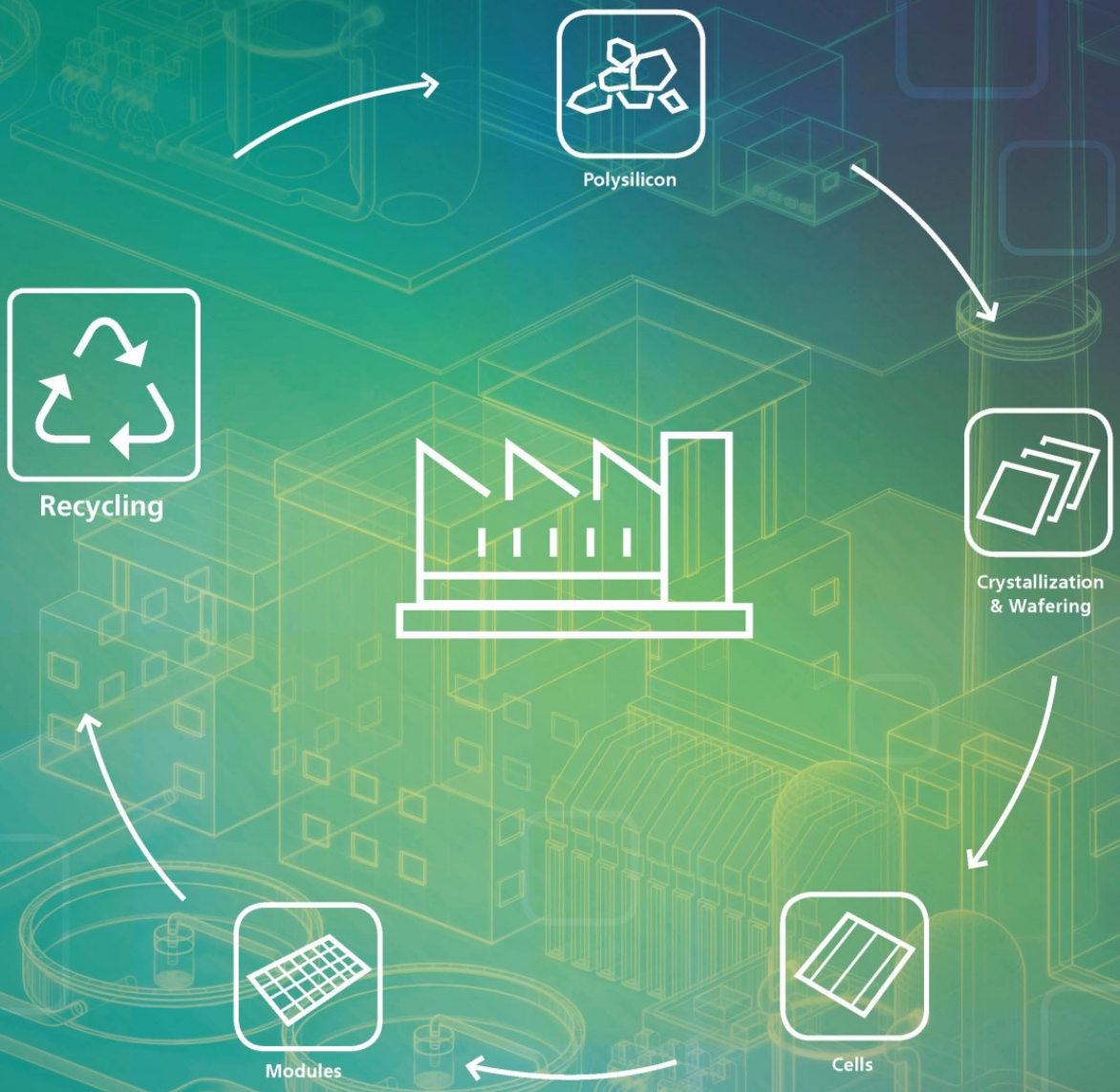
Sustainable PV Manufacturing in Europe



An Initiative for a 10GW GreenFab

Photovoltaics and Climate Change

At the COP21 event held in Paris in 2015, the world debated how to deal with the challenge of climate change due to the CO_2 increase in the atmosphere. The COP21 debates resulted in a milestone that almost all governments worldwide agreed upon: to limit the temperature increase to 1.5 °C. This in turn means that the **transition of the energy system from fossil to renewable energy sources must be accelerated**. Almost all energy system scenarios show that photovoltaic (PV) technology will be the main pillar of the future energy supply.

