization of operations and maintenance (O&M) processes could further increase solar PV deployment and operational efficiency.

Solar PV innovation and commercialization could reduce global energy system costs by US$170 billion per year (1.5% of total) on average between now and 2050. Innovation in solar power can benefit the energy system by reducing the cost of low-carbon electricity, thereby reducing the cost of decarbonization in many end-use sectors that rely on electrification to decarbonize, including industry, transport, and buildings. By 2050, the undiscounted value of cost savings could reach more than US$200 billion per year.

To realize the full benefits of low-cost solar PV, public spending on research, development, and deployment (RD&D) and commercialization of some US$5 billion per year and US$4 billion per year, respectively, is required. These sums are equivalent to more than double the current public RD&D spending on solar PV, which totaled US$2.2 billion in 2019. Most of the RD&D spending could be directed to development of technologies currently at the pilot stage, such as perovskites. Commercialization spending would help bring to market technologies that have already reached demonstration, such as PERC cells, as well as expand deployment of first-generation technologies through innovative applications and processes like floating solar. In addition to spending, governments can support solar PV deployment through a widened package of policies addressing market barriers. In particular, these policies could include improved permitting for solar developments, well-defined long-term targets and supporting schemes, adequate skills development, and robust carbon pricing.

Innovation in solar PV, in which annual investment is projected to reach more than US$300 billion by 2050, could be a valuable business opportunity for suppliers and developers across the value chain. By 2050, the gross value added (GVA) by the construction and operation of solar PV projects could be US$150 billion, and more than 1.2 million jobs for engineers, construction and factory workers, technicians, and safety experts could be supported. Gains across the economy are likely to be much larger as the upstream and downstream stages of the value chain, such as raw material suppliers, are included.

Public benefits (i.e., energy system cost savings)	Cumulative for 2021–2050, undiscounted: US$5 trillion Cumulative for 2021–2050, discounted at 5% per year: US$2 trillion Annual average for 2021–2050, undiscounted: US$170 billion
Business opportunities	2035: US$125 billion GVA, 1.7 million direct jobs 2050: US$150 billion GVA, 1.3 million direct jobs
Public spending required	Commercialization, annual average 2021–2035: US$4 billion RD&D, annual average 2021–2035: US$5 billion

