ETH Zurich Department of Architecture
ARCHITECTURE OF TERRITORY
Chair of Architecture
and Territorial Planning
Professor Milica Topalović

Power to the People
Fall 2022

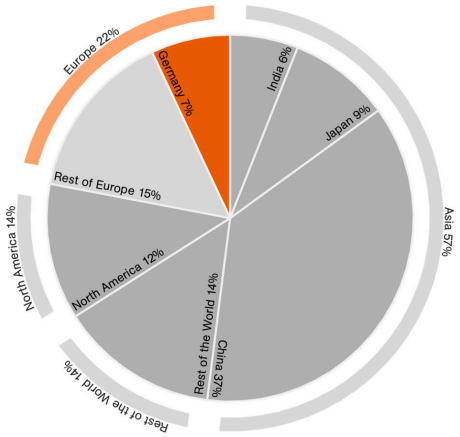
Atlas

Solar

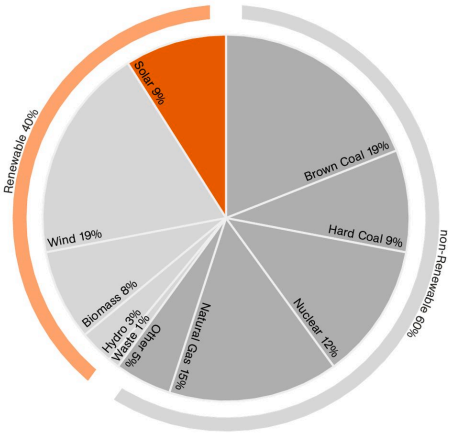
Bastien Terrettaz, Eu Juin Toh, and Esad Mujanovic

Solar power for electrical energy has been promoted by the state since the 1980 *Energiewende* in Germany. But the complexity of stakeholders involved in the construction of solar energy production sites as well as the existing land use legislations complicate the quick expansion. Moving between scales, we aim to identify different forms of solar energy production, their effectiveness and its repercussions (both tangible and intangible), among them solar photovoltaics, a hybrid technology which might provide alternatives scenarios for the future of German territories.

Germany: A Leader In Solar Energy?



GLOBAL CUMULATIVE PV POWER BY REGION (2021)
Source: International Renewable Energy Agency (IRENA), 2022 [https://www.irena.org/Data/View-data-by-topic/Capacity-and-Generation/Country-Rankings]

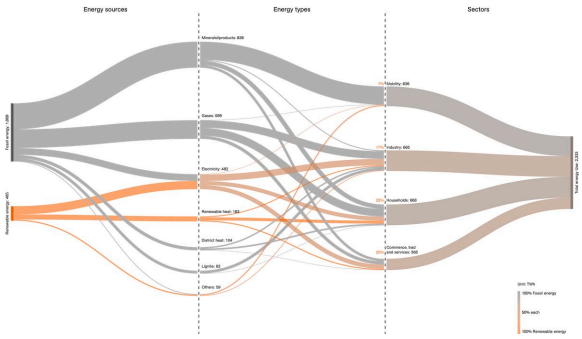


SHARE OF ELECTRICITY PRODUCTION IN GERMANY (2021)
Source: Statistisches Bundesamt (Destatis), 2022 [https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/_Grafik/_Interaktiv/bruttostromerzeugung-erneuerbare-energien.html;jsessionid=23C692346F45D0E75EF0BE6A2650C4F3.live731]

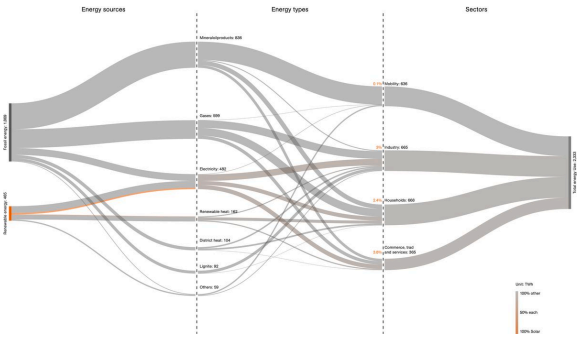
The promotion of renewable energy began in Germany in the 1990s and was firmly anchored in 2000 with the Erneuerbare-Energien-Gesetz (EEG). An instrument was conceived that is constantly being developed further. The aim is to increase the share of renewable energies in the electricity supply to at least 80 % by 2050 and to manage the phase-out of nuclear energy. Germany is therefore one of the first countries to feed energy from PV plants directly into the electricity grid, as it also aims to reduce dependence on international oil and gas imports.

To date, Germany spends around 45 billion euros annually on imports of coal, oil and natural gas. In addition, the expansion of renewable energies will create an average of 440,000 jobs between 2022 and 2035. Future electricity consumption will also increase due to current developments such as e-mobility and heat pumps, which will soon account for a large share of electricity consumption.

Germany has seen great potential in solar energy, which is economically as well as politically lucrative. Solar energy accounts for a remarkable 9 % of electricity generation in Germany and sets a high bar in international comparison.