Photovoltaic technology is the key to solve the challenges arising from climate change.

Market and Photovoltaic Production

Due to this fact the PV market will grow rapidly; up to 12 TW[1] are expected to be installed in 2030 worldwide[2]. This is an impressive increase compared with today's installed capacity of about 630 GW. Many countries have just started to install PV on a larger scale. Thus, **the PV market is a great opportunity for the manufacturing industry**. Europe was leading the manufacturing of PV at the beginning of the 21st century and is still leading today in the field of R&D. However, since 2007 China has been much more successful in setting-up PV production capacity since the Chinese government recognized the strategic and political impact which the leadership in a technology with such a gigantic market growth would bring. Chinese companies received strong support while Europe lost its leadership position in PV production. A chance still exists, however, for Europe to play a role in this big future market. **Now is the right time to invest in PV manufacturing in Europe**, especially since more PV must inevitably be installed in order to fulfill the climate goals agreed upon in Paris. Further cost reduction, new business models and progress in system and battery technologies will lead to more PV installations in Europe. Hence, **the European home market must and will grow substantially beyond several tens of GW per year** as many analyses confirm[3].

The global and European photovoltaic market will grow rapidly and covers a multi-billion market volume.

[1] 1 TW = 1.000 GW = 10^{12} Watt = 1.000.000.000.000 Watt

[2] C. Breyer et al., On the role of solar photovoltaics in global energy transition scenarios, Progress in Photovoltaics 25 (2017)

[3] See for example: H.-M. Henning, A. Palzer, What will the Energy Transformation cost? Pathways for Transforming the German Energy System by 2050 (2015); Solar Power Europe, Global Market Outlook 2019-2023 (2019)

PV Production and Sustainability – New High-Tech Solutions

Europe should use this chance to cover a large share of its domestic energy market with European products. This is not only a big opportunity for high-tech manufacturing in Europe, but also **a chance to ensure energy security by reducing dependency on imports in the sensitive field of energy generation.** Another crucial factor is sustainability. Why transport large and heavy PV modules the long distance from Asia and cause CO_2 emissions and adding cost? For example, module costs of 20 €cents/W can be soon realized, and transport costs from China to Europe can be up to 2.5 €cents/W. Moreover, during the production sequence of the PV modules, CO_2 and other environmentally harmful emissions occur. These emissions need to be minimized and in Europe strict controls are already now imposed for this purpose. Thinking about cycling economy, cradle-to-cradle, and recycling concepts, Europe is predestined to introduce real sustainability into the energy system and provide real »green« energy[1]. Furthermore, the global demand for solar products is going to reach massive volume with the emergence of markets in all countries of the world. By taking a leading role in providing the world with sustainable PV products, Europe would secure its economic future and will be the source for premium products[2].

This vision of high-tech and sustainable PV production along the value chain in Europe can become reality since R&D centers in Europe already provide efficient and more **sustainable technologies** compared to today's world market products. For example, there is progress for manufacturing poly-Silicon and wafers more sustainable using less energy. Kerfless wafer technologies are under development in the R&D centers. Higher efficiencies for solar cells – which reduce the area required – for different cell technologies are available and ready to be transferred into industrial production. Moreover, tandem solar cell structures are progressing fastly and achieved already higher efficiencies than single-junction solar cells. For PV modules, technologies reducing the cell-to-module losses are ready for production. All these technologies are more sustainable than today's PV products and require fewer resources, but are at the same time cost competitive on a system level.

Manufacturing of PV modules in Europe means:

- secure independency from imports in the energy sector
- address a huge market in Europe
- create and secure jobs
- produce sustainably
- provide high-tech products

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[1] The European Commission has recently underlined its ambition for a cleaner and more competitive Europe through the *Circular Economy Action Plan* (2020).

[2] See also *A New Industrial Strategy for Europe* (COM(2020 102 final). PV needs to play an important role in addressing the ecological and digital transition of the European industry to ensure Europe's sovereignty.