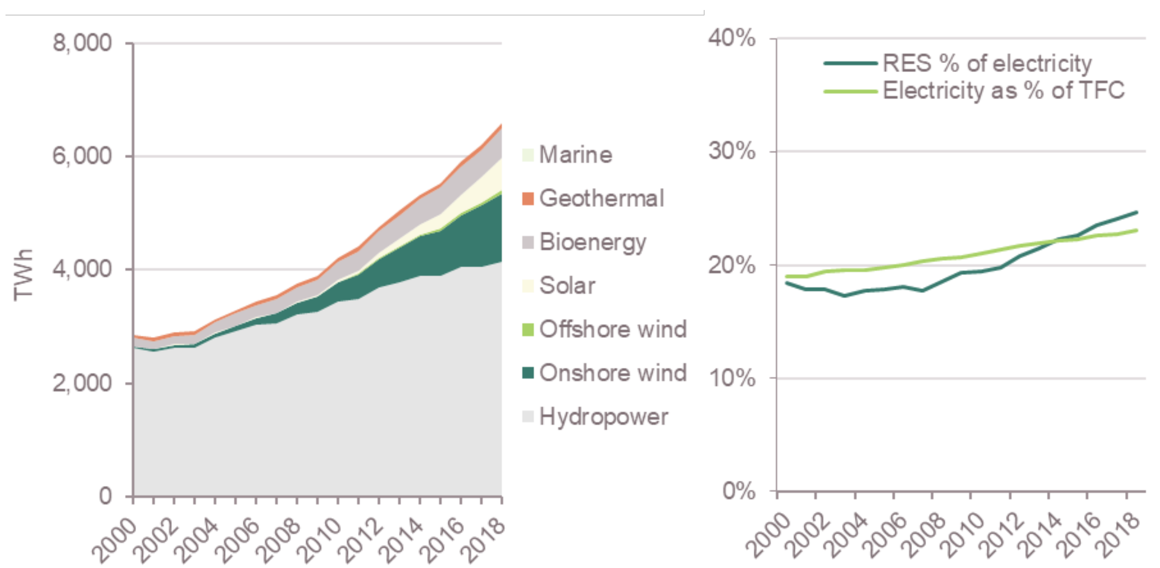
1. Solar power and the energy system

Current role in the energy system

Renewable electricity plays a key role in decarbonizing the power sector and the global economy as a whole. The power sector is a major source of emissions from the global economy: in 2018, it emitted roughly 13 $GtCO_2$, equivalent to 30% of global greenhouse gas (GHG) emissions. The combustion of fossil fuel sources accounted for 64% of electricity generation in 2018 and is the main contributor of emissions from the power sector. Renewable electricity can reduce the power system's reliance on fossil fuel sources and mitigate emissions. In 2018, electricity generation from renewable sources was 27% of total electricity production, up from 20% in 2010.

In 2019, solar power represented 9% of global renewable electricity production. Today, solar power accounts for about 2% of global electricity generated, with 707 GW of cumulative installed capacity in 2020 (IRENA 2021a,b). This capacity is concentrated mainly in Asia (331 GW) and Europe (132 GW) (IRENA 2020c). Most of it was installed in the last decade, thanks to a substantial period of growth for solar PV. In 2010, installed solar power amounted to less than 42 GW and provided just 0.1% of global electricity production. Utility-scale PV represents the bulk of new installed capacity. In 2019, more than 60% of the new capacity was represented by utility-scale PV; the remainder was residential and commercial PV (IEA 2019). The significant drop in solar PV costs largely explains the increase in solar PV capacity during the past decade: the weighted average total installed costs of new utility-scale PV capacity commissioned in 2019 was US$ 995/kW, 18% lower than in 2018 and 79% lower than in 2010. Similarly, depending on the geography, residential and commercial PV costs saw a decline in total installed costs of up to 86% between 2010 and 2019 (IRENA 2020d).

Figure 1. Global electricity generation from renewable energy sources (RES), 2000–2018.



Source: Vivid Economics based on IRENA (2020b) and IEA (2021a).

Future role and deployment potential

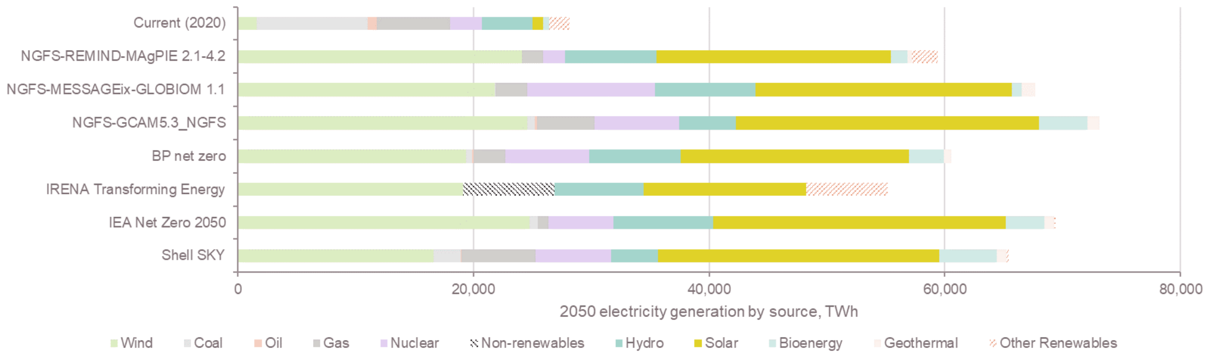
Global electricity demand is expected to more than double by 2050 as the energy system moves away from emission-intensive energy sources. System decarbonization will require electricity to partly replace emission-intensive energy sources across all sectors, including industry, transport, and buildings. By 2050, electricity generation could increase from 26,500 TWh today to 42,000–73,000 TWh (IEA 2021a). Renewable energy sources will play an important role in supplying low-carbon electricity to meet increased demand by 2050.

Across the scenarios that limit warming to 1.5°C, solar power generation increases significantly to supply 25%–36% of global electricity by 2050, up from about 2% today. Figure 2 below displays the 2050 electricity mix from a range of selected scenarios, all but two of which are compatible with the Paris Agreement. The scenarios vary in terms of the pace at which global emissions decline and in terms of the relative size of mitigations across sectors and energy sources. Despite these differences, solar power is consistently one of the major driving forces for electrification and power sector decarbonization: on average, annual solar power generation grows from 700 TWh currently to 22,000 TWh by 2050, meeting 35% of total electricity demand.