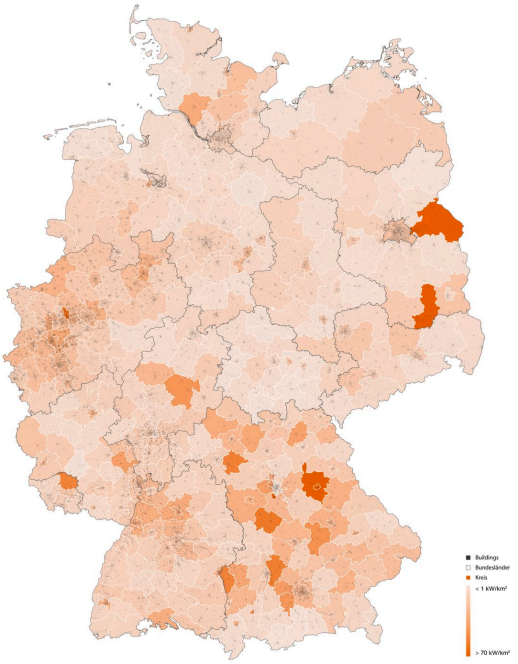


NATIONAL ENERGY SOURCES AND USE (2020)
Source: Umweltbundesamt auf Basis AG Energiebilanzen, 2022
[https://www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#allgemeine-entwicklung-und-einflussfaktoren]

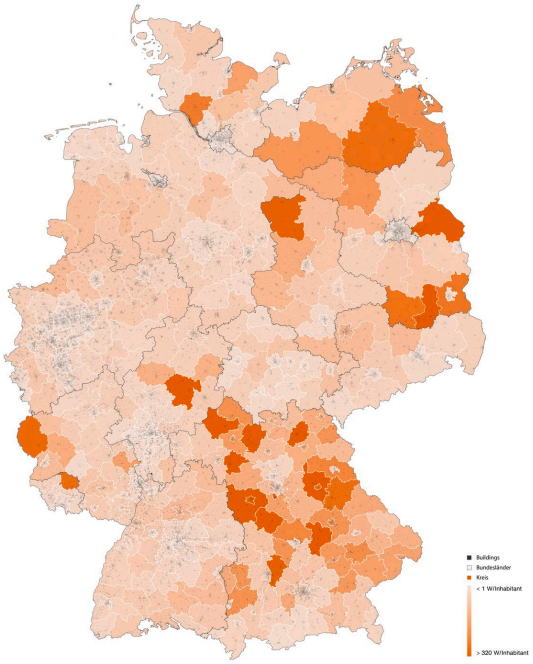


SOLAR ENERGY SOURCES AND USE (2020)
Source: Umweltbundesamt auf Basis AG Energiebilanzen, 2022
[https://www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#allgemeine-entwicklung-und-einflussfaktoren]

Although Germany is one of the top countries in the international comparison with 9 % of electricity production from photovoltaics, this diagram clearly shows how small the share of solar power is compared to the total energy consumption in Germany. Mineral oil products currently account for the largest share due to mobility. In the future, however, the automotive industry will increasingly focus on e-cars and with time also completely abandon the combustion engine. This change will depend heavily on the power supply and its reliability.

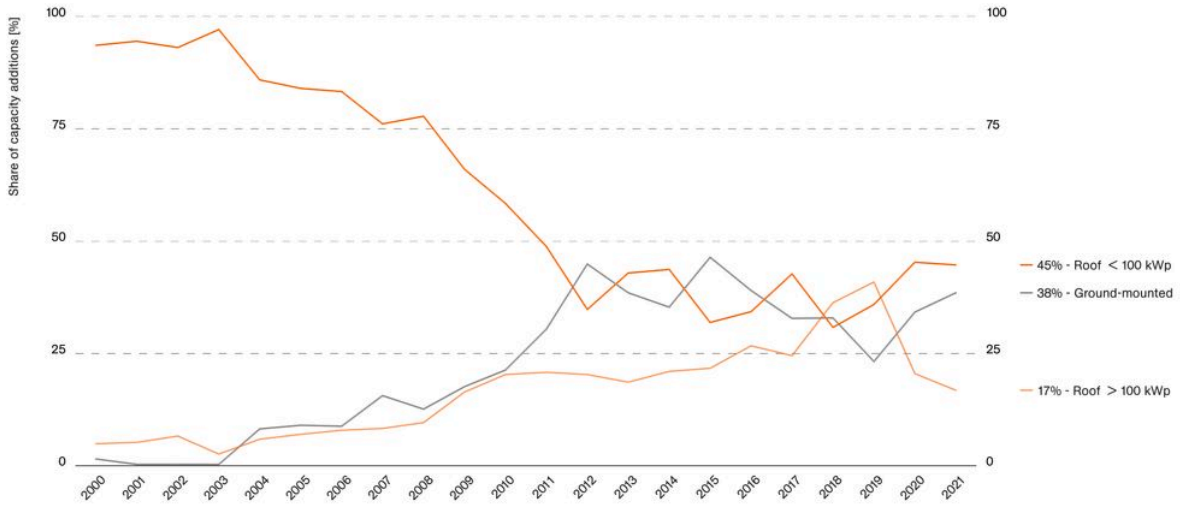


PV POWER INSTALLED PER SURFACE (2022)
Source: MaStR, 2022 [https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht] / Solarbranche.de, 2022 [https://www.solarbranche.de/ausbau/kreise-photovoltaik]



PV POWER INSTALLED PER CAPITA (2022)
Source: MaStR, 2022 [https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht] / Solarbranche.de, 2022 [https://www.solarbranche.de/ausbau/kreise-photovoltaik]

Solar plants consume space that is usually not available in urban areas and costs too much money. For this reason, solar parks are mainly placed in rural areas, close to consumers or large cities. The area between Berlin and Hamburg is a hotspot for large-scale solar energy production as well as in the south around Nuremberg and Munich. In the cities, PV systems are mainly found on the roofs of buildings. However, these only account for a fraction of the energy generated by the solar parks.