Supporters

Company/ R&D Organisation	Address
ACI Systems GmbH	Albring 18 78658 Zimmern o. R. Germany
acp systems AG	Albring 18 78658 Zimmern o. R. Germany
AZUR SPACE Solar Power GmbH	Theresienstrasse 2 74072 Heilbronn Germany
cire Cologne Institute for Renewable Energy	Faculty of Process Engineering and Mechanical Systems Betzdorfer Strasse 2 50679 Cologne Germany
Helmholtz-Zentrum Berlin PVcomB	Schwarzschildstrasse 3 12489 Berlin Germany
Hennecke Systems GmbH	Aachener Strasse 100 53909 Zuelpich Germany
IBC SOLAR AG	Am Hochgericht 10 96231 Bad Staffelstein Germany
IEO - Institute for Renewable Energy	Fletniowa 47B 03-160 Warsaw Poland
IPVF	18, boulevard Thomas Gobert 91120 Palaiseau France
ISC Konstanz	Rudolf-Diesel-Strasse 15 78467 Konstanz Germany
Jonas & Redmann Group GmbH	Kaiserin-Augusta-Allee 113 10553 Berlin Germany
M10 Industries AG	Munzinger Strasse 10 79111 Freiburg Germany
NexWafe GmbH	Hans-Bunte-Strasse 19 79108 Freiburg Germany
Polish Industrial PV Platform (Bruk-Bet, Hanplast, ML System, Corab)	Mokotowska 4/6 00-641 Warsaw Poland
RCT Solutions GmbH	Line-Eid-Strasse 1 78467 Konstanz Germany

Rena Technologies GmbH	Hoehenweg 1 78148 Guetenbach Germany	
ROSI return of silicon	PEI – Bâtiment Galilée 1270 rue de la Piscine 38400 Saint-Martin-d'Hères France	
Singulus Technologies AG	Hanauer Landstraße 103 63796 Kahl am Main Germany	
Wacker Chemie AG	Hanns-Seidel-Platz 4 81737 Muenchen Germany	

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Annex

In the following details and background information are presented to underline the idea of a 10 GW GreenFab.

Realization

In order to compete in the world market, it is important that Champions can emerge. This includes, among other things, a sufficient size. Therefore, a production size of 10 GW is proposed, which is then continuously expanded. The creation of photovoltaic production along the value chain from wafer to module would create **up to 7,500 new jobs** and continue to provide many jobs in the supply industry that could be lost in the medium term if no PV manufacturing is set up in Europe. These jobs are long-term. In addition, the installation of PV systems creates additional jobs. The installation of 1 GW per year corresponds to about 3,500 full-time jobs.
Thus, the **high-tech production of PV modules along the value chain brings benefits for Europe as a whole - and for regions where industrial production is located in particular**.
Sites where structural changes are pending for political reasons or which are to be developed in terms of industrial policy are particularly suitable as a nucleus for a 10 GW PV production. Locations are conceivable where local characteristics are given, e.g. in the coal regions in North Rhine-Westphalia or Lausitz or in Croatia, where there is a national interest in promoting industrial sites.

The Multi-Regional Approach

The 10 GW GreenFab can be also realized by combining different sites with at least 1 GW manufacturing capacity each. This would allow to receiving regional local support. Each single manufacturing site can be a copy of the others. In any case it is important that the purchase, sales and administration is in one hand. This multi-regional approach allows also including already existing sites into the 10 GW GreenFab concept. For the realization of this approach the EU has to consider the PV sector as Strategic Value Chain and go towards IPCEI.

Investment need, area and staff requirements

	CAPEX in M€	Total manufacturing area	Staff 24/7 (5 shift)
Ingot/Wafer	570	210,000 m²	max. 2,100
Cell	970	140,000 m²	max. 2,700
Module	395	150,000 m²	max. 2,700
Total	**1,935**	**500,000 m²**	**max. 7,500**

Estimation of investment, area and staff requirement for a 10 GW PV factory. (Source: Fraunhofer ISE, Estimated data by scaling up from a factory size of 1 GW)

Frequently Asked Questions

The European solar cell and module manufacturers have all disappeared from the market. The production for mass products takes place in the Asian region. Can Europe really compete with cheap production?

PV production technology has been undergoing rapid innovation cycles. This is the reason why strong cost and price reductions in the photovoltaic sector have become possible. Since 2007, when Europe was still the market leader in PV production, efficiency has increased by 40 %, productivity by 400 % and global production capacity by 40 times. This is a merit of the PV producers, based to a large extent on the innovations in mechanical engineering and material manufacturing, a process which constantly needed new investments. The required financial flows for investments were provided in China. European companies could not keep up and have therefore disappeared from the market. It should be noted that also in China many companies have disappeared from the market and the PV market leader changes almost every year.