Meeting this level of increased solar power generation would require accelerated deployment of solar PV infrastructure. Total installed capacity of solar PV was 707 GW in 2020, a year in which 127 GW of new solar capacity was installed (IRENA 2021a,b). Achieving the level of solar power generation compatible with Paris-aligned scenarios could require installed capacity to increase to more than 8,000 GW by 2050, with annual solar installations of more than 240 GW on average between 2020 and 2050.

Given the scale of solar PV deployment in the future, any innovations that reduce the cost of solar power can help lower costs of the energy system significantly. Solar PV is a relatively mature technology that has experienced substantial cost reductions over the last decade. In many areas of the world, and especially in areas with high levels of solar irradiation, solar PV is already one of the cheapest sources of power available on the market. The scale of solar PV deployment required to achieve system decarbonization explains why even additional small technology cost reductions can have a large impact on system costs. Section 2 describes in greater detail the innovations with the greatest potential to reduce the costs of solar PV technologies.

Figure 2. Electricity generation by source in 2050 across selected scenarios compared to current generation levels.



Note: Shell Sky and IRENA Transforming Energy Scenario are below-2-degrees scenarios. The other scenarios shown are 1.5-degrees scenarios, generally featuring net-zero emissions between 2050 and 2060.

Source: Vivid Economics based on scenarios published by IEA (2021a), IRENA (2020b), BP (2020), Shell (2018), and NGFS (2021).

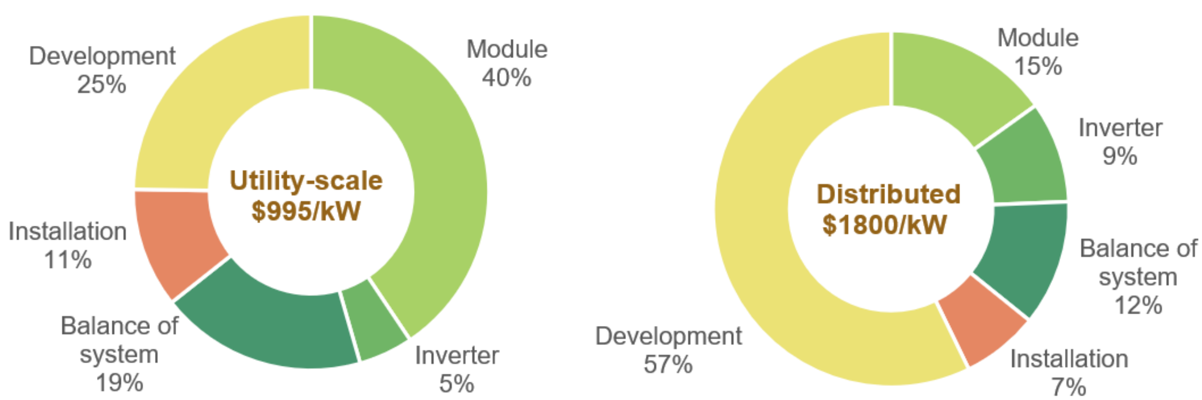
2. Innovation opportunities

Costs and deployment barriers

Capital costs represent most of solar power's lifetime costs; operation, maintenance, and decommissioning contribute to the remainder of costs. On average globally, capital expenditure for distributed PV is roughly 80% higher than that for utility-scale PV. Distributed PV is relatively more expensive primarily because of its smaller scale and higher costs of installation and development, including project planning and permitting. Capital costs can vary significantly by location, largely due to both differences in hardware costs, such as modules, and in soft costs of installation and development. A detailed breakdown of average upfront capital costs is presented in Figure 3.

Solar power costs decreased significantly in the past decade, but opportunity for further cost reductions exists. Solar PV's global levelized cost of energy (LCOE) dropped by 82% between 2010 and 2019. This decrease was largely driven by improvements in materials and manufacturing processes, lowered labor costs, and enhanced module efficiency (IRENA 2020d). Many opportunities to innovate and reduce costs of solar PV technologies remain, and experts suggest that upfront capital costs could be lowered an additional 70% by 2050 (IRENA 2019).

Figure 3. Breakdown of upfront capital expenditure of solar power, current estimates.



Source: Vivid Economics based on Feldman (2021).