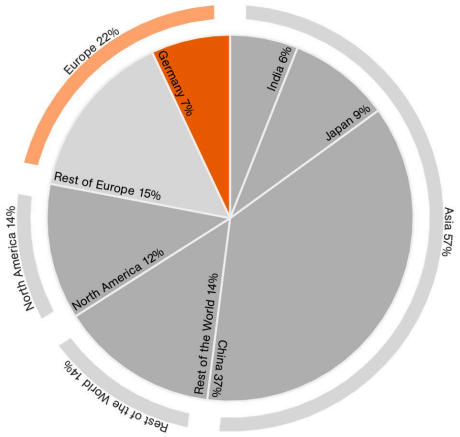


EVOLUTION OF THE DIFFERENT TYPES OF SOLAR ENERGY INFRASTRUCTURE
The fluctuations in ground-mounted and roof PVs is heavily informed by the amendments to the German Renewable Energy Sources Act, EEG.
Source: Fraunhofer ISE, 2022 [https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html] / MaStR, 2022 [https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht]

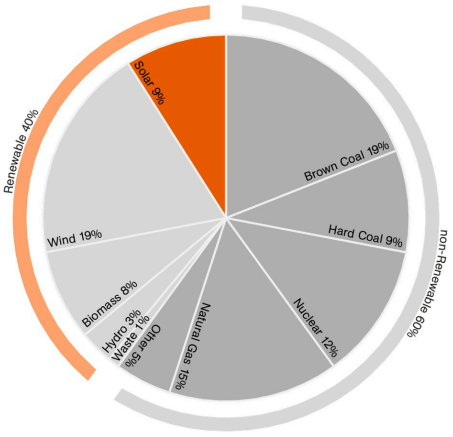
Germany's installed photovoltaic capacity, its average power output, produced electricity, and its share in the overall consumed electricity, showed an exponential growth for more than two decades up to about 2012. The government has created policies that enabled small-scale projects to feed back into the national electricity grid.

Beginning from 2000, the introduction of the Feed-in Tariffs (FIT) scheme by the new German Renewable Energy Sources Act, EEG sparked the rapid uptaking of renewable energies like PV. However, at this point, it does not mean that the goal of democratising electrical energy is achieved, as solar energy is still used as a way for big corporations of sustainable energy producers to exacerbate the existing economic and social inequalities. Since 2012, growth has slowed down significantly due to major tariff cuts in PVs and Free-standing photovoltaic systems on nature conservation areas were excluded from remuneration.

The overall trend also shows a self-informed economic feedback by the government as it struggles with funding the increasing difference between generators of renewable energy and the retail price of electricity rates as well as balancing social equality. In the process of the achieving climatic agendas, the limitations of the government is thus shown.



GLOBAL CUMULATIVE PV POWER BY REGION (2021)
Source: International Renewable Energy Agency (IRENA), 2022 [https://www.irena.org/Data/View-data-by-topic/Capacity-and-Generation/Country-Rankings]

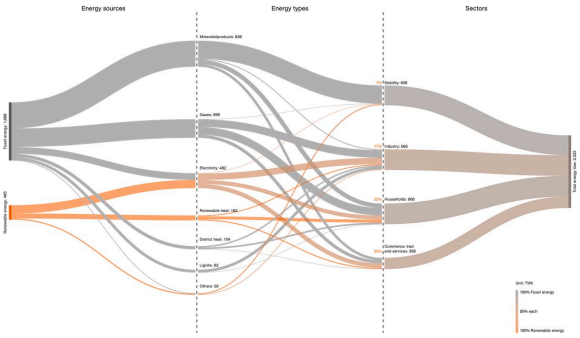


SHARE OF ELECTRICITY PRODUCTION IN GERMANY (2021)
Source: Statistisches Bundesamt (Destatis), 2022 [https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/_Grafik/_Interaktiv/bruttostromerzeugung-erneuerbare-energien.html;jsessionid=23C692346F45D0E75EF0BE6A2650C4F3.live731]

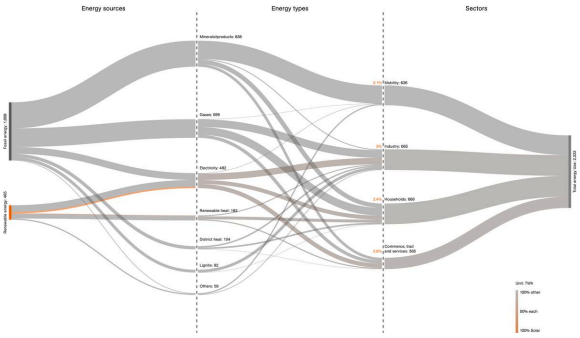
The promotion of renewable energy began in Germany in the 1990s and was firmly anchored in 2000 with the Erneuerbare-Energien-Gesetz (EEG). An instrument was conceived that is constantly being developed further. The aim is to increase the share of renewable energies in the electricity supply to at least 80 % by 2050 and to manage the phase-out of nuclear energy. Germany is therefore one of the first countries to feed energy from PV plants directly into the electricity grid, as it also aims to reduce dependence on international oil and gas imports.