Technologically, Europe is still leading, and also mass production is possible in Europe, as the automotive industry demonstrates. Thus, there is no reason why mass production should not take place in Europe at world market prices[1].

Existing »old« companies in Europe (as the SolarWorld example shows) were unable to streamline their internal structures and respond dynamically and agile to the rapidly changing market. With a restart of PV production in Europe, there is no »inherited burden«.

Why should European companies now succeed in the market?

Today's production of PV products is fully automated – also in China and other Asian countries. The personnel costs are thus negligible during production. Yield and quality assurance are at the highest level in Europe. Therefore, PV can be produced at the same low cost as in the Asian region. A decisive prerequisite for success is full integration from the wafer to the module (ideally up to the energy supplier as operator of PV power plants). This means independence from purchasing components as wafers and cells. It is also a prerequisite that the purchase for large quantities (10 GW) takes place centrally.

In addition, the modules are currently being produced at costs of 25 €cents/W. With further innovations 20 €cent/W will be possible. As a result, the overall cost distribution shifts – especially in the direction of logistics. Therefore, local and fully integrated production is an advantage. At the same time, local production enables strategic autonomy in the energy sector, as requested, for example, by Maroš Šefčovič as a member of the European Commission.

Why sustainability? Does this make the module more expensive?

Sustainability includes energy and resource efficient production technology which aims for higher efficiencies and lower material consumption, a longer lifetime for modules and the most complete reuse of materials at the end of their lifetime. If this is taken into account from the beginning in the planning of a production as well as in the cell and module design, the PV module will not be more expensive. Ultimately, the reduced use of materials and energy will make it possible to cut costs overall.

[1] See: http://pv.vdma.org/en/viewer/-/v2article/render/39286041

What has changed since previous initiatives, such as the x-GW initiative in 2013/14?

Ultimately, the x-GW concept is still right. However, with a meanwhile grown market it turns out that x should rather be 10, meaning that a size of 10 GW should be implemented as a first step. This size makes sense for global competitiveness today.
What has also changed is that the CAPEX costs have fallen significantly in recent years and that the Al-BSF cell structure has been replaced by the highly efficient PERC structure in industrial production. Further cell architectures with even higher efficiency potential have been developed in European laboratories and are thus available for industrial implementation.

The already significant cost reduction and the prospect of even further reducing the cost in PV production leads to the conclusion that local production can bring cost advantages. This is a new development.

Furthermore, the reduction of CO_2 emissions is even more strongly on the agenda of all countries. This can only be done with wind and PV technology. To meet this goal, the PV market – including in Europe – will have to grow substantially. That is why now the right time to invest is. The local market will be available for the take-off of the products.

Is it possible to find investors for a 10 GW GreenFab?

The initiative is intended to awaken politics, society and the economy, and to point out the commercial opportunities for investors. No investment is without risk. However, the boundary conditions have changed a lot in recent years. The initiators are ready to work out concrete business plans with investors.

The initiative has a strong political and strategic aspect because the independence and security of energy supply is a central concern of society. It is necessary to create framework conditions that provide sufficient security for investors.

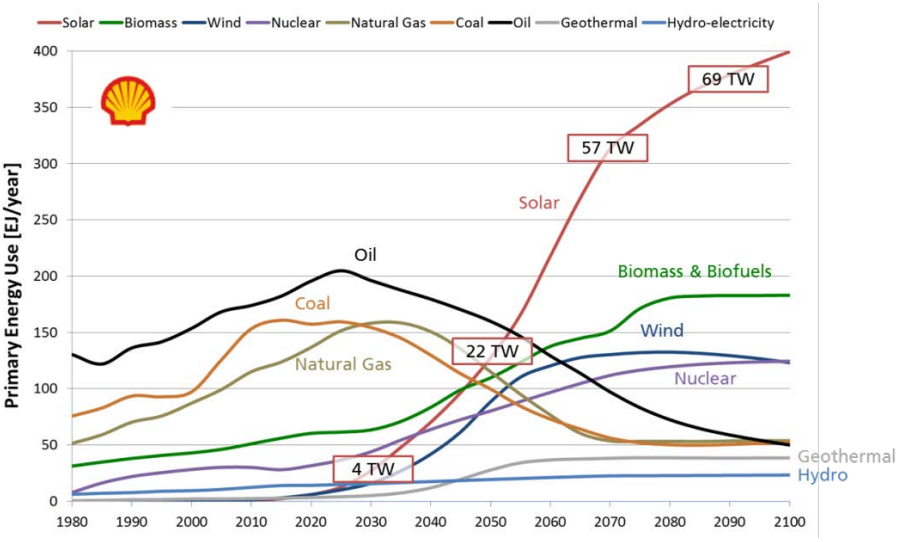
The European market will grow substantially with or without the 10 GW GreenFab. The question though is, if modules are being produced 100% outside of Europe or if at least part of the market will be served by local European production. Also for an Asian PV manufacturer an investment in European production could be strategically important to avoid transport cost and cost possibly arising for products with higher CO_2 footprints.