Although solar installations have increased in recent years, new investments are still held back by barriers at different levels:

- **High capital costs and long payback periods** can hinder solar power's competitiveness, especially in regions that do not benefit from high levels of solar irradiation and financing support mechanisms. Further capital cost reductions can make solar PV more competitive with other sources of power generation across a wider range of geographies.
- **Grid development and integration** pose another technical barrier to solar developments. Because solar farms may be located far from centers of electricity demand, grid developments

can often be costly. Furthermore, the lack of adequate energy storage can lead to curtailment of solar power, hindering its integration into the energy system. The lack of grid flexibility limits the potential benefits of solar power, especially for users of distributed, small-scale PV.

There are other policy, regulatory, and market barriers to solar deployment, most notably barriers involving permits and regulatory frameworks. These barriers require policy action, but because they not directly related to innovation, they are not covered here.

Key innovations

Innovation in solar technologies can further reduce capital costs of utility-scale and distributed solar PV by 66% and 49%, respectively, by 2050. Table 1 below reports the cost reduction pathways to 2050 for both the high- and low-innovation scenarios, split into capital and fixed operating costs. The scenarios are constructed from an extensive review of cost reduction studies for utility-scale and distributed solar PV. Capital and fixed operation costs decline in the low-innovation scenario due to economies of scale, learning-by-doing, and near-term technological improvements. The high-innovation scenario sees additional cost reductions both in capital and operating costs to 2050.

Table 1. Utility-scale and distributed solar PV cost assumptions under high- and low-innovation scenarios

Technology	Cost component	2020	2050 low innovation	2050 high innovation	% further cost reduction under high innovation	% further LCOE reduction under high innovation
Utility-scale PV	Capex, US$m/GW	995	480	165	66%	61%
	Fixed Opex, US$m/GW/year	14	7	4.5	38%	
Distributed PV	Capex, US$m/GW	1,800	790	400	49%	49%
	Fixed Opex, US$m/GW/year	22	8	4.5	46%	

Source: Vivid Economics based on NREL (2020) and IRENA (2019, 2020d).

Advanced module materials offer many opportunities for efficiency improvements and cost reductions. Crystalline silicon panels are the most widespread PV panels with 95% of the market share worldwide. Innovative module materials, which are aimed at increasing cell efficiency and reducing costs, generally include PERC cells and thin film. PERC cells are advanced silicon-based cells that only recently entered the commercialization stage. Thanks to an extra layer of material, they are more efficient than conventional crystalline silicon panels. Thin film cell technologies can be silicon-based and non-silicon-based. The mineral perovskite, which falls into the latter category, is very good at absorbing light. It is roughly as efficient as silicon-based cells and can be cheaper to produce than those cells. Perovskite solar cells are currently at the pilot stage and will require further research and development before entering the market (IRENA 2019).

Advanced cell architecture can help increase efficiency levels. Using innovative cell and module designs, advanced architectures can improve the performance of a solar panel. Bifacial solar cells, half-cells, multi-busbars, and solar shingles are some of the most promising cell designs being developed to increase system output levels.

Other promising areas for innovation include solar application, O&M, and decommissioning:

- **Innovative solar applications can offer multiple advantages.** Applications such as floating solar or solar trees can help deliver increased solar capacity in areas with stringent land constraints. Others, such as building-integrated PV panels, use existing infrastructure to deploy solar panels and cut costs. Some PV applications combine electricity production with other activities. One example is agrophotovoltaic, which combines solar PV and agricultural activity on the same land.
- **Innovations in O&M can improve the PV system's performance and extend its lifetime.** Intelligent drones can be used to monitor large-scale PV plants with increased frequency and efficiency. This surveillance, combined with automated and predictive maintenance, can help quickly identify and fix performance issues at low cost. Advanced meteorological forecasting can help predict PV production and can help developers capture higher rents. Innovative coatings for PV modules can protect solar cells from external agents, such as water or heat, and can increase their lifetime, which is currently about 25 years.
- **Innovative decommissioning processes can lead to increased recycled materials and the creation of new industries.** Once a solar PV system reaches the end of its useful life, many of its materials and components can be reused to produce new PV panes or other products. This recycling can reduce the use of raw materials and increase the circularity and sustainability of the PV industry. In the long term, a growing market for secondary raw materials can potentially help create new industries and jobs in the waste management industry.