To date, Germany spends around 45 billion euros annually on imports of coal, oil and natural gas. In addition, the expansion of renewable energies will create an average of 440,000 jobs between 2022 and 2035. Future electricity consumption will also increase due to current developments such as e-mobility and heat pumps, which will soon account for a large share of electricity consumption.

Germany has seen great potential in solar energy, which is economically as well as politically lucrative. Solar energy accounts for a remarkable 9 % of electricity generation in Germany and sets a high bar in international comparison.

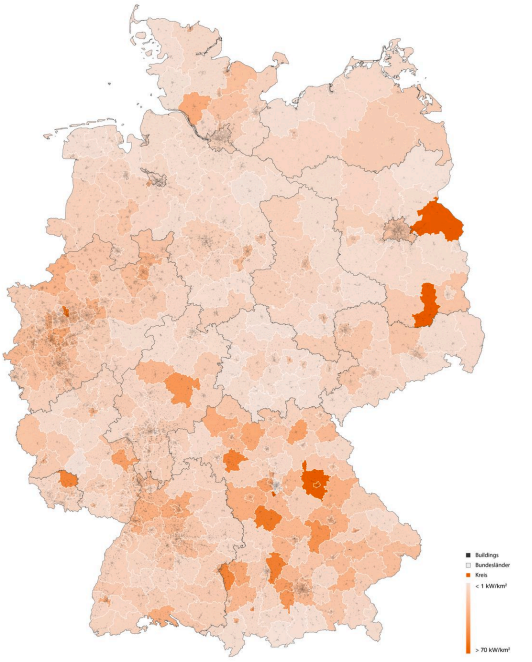


NATIONAL ENERGY SOURCES AND USE (2020)
Source: Umweltbundesamt auf Basis AG Energiebilanzen, 2022
[https://www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#allgemeine-entwicklung-und-einflussfaktoren]

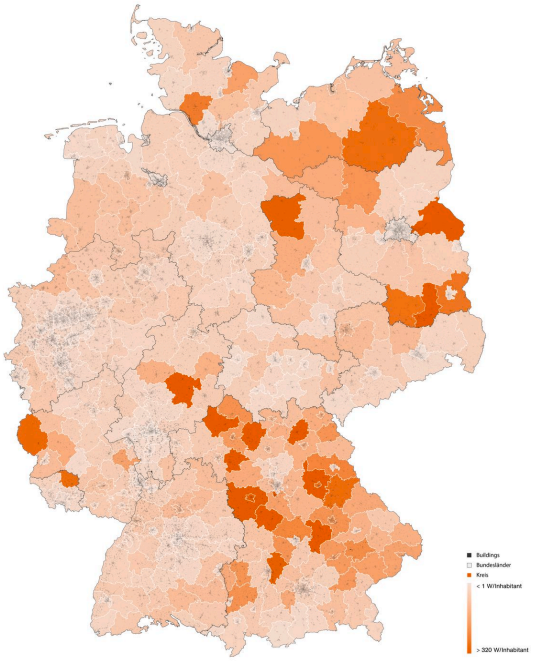


SOLAR ENERGY SOURCES AND USE (2020)
Source: Umweltbundesamt auf Basis AG Energiebilanzen, 2022
[https://www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#allgemeine-entwicklung-und-einflussfaktoren]

Although Germany is one of the top countries in the international comparison with 9 % of electricity production from photovoltaics, this diagram clearly shows how small the share of solar power is compared to the total energy consumption in Germany. Mineral oil products currently account for the largest share due to mobility. In the future, however, the automotive industry will increasingly focus on e-cars and with time also completely abandon the combustion engine. This change will depend heavily on the power supply and its reliability.



PV POWER INSTALLED PER SURFACE (2022)
Source: MaStR, 2022
[https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht] / Solarbranche.de, 2022
[https://www.solarbranche.de/ausbau/kreise-photovoltaik]



PV POWER INSTALLED PER CAPITA (2022)
Source: MaStR, 2022
[https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht] / Solarbranche.de, 2022
[https://www.solarbranche.de/ausbau/kreise-photovoltaik]

Solar plants consume space that is usually not available in urban areas and costs too much money. For this reason, solar parks are mainly placed in rural areas, close to consumers or large cities. The area between Berlin and Hamburg is a hotspot for large-scale solar energy production as well as in the south around Nuremberg and Munich. In the cities, PV systems are mainly found on the roofs of buildings. However, these only account for a fraction of the energy generated by the solar parks.