PV technology has already proven today that it is the cheapest and most sustainable source of energy in every respect. If it is possible **to work out a coordinated implementation concept via the European Commission through cooperation between countries** (such as France-Germany, Germany-Poland, Croatia-Germany ...) and other regions, and considering the today´s overall political situation, **the chances high to find investors**.

Background Data and Facts

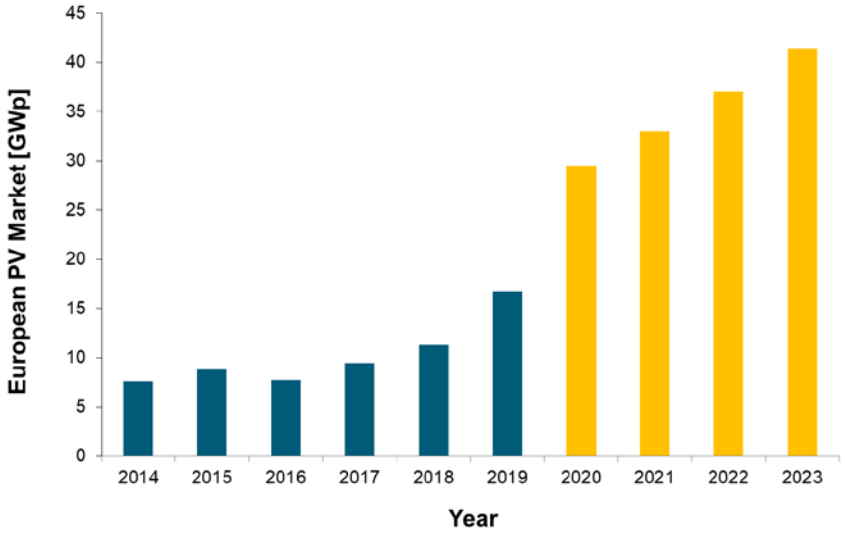
In the following, some relevant facts are shown which underline the potential of a 10 GW GreenFab.

Market



The Sky scenario created by Shell illustrates how the primary energy deployment could develop worldwide by 2100. Ultimately, PV technology will be central to the global energy supply. It will thus create a very large market. Today we are only at the beginning of development. (see: https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/shell-scenario-sky.html)

Many scenarios, for example from Solar Power Europe also expect a strong growth of the European PV Market already in the short term. The main drivers being the binding national targets for renewable in many EU-28 countries leading to high tender volumes, the strong price decrease due to the restructuring of the Chinese market as well as activities of utilities, corporates, and big funds in Europe who invest in PV as both the lowest cost and most versatile energy generation source.



European annual solar PV market and scenario until 2023 (Source: Solar Power Europe). The expected growth of the European market is also underlined by the national targets. Some of those are listed in the following.