3. Benefits of innovation

Low-cost decarbonized energy

Lower energy costs are unlocked by the system benefits of innovation. System benefits of innovation refer to the net reduction in costs across the entire energy system as a result of increased RD&D *and* commercialization of technologies. In the context of this report, system benefits are calculated as the difference in the total system costs of a high-innovation scenario and those of a low-innovation scenario, whereby

- System costs are all capital, operating, and fuel costs within the global energy system[1]
- Low-innovation scenario represents market-driven progress with inadequate government support
- High-innovation scenario represents progress driven in part by government support of RD&D and deployment (i.e., commercialization) that accelerates cost reductions.

This metric provides an aggregate estimate of how innovations in selected technologies can reduce system costs after least-cost optimization of all energy carries and technologies from both the supply and the demand sides.

Innovation in solar power could reduce total energy system costs by US$170 billion per year (1.5% of total) on average between now and 2050. In both low- and the high-innovation scenarios, global energy system costs start at around US$10 trillion a year in 2021, then begin to diverge after 2025, when savings in the high-innovation scenario are already US$80 billion a year. Savings peak at US$350 billion per year in the 2040s, when the bulk of the expected solar cost reductions have been achieved. Table 2 presents system benefits of high innovation solar power across all years to 2050 and the yearly average.

Table 2. System benefits of innovation in solar power

System benefits	2021–2050, cumulative, undiscounted	2021–2050, cumulative, discounted 5%	2021–2050, annual average, undiscounted
High innovation in solar PV	US$5 trillion	US$2 trillion	US$170 billion

Note: Discounting reduces the present value of future benefits. *Source:* Vivid Economics.

[1] System benefits may be calculated on an annual basis or cumulatively between 2020 and 2050 (with or without discounting).

Innovations in solar power, like innovations in other renewable energy technologies, benefit the energy system by lowering the costs of low-carbon electricity. As PV technology costs decrease, solar power can advance in merit order and become cost-competitive with other forms of electricity production, such as coal or natural gas, potentially displacing them. The higher availability of cheap forms of electricity production can reduce the electricity price overall. This price decrease can influence the entire energy system through three main channels:

1. **Reduced cost of electrification in end-use sectors**

   All end uses of electrons can benefit from reductions in the cost of electricity. For example, in the passenger transport sector, the total cost of ownership of an electric vehicle can decrease and savings for consumers can increase. In addition, low-cost electricity can increase the cost competitiveness of electricity-based end uses that would otherwise be uncompetitive with their fossil-fuel-based counterparts. For example, studies on the maritime shipping sector suggest that reducing the cost of electricity from US$ 0.07/kWh to US$ 0.02/kWh can reduce the cost premium of an electric bulk carrier by 4% compared to its conventional counterpart (Energy Transitions Commission 2018).

2. **Reduced cost of fuel production (e.g., hydrogen)**

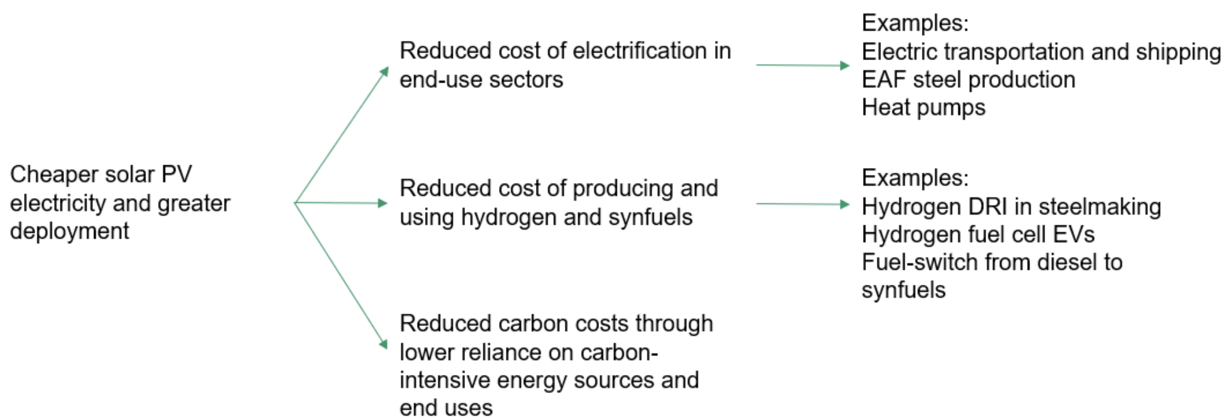
   Reduced costs of electricity can reduce the cost of electrolysis and increase the cost-competitiveness of green hydrogen. Similarly, cheaper electricity can reduce the cost of synthetic fuels production, which requires hydrogen. Cheaper hydrogen and synthetic fuels can reduce the operating costs of all their end uses in many sectors, including industry, transport, and heating and cooling.