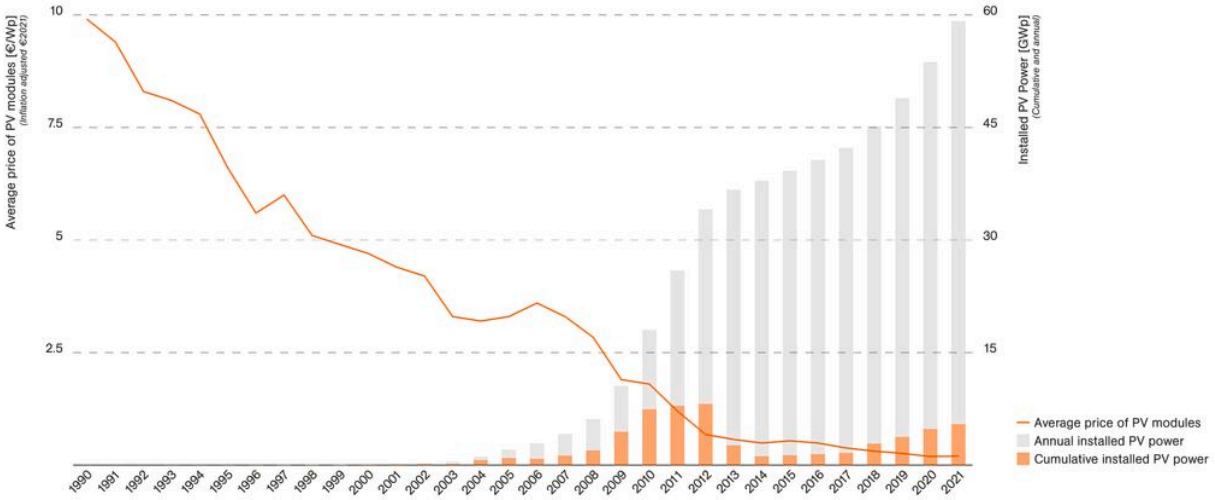
EVOLUTION OF THE DIFFERENT TYPES OF SOLAR ENERGY INFRASTRUCTURE
The fluctuations in ground-mounted and roof PVs is heavily informed by the amendments to the German Renewable Energy Sources Act, EEG.
Source: Fraunhofer ISE, 2022 [https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html] / MaStR, 2022 [https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht]

Germany's installed photovoltaic capacity, its average power output, produced electricity, and its share in the overall consumed electricity, showed an exponential growth for more than two decades up to about 2012. The government has created policies that enabled small-scale projects to feed back into the national electricity grid.

Beginning from 2000, the introduction of the Feed-in Tariffs (FIT) scheme by the new German Renewable Energy Sources Act, EEG sparked the rapid uptaking of renewable energies like PV. However, at this point, it does not mean that the goal of democratising electrical energy is achieved, as solar energy is still used as a way for big corporations of sustainable energy producers to exacerbate the existing economic and social inequalities. Since 2012, growth has slowed down significantly due to major tariff cuts in PVs and Free-standing photovoltaic systems on nature conservation areas were excluded from remuneration.

The overall trend also shows a self-informed economic feedback by the government as it struggles with funding the increasing difference between generators of renewable energy and the retail price of electricity rates as well as balancing social equality. In the process of the achieving climatic agendas, the limitations of the government is thus shown.

Solar Energy and the Energiewende 1980



EVOLUTION OF THE MWP INSTALLED AND THE
AVERAGE PRICE OF PV MODULES, 1990–2021
Source: Bundesministerium für Wirtschaft und Klimaschutz, 2022
[https://www.bmwk.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html] / Fraunhofer ISE, 2022
[https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html]

Even prior to the 1990s, the core ideology of *Energiewende* has already been present with the “pan-European upsurge of protests against glaring inequalities and injustices of industrial capitalism during and after the 1968s” (*The Subversion of Politics*, Katsiaficas, 1997). The subsequent resistance to nuclear power also gave rise to the *Autonomen* which “developed forms of self-managed consensus rather than relying on powerful individuals or hierarchical organisations” (*People’s Power*, Dawson, 2020). The dynamics of German politics in energy questions was one that sprung up from the grassroots. Renewable energy like that of solar was a crucial yet extremely precarious medium of the *Energiewende* because of the fluctuations in costs ramifications of PV industries moving parallel with changes in political power and societal influences.


BIKING ON AUTOBAHN: BEHAVIORAL CHANGE
Source: crudeoilpeak.info

First Oil Crisis

1970

Green Party Founded

Reseach on Solar Panels is growing


A STATE UNIVERSITY PROFESSOR SHOWING A SOLAR PANEL IN NEW MEXICO, APRIL 1974
Source: US National Archives and Records Administration

1970

1973: Germany's First Oil Crisis
Previously, in the 1950s and 1960s, energy policy had been viewed primarily from the perspective of economics. Between 1950 and 1973, energy consumption increased annually by 4.5 %, with oil playing a particularly important role, which became the most important energy source during this period. At the same time, energy consumption was perceived as a central indicator of economic prosperity, which led to great fears of economic decline, since energy consumption in Western Europe was not growing as quickly as in Eastern Europe. The oil price crisis of 1973 demonstrated the industrialized countries ' dependence on fossil energy, particularly on fossil fuels.

1973: Green Party Founded
The political party The Greens (German: Die Grünen) sprung out of grassroots mobilisations from the wave of New Social Movements that were active in the 1970s, including environmentalist, anti-war, and anti-nuclear movements which can trace their origin to the student protests of 1968. The party sought to give these movements political and parliamentary representation, as the pre-existing peoples parties were not organised in a way to address their stated issues.

1974: Research on Solar Panels is Growing
After its successful use in the aerospace sector, the development of photovoltaics has continued with the aim of being used on land. Multiple research centres have been created and the race for efficiency has begun.