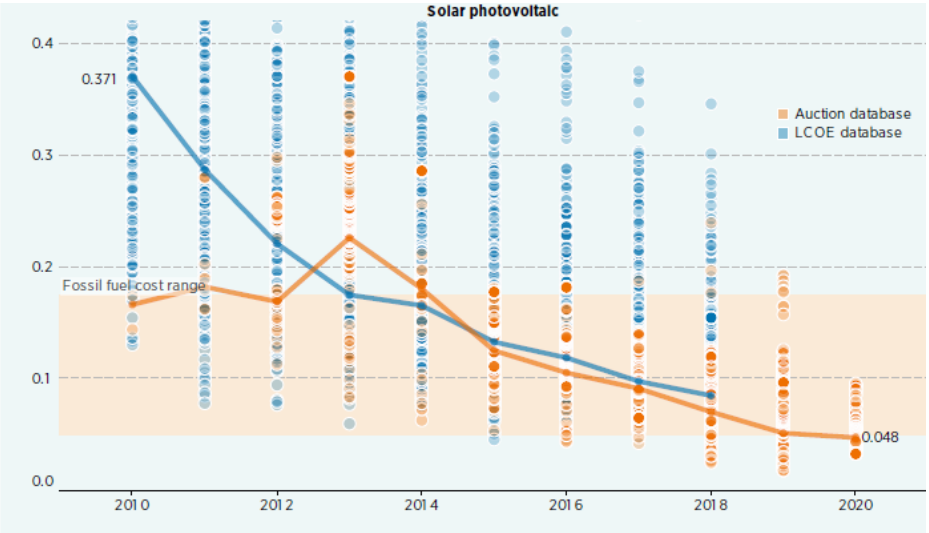
Announcements in respect to the French market:
11.Dezember 2017: EDF announces 30 GW plan for France
https://www.pv-magazine.com/2017/12/11/edf-launches-30-gw-solar-plan/
29. Juni 2018: Total announces 10GW plan for France
https://www.pv-magazine.com/2018/06/29/france-makes-room-for-solar-total-announces-10-gw-plan/
28. September 2018: The newly released energy strategy of France expects 17.2 GW PV installations till 2025.
https://www.pv-magazine.de/2019/01/28/frankreich-schreibt-172-gigawatt-photovoltaik-bis-2025-aus/
23. April 2020: France makes 44 GW solar target official.
https://www.pv-magazine.com/2020/04/23/france-makes-2028-solar-target-official/

German market
Currently, installations of up to 2.5 GW/year are planned. This installation capacity is not sufficient to meet the CO_2 targets. Therefore, this cap is currently in the political discussions. As agreed within the framework of the formation of the government, an additional 4 GW photovoltaic will be realized in special tenders from 2019 to 2021. Actually a limit for up to 2.5 GW per year is seen. https://www.solarserver.de/solar-magazin/nachrichten/aktuelles/2018/kw45/bundeskabinett-beschliesst-sonderausschreibungen-und-20-prozent-degression-fuer-photovoltaik.html
31. January 2020: Germany added almost 4 GW of PV in 2019
https://www.pv-magazine.com/2020/01/31/germany-added-almost-4-gw-of-pv-in-2019/

Dutch market
In the Netherlands, in 2018, the gigawatt mark was exceeded for PV new installations for the first time, resulting in a total installed capacity of 4 GW. It is expected to reach 9 GW by 2020, 15 GW by 2023 and 27 GW by 2030.
https://www.pv-magazine.com/2019/01/09/netherlands-a-gigawatt-solar-market/
https://www.pv-magazine.com/2019/11/04/netherlands-to-reach-27-gw-of-solar-by-2030/

Spanish market
Strong cuts in PV production led to a sharp decline in PV installations in Spain in the late 2000s. Now a turnaround is emerging: The Spanish government aims to provide 35 % renewable energy by 2030, which will require around 50 to 60 GW of photovoltaic power. Currently there are about 8.7 GW installed in Spain, of which 4 GW were added in 2019.
https://www.pv-magazine.com/2018/11/09/nothing-can-stop-spains-solar-train-now/
https://www.pv-magazine.com/2020/01/27/spain-reaches-8-7-gw-of-cumulative-solar/