3. **Reduced carbon costs**

   The wider availability of cheap sources of low-carbon power can help displace carbon-intensive sources of power and end uses, reducing the cost of carbon emissions. The displacement of carbon-intensive power sources and end uses can deliver savings on the cost of carbon emissions associated with those sources and uses, and those savings can increase as the carbon price in place increases.

The benefits to the wider energy system from cheaper solar power can be partly offset by higher needs for transmission and storage capacity, which increase total system costs. Solar PV modules are most cost-effectively located in areas with a high supply of solar energy. These locations can be far away from centers of electricity demand, such as big cities. Therefore, as solar PV capacity increases, the system will require additional transmission lines to connect solar power supply with centers of demand as well as require greater electricity storage to limit curtailment and provide electricity at times of low renewable supply. The cost of additional transmission lines and storage capacity would increase total system costs.

Figure 4. Impact of innovation on the energy system.



Source: Vivid Economics.

Jobs and Growth

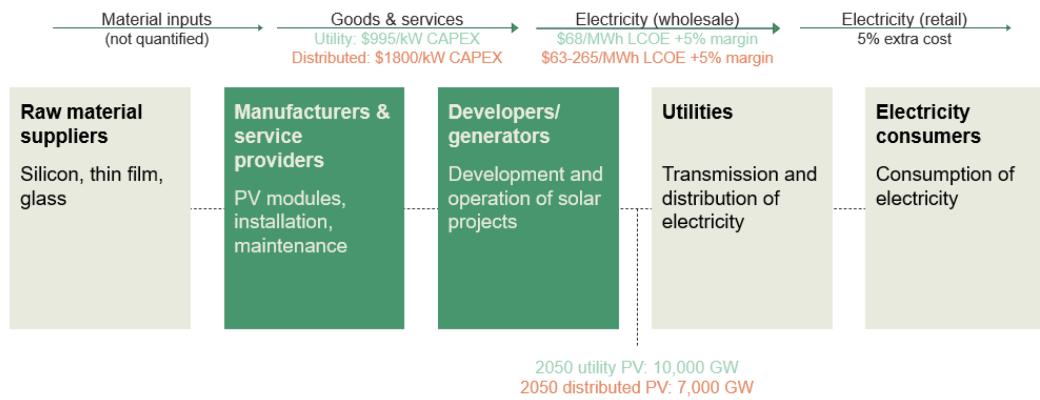
The solar PV market already provides substantial opportunities for businesses and attracts some US$150 billion of investment every year. The solar PV market has substantially expanded in the last decade, going from 42 GW of installed capacity in 2010 to more than 580 GW in 2019 (IRENA 2019). This growth has led to a significant increase in global investment in solar PV: of the US$800 billion invested in the power sector globally in 2020, the solar PV sector attracted roughly US$150 billion, up from US$100 billion in 2010. Technology innovation and reduced costs increased the productivity of investment over time: Estimates suggest that a dollar spent on solar PV deployment in 2020 is associated with four times more output than a dollar spent on the same technology in 2010 (IEA 2021b).

Rapid solar PV deployment could significantly increase annual investment in solar power to US$330 billion by 2050. Studies suggest that the annual investment in renewables required to achieve an energy mix compatible with a 1.5°C pathway may need to almost triple from US$322 billion today to US$797 billion (IRENA 2020a). With capital cost reductions, solar PV could replace more expensive energy sources. Paired with continued economies of scale, these cost reductions could further increase the market size of solar PV. By 2050, cumulative solar PV capacity could reach more than 13,000 GW, with a corresponding investment opportunity of US$330 billion in that year.

An expanding PV market could benefit suppliers and service providers across the value chain. Raw material suppliers can benefit from increased solar PV penetration through the increased demand for polysilicon and other materials, although innovations in the reuse and recycling of decommissioned PV systems could partly counteract this tendency. Manufacturers and service providers can capture a large share of the business opportunity by producing and installing a larger number of PV systems at lower costs. Developers of solar projects can sell larger quantities of solar-generated electricity to utilities and consumers at the retail price or through power purchase agreements (PPAs). As deployment of distributed PV accelerates, business models such as net billing will be important to support the expansion of distributed energy resources while guaranteeing revenues to suppliers.