MARINE BEACON
Source: unknown

Beginning of Solar Panel use on Earth

1980

"Energywende"

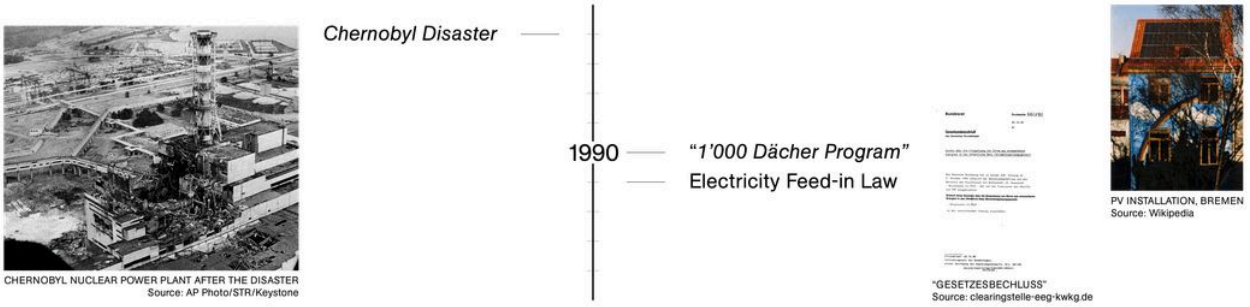


BOOK "ENERGIEWENDE"
Source: industriemuseum.lvr.de

1980

1980: Debut of Solar Panel on Ground and not in Space
Development of the first Solar Cells to be used on Earth

1980: *Energywende*
“Energy transition: growth and prosperity without oil and uranium”
A rural community in a conservative part of the country rose up in opposition to government plans to “develop” the area through the construction of a nuclear power plant and the attraction of new industries to buy all the new power.



1990

1986: Chernobyl disaster
Large parts of Germany were covered with radioactive contamination from the Chernobyl disaster and Germans went to great lengths to deal with the contamination. Germany’s anti-nuclear stance was strengthened. From the mid-1990s onwards, anti-nuclear protests were primarily directed against transports of radioactive waste in “CASTOR” containers.

1991: Electricity Feed-in Law
The 1991 Electricity Feed-in Law, the first green electricity feed-in tariff scheme in the world, ensured grid access for electricity generated from renewable energy sources. Moreover, it obliged utilities operating the public grid to pay premium prices (feed-in tariffs) for the electricity supplied from these renewable energy power plants. Although the act helped stimulate the rapid growth of wind power in Germany, deployment of solar power was initially disappointingly low, a fact that reflected the low levels of remuneration for solar at the outset.


EEG ILLUSTRATION
Source: cleanenergywire.org

2000 — *"100'000 Dächer Program"*
2000 — German Renewable Energy Act, EEG
PV Interim Act
EEG Amendment

2000

2000: German Renewable Energy Sources Act, EEG
A replacement of the original Electricity Feed-In Law under a coalition government led by the Green Party. The original legislation guaranteed a grid connection, preferential dispatch, and a government-set feed-in tariff for 20 years, dependent on the technology and size of project. The scheme was funded by a surcharge on electricity consumers, with electricity-intensive manufacturers and the railways later being required to contribute as little as 0.05 cents/kWh. The EEG has generally been regarded as a success and led to the particularly rapid uptake of two renewable energy technologies: wind power and photovoltaics.

2004: EEG Amendment
Together with the PV Interim Act (2003), the EEG Amendment from 2014 raised photovoltaic tariffs and in particular for small rooftop installations, to compensate for the ending of low-interest loans under the expiring 100,000 roofs program. The limit on free-standing photovoltaic systems exceeding 100 kWp and the 1000 MWp cap on photovoltaic installations in total were both removed. Furthermore, detailed measures were introduced to deal with market complexities, windfall profits, and the incentives for innovation and cost reduction. Eligible projects may no longer degrade ecologically sensitive areas.


EXPLOSION OF NUCLEAR REACTOR
Source: ocean4future.org

Great Recession
Fukuschima Nuclear Disaster
2010 — EEG Amendment
2010 — PV Act
EEG Revised
PV Act
EEG Amendment (PV Tendering Scheme)

2010

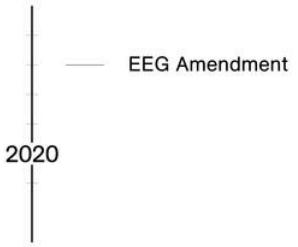
2009: EEG Amendment
The 2009 amendments were undertaken alongside a boom in renewable electricity uptake. In 2009, renewables accounted for 16.3% of total electricity generation, up from 9.3% in 2004. More specifically, the photovoltaic tariffs were reduced somewhat, but not enough to affect uptake. The degression for PV was tightened from 5% to 8–10%, depending on the size of installation. A new 'self-consumption incentive' granted a fixed tariff of 25.01 cents/kWh for electricity consumed by a PV operator within their own house. A 'flexible degression cap' was introduced, under which the degression rate could be adjusted to keep the uptake of photovoltaics within a specified corridor.

2010: PV Act
It was becoming clear that action on the photovoltaic remuneration was necessary. The growth in photovoltaics had exceeded all expectations. In 2009 alone, 10600 MWp of capacity was installed. As a result, the support costs had skyrocketed. The legislation introduced a dramatic reduction in photovoltaic tariffs, cutting these between 8 and 13% depending on the installation type, followed by a second cut of 3%. The self-consumption incentive was significantly raised to around 8 cents/kWh and eligibility extended to systems up to 500 kWp. The feed-in rate itself was dependent on the system size and the proportion of demand that was consumed on-site.