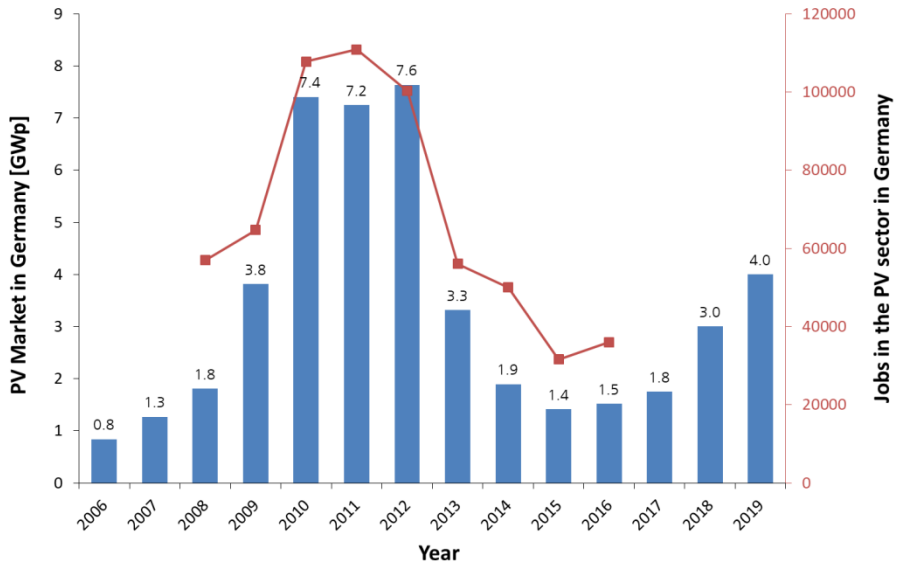
Prices for PV Produced Electricity



Levelized Costs of Electricity (LCOE) in US$/kWh for solar PV projects. Source: Future of Solar Photovoltaics, Report, IRENA, 2019

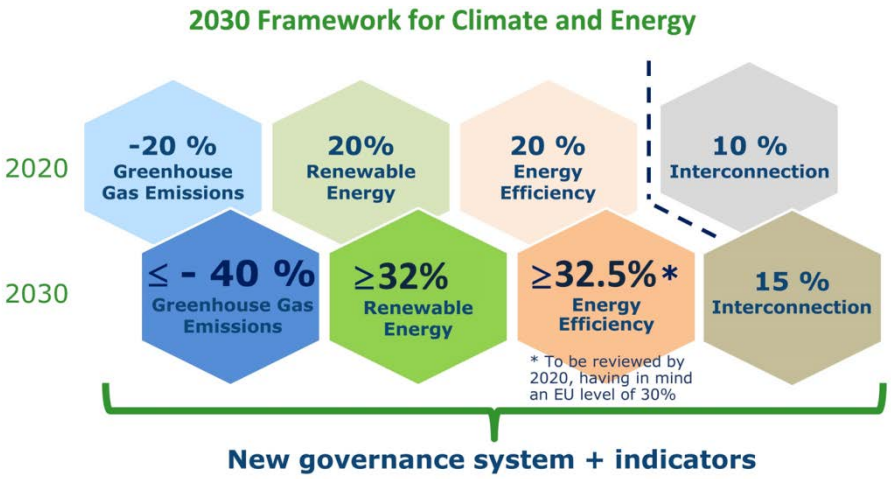
The graph shows Levelized Costs of Electricity (LCOE) in US$/kWh for projects and global weighted average values for solar photovoltaica. PV electricity has seen a very significant price reduction. Prices below coal and nuclear power generation are possible. This makes PV power competitive! In the last years tenders for energy installations were implemented where PV power was by far the cheapest form of energy. Due to the low electricity production costs of PV, the market for PV will grow and new markets will open up.

Job Creation

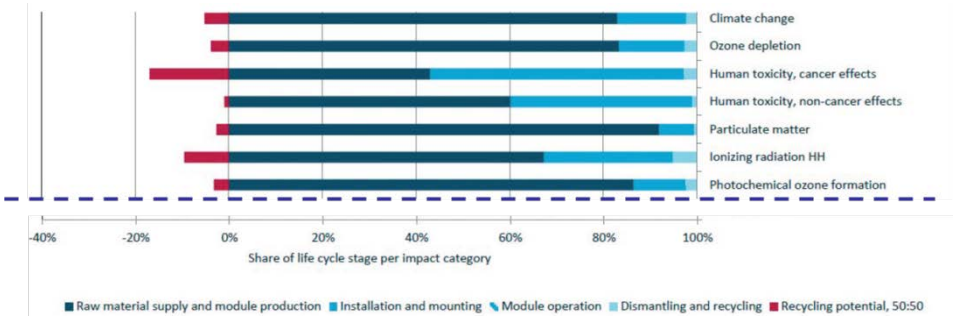


Correlation between PV domestic market and job creation: A growing PV market in Europe will foster a high number of jobs in Europe. (Data 1990-2016: Jobs BSW-Solar, Market: BNA; 2017-2019: IHS)