A large share of the private benefits from an expanded solar PV market could be concentrated in Asia. By 2050, more than half of global PV capacity could be located in Asia, with China hosting the bulk of capacity (IRENA 2019). An expanded local PV market will greatly benefit local solar PV developers. However, large opportunities could come from the upstream solar supply chain in which China holds a dominant position, controlling 64% of polysilicon material worldwide, 80% of the market share for solar cells, and 75% of the market share for solar modules (Rapoza 2021).

Figure 5. Simplified value chain for solar power.



Note: The blocks in dark green represent the scope of business opportunities quantified in this section.
Source: Vivid Economics.

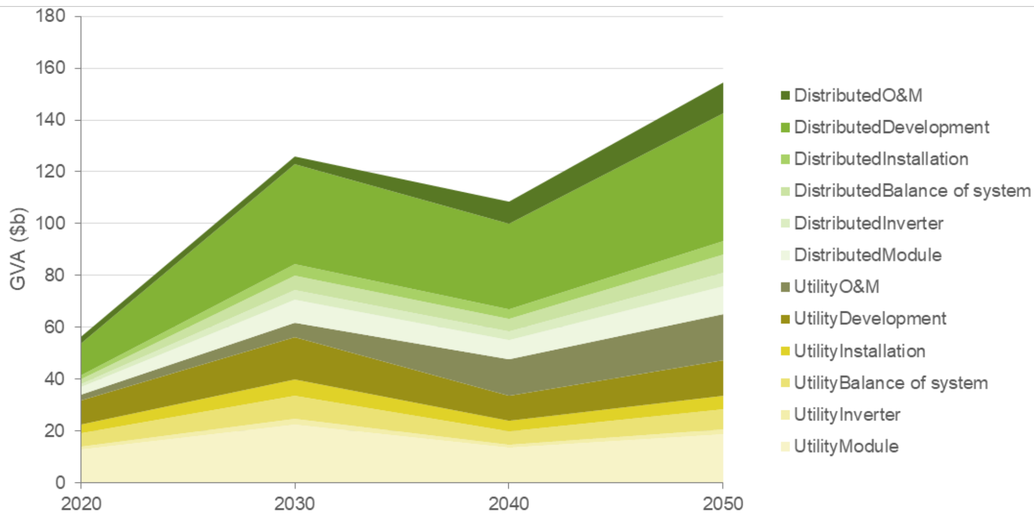
By 2050, innovation in solar power could support a direct GVA of more than US$150 billion per year in construction and operation alone. More than US$60 billion of this GVA could be associated with the development phase of new solar PV projects, particularly distributed PV, which accounts for some 60% of the total value generated in 2050. The value related to operation and maintenance starts growing in the 2030s, when substantial new capacity has already been deployed, and it accounts for 20% of the total value by 2050. The trend by cost component is described in detail in Figure 6.

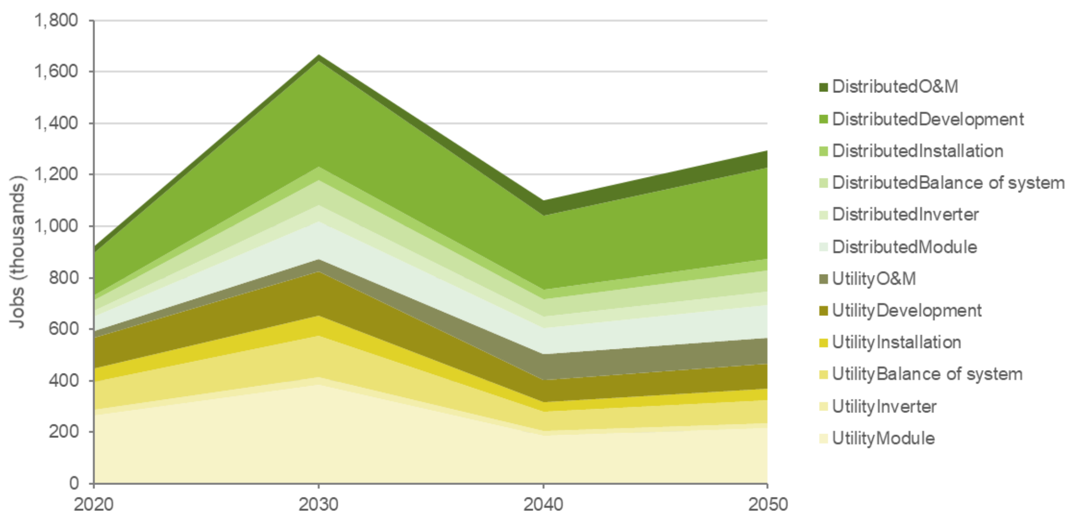
Deployment of solar power could directly support more than 1.2 million jobs in the construction and operation of solar projects.[1] The PV industry can support a range of jobs and skills across its value chain, but particularly in the part of the supply chain that is trade-exposed and highly innovative. Capturing the market share in this part of the supply chain could translate to secure industry development and long-term employment opportunities for engineers to develop solar projects and components, construction and factory workers to manufacture PV equipment, and technicians and safety experts to install and maintain solar systems over their lifetime. Most of the demand for labor-intensive development and maintenance services will likely come from the distributed PV sector, where economies of scale are limited and innovations in maintenance (e.g., predictive maintenance) are not economical to adopt. The solar PV value chain can also support jobs upstream and downstream of that chain. For example,