2012: EEG Revised
The new EEG sought to advance the dynamic expansion of renewable electricity generation, control the rising costs associated with the scheme, and enhance market and grid integration, while adhering to the principles of a feed-in system. The revised system includes a market premium scheme, the market premium was intended to prepare renewables for the market and to eventually lower their dependence on explicit policy measures. The rising shares of variable renewable generation had led to concerns about the ability of the electricity system to cope. The new act included measures for the grid integration of photovoltaic systems. Grid operators could now limit the feed-in of photovoltaics in times of grid overload, with the plant operators receiving compensation for their loss of revenue.

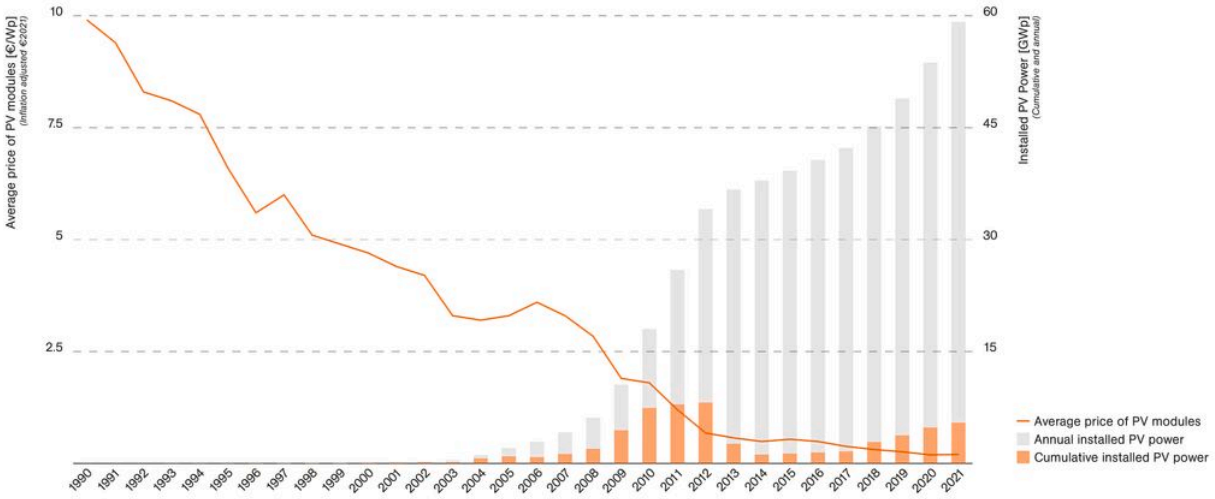
2013: PV Act
The tariff cuts were up to 30%, with the tariff cuts scheduled in the EEG (2012) for 1 July 2012 advanced and tightened from their original 15%. A hard cap on the total photovoltaic capacity was introduced, set at 52 GWp. The self-consumption privilege was removed for new installations, as grid parity was already met

2014: PV Tendering Scheme
A system of competitive bidding in which generators of renewable power must compete against one another to win contracts from the state. The goal of these competitive bidding laws is to cut the cost of renewable power but the effect has been to dramatically undermine the decentralized and democratic character of the energy transition since small renewables companies and community-based cooperatives generally lack the capital to submit artificially inexpensive bids. The result has been a shocking crash in levels of investment and deployment of renewables.



2020

2017: EEG Amendment
After three years of testing and proving its worth, the tendering system is now in place. The government thus has the means to “control” the market and to be able to prevent a too strong increase of solar installations which would influence the stock market.



EVOLUTION OF THE MWP INSTALLED AND THE
AVERAGE PRICE OF PV MODULES, 1990–2021
Source: Bundesministerium für Wirtschaft und Klimaschutz, 2022
[https://www.bmwk.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html] / Fraunhofer ISE, 2022
[https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html]

Even prior to the 1990s, the core ideology of *Energiewende* has already been present with the “pan-European upsurge of protests against glaring inequalities and injustices of industrial capitalism during and after the 1968s” (*The Subversion of Politics*, Katsiaficas, 1997). The subsequent resistance to nuclear power also gave rise to the *Autonomen* which “developed forms of self-managed consensus rather than relying on powerful individuals or hierarchical organisations” (*People’s Power*, Dawson, 2020). The dynamics of German politics in energy questions was one that sprung up from the grassroots. Renewable energy like that of solar was a crucial yet extremely precarious medium of the *Energiewende* because of the fluctuations in costs ramifications of PV industries moving parallel with changes in political power and societal influences.



BIKING ON AUTOBAHN: BEHAVIORAL CHANGE
Source: crudeoilpeak.info

1970

First Oil Crisis

Green Party Founded

Reseach on Solar Panels is growing



A STATE UNIVERSITY PROFESSOR SHOWING A SOLAR PANEL IN NEW MEXICO, APRIL 1974
Source: US National Archives and Records Administration

1970

1973: Germany's First Oil Crisis
Previously, in the 1950s and 1960s, energy policy had been viewed primarily from the perspective of economics. Between 1950 and 1973, energy consumption increased annually by 4.5 %, with oil playing a particularly important role, which became the most important energy source during this period. At the same time, energy consumption was perceived as a central indicator of economic prosperity, which led to great fears of economic decline, since energy consumption in Western Europe was not growing as quickly as in Eastern Europe. The oil price crisis of 1973 demonstrated the industrialized countries ' dependence on fossil energy, particularly on fossil fuels.

1973: Green Party Founded
The political party The Greens (German: Die Grünen) sprung out of grassroots mobilisations from the wave of New Social Movements that were active in the 1970s, including environmentalist, anti-war, and anti-nuclear movements which can trace their origin to the student protests of 1968. The party sought to give these movements political and parliamentary representation, as the pre-existing peoples parties were not organised in a way to address their stated issues.

1974: Research on Solar Panels is Growing
After its successful use in the aerospace sector, the development of photovoltaics has continued with the aim of being used on land. Multiple research centres have been created and the race for efficiency has begun.


MARINE BEACON
Source: unknown

Beginning of Solar Panel use on Earth — 1980 — *"Energywende"*



BOOK "ENERGIEWENDE"
Source: industriemuseum.lvr.de

1980

1980: Debut of Solar Panel on Ground and not in Space
Development of the first Solar Cells to be used on Earth

1980: *Energywende*
"Energy transition: growth and prosperity without oil and uranium"
A rural community in a conservative part of the country rose up in opposition to government plans to "develop" the area through the construction of a nuclear power plant and the attraction of new industries to buy all the new power.


CHERNOBYL NUCLEAR POWER PLANT AFTER THE DISASTER
Source: AP Photo/STR/Keystone

Chernobyl Disaster

1990 — *"1'000 Dächer Program"*
Electricity Feed-in Law


"GESETZESBECHLUSS"
Source: clearingstelle-eeg-kwkg.de


PV INSTALLATION, BREMEN
Source: Wikipedia

1990

1986: Chernobyl disaster
Large parts of Germany were covered with radioactive contamination from the Chernobyl disaster and Germans went to great lengths to deal with the contamination. Germany's anti-nuclear stance was strengthened. From the mid-1990s onwards, anti-nuclear protests were primarily directed against transports of radioactive waste in "CASTOR" containers.

1991: Electricity Feed-in Law
The 1991 Electricity Feed-in Law, the first green electricity feed-in tariff scheme in the world, ensured grid access for electricity generated from renewable energy sources. Moreover, it obliged utilities operating the public grid to pay premium prices (feed-in tariffs) for the electricity supplied from these renewable energy power plants. Although the act helped stimulate the rapid growth of wind power in Germany, deployment of solar power was initially disappointingly low, a fact that reflected the low levels of remuneration for solar at the outset.

"100'000 Dächer Program"
2000 — German Renewable Energy Act, EEG


EEG ILLUSTRATION
Source: cleanenergywire.org

PV Interim Act
EEG Amendment

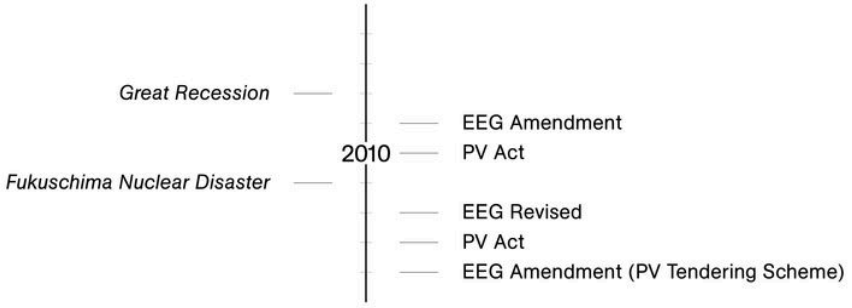
2000

2000: German Renewable Energy Sources Act, EEG
A replacement of the original Electricity Feed-In Law under a coalition government led by the Green Party. The original legislation guaranteed a grid connection, preferential dispatch, and a government-set feed-in tariff for 20 years, dependent on the technology and size of project. The scheme was funded by a surcharge on electricity consumers, with electricity-intensive manufacturers and the railways later being required to contribute as little as 0.05 cents/kWh. The EEG has generally been regarded as a success and led to the particularly rapid uptake of two renewable energy technologies: wind power and photovoltaics.

2004: EEG Amendment
Together with the PV Interim Act (2003), the EEG Amendment from 2014 raised photovoltaic tariffs and in particular for small rooftop installations, to compensate for the ending of low-interest loans under the expiring 100,000 roofs program. The limit on free-standing photovoltaic systems exceeding 100 kWp and the 1000 MWp cap on photovoltaic installations in total were both removed. Furthermore, detailed measures were introduced to deal with market complexities, windfall profits, and the incentives for innovation and cost reduction. Eligible projects may no longer degrade ecologically sensitive areas.



EXPLOSION OF NUCLEAR REACTOR
Source: ocean4future.org



2010

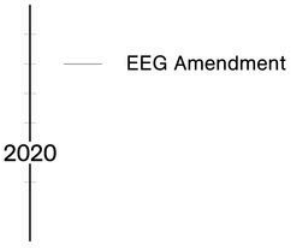
2009: EEG Amendment
The 2009 amendments were undertaken alongside a boom in renewable electricity uptake. In 2009, renewables accounted for 16.3% of total electricity generation, up from 9.3% in 2004. More specifically, the photovoltaic tariffs were reduced somewhat, but not enough to affect uptake. The degression for PV was tightened from 5% to 8–10%, depending on the size of installation. A new ‘self-consumption incentive’ granted a fixed tariff of 25.01 cents/kWh for electricity consumed by a PV operator within their own house.
A ‘flexible degression cap’ was introduced, under which the degression rate could be adjusted to keep the uptake of photovoltaics within a specified corridor.

2010: PV Act
It was becoming clear that action on the photovoltaic remuneration was necessary. The growth in