Aspects of Sustainability

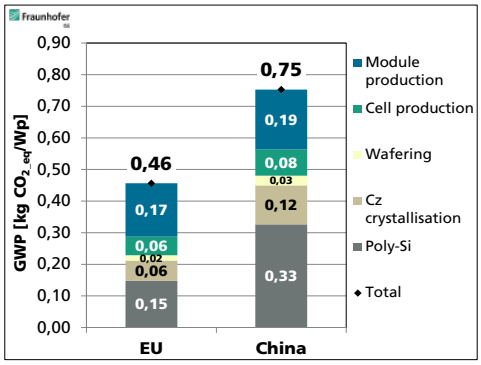


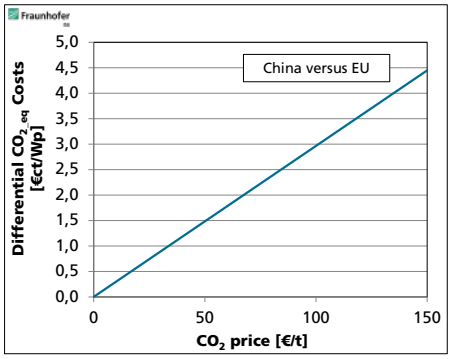
The European 2030 climate and energy framework sets key targets for the year 2030 (Source: European commission, COM (2014) 15 final/2). Without PV technology the goals can be hardly achieved.



Life cycle analyzes carried out for PV installations highlight the potential for more sustainable PV production and installation. The graph clearly shows that the greatest potential for all Product Environmental Footprint Category (PEFCs) lies in material flow and production towards the module (see also: http://www.etip-pv.eu/fileadmin/Documents/ETIP_PV_Publications_2017-2018/181122_-_ETIP_PV_Report_on_PV_Quality_and_Economy_web.pdf)

Emissions during manufacturing of PV modules





Carbon footprint of a Cz PERC glass-backsheet module production (left). Delta CO_2 cost of a Cz PERC module production located in Germany compared to China (right). Source: own calculations.

Solar panel manufacturers need electricity and thermal energy. Carbon emissions can vary widely with location. For example, panels produced in China, which relies heavily on coal for power, have a larger carbon footprint than those produced in Europe. The effect of a CO_2-prize on the carbon footprint of PV modules is also shown. Such a system is currently being discussed in Europe.

International Label for Sustainability

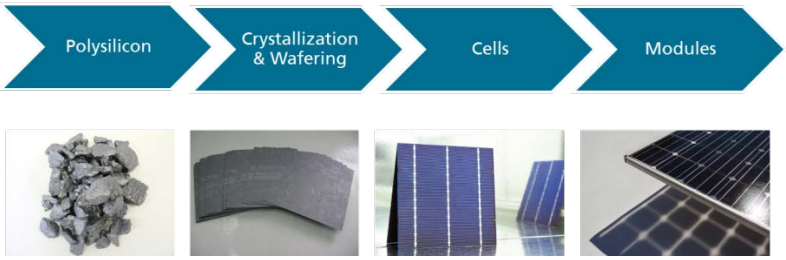
"The EU Ecolabel helps you identify products and services that have a reduced environmental impact throughout their life cycle, from the extraction of raw material through to production, use and disposal. Recognised throughout Europe, EU Ecolabel is a voluntary label promoting environmental excellence which can be trusted."

Fraunhofer ISE ines ENEA

Framework and mission of EU Ecolabel initiative driven by CEA-INES, ENEA and Fraunhofer ISE. New high-tech PV modules will qualify for this new Ecolabel.

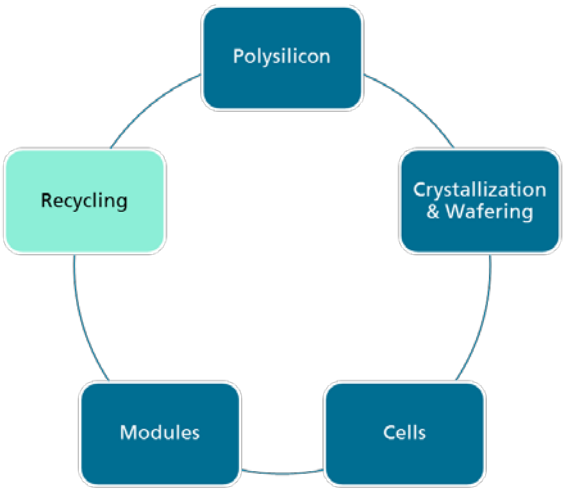
Recycling

Today's view on the value chain in PV:



Only the cost up to the module is considered. Costs for recycling are not yet regraded.

Future, sustainable view:



At the end of the life cycle nearly 100 % of the parts of a module will be made available for a new life cycle. The cost for the recycling process must be considered at the beginning of the cycles.