[1] These estimates focus only on the construction, operation, and maintenance of solar projects, which is where key innovations occur. While solar power could support further economic activity in the value chain, they are excluded from the scope of this analysis.

development of a 1MW solar PV plant could require more than 200 tons of raw materials, suggesting that jobs in the supply chains for these materials could also benefit from growth in the solar PV sector.

Figure 6. GVA and jobs directly supported by global deployment of utility-scale and distributed solar PV.





Note: Employment declines relative to GVA due to assumed productivity growth in the solar industry.
Source: Vivid Economics.

4. The case for supporting innovation

To realize the full benefits of low-cost solar power, public spending on RD&D and commercialization of US$5 billion per year and US$4 billion per year, respectively, is required. These sums are equivalent to more than double the current public RD&D spending, which totaled US$2.2 billion in 2019 (FS-UNEP Collaborating Centre 2020). Most of the RD&D spending could be directed to development of innovative module materials that are currently at the pilot stage, such as perovskite solar cells and other innovative thin film cell technologies, and to advanced cell architectures, such as tandem and hybrid cells. Commercialization spending would help bring to market technologies that have already reached the demonstration stage, such as PERC cells, as well as expand the deployment of first-generation technologies through innovative applications and processes. These technologies include floating solar applications, automated and predictive module maintenance, and innovative decommissioning processes.

Although sizeable, the required RD&D and commercialization spending is small relative to the benefits. Modeling scenarios suggest that innovation in advanced fuels, enabled by government RD&D and commercialization support, could bring on average US$170 billion in system benefits between 2020 and 2050. RD&D and commercialization spending by the public sector is, therefore, only about 5% of annual benefits.

Without strong government support for innovation, progress within the solar industry will slow down. The solar PV industry witnessed substantial cost reductions over the past decade. These reductions were the result of economies of scale and improved business models, but most of all the result of the introduction of cheaper, more efficient modules and supporting infrastructure. Solar PV is already competitive with many other power generation technologies, and the industry could still grow in the absence of innovation. However, the pace at which solar PV is deployed would slow down without the introduction of innovative technologies and processes. Furthermore, the projected scale of solar deployment in the future justifies spending for any innovations that can reduce solar PV costs because these innovations can help substantially lower costs to the energy system.

Government action is needed to create an enabling environment that addresses market barriers and facilitates the entry of private investors. Improvements in the permitting process to install solar infrastructure and connect it to the electricity grid could reduce costs and timelines for project developers, especially new market entrants. Setting well-defined, long-term targets and supporting schemes for deployment can reduce investment risk and costs, ensuring greater visibility for private investors. Furthermore, adequate support for skills development–especially in the areas of materials engineering, system design, installation, and maintenance–could help increase the pool of skilled labor and reduce the talent search cost that solar developers face.

Government support for RD&D and commercialization will need to be accompanied by pull policies that ultimately drive deployment. Pull policies drive deployment and, hence, elicit innovations. These policies may include carbon pricing or renewable obligations favoring solar power over fossil fuel power generation. An effective combination of policies can ensure that sufficient investments in solar innovations are deployed rapidly to achieve cost-effective decarbonization of the energy system at scale.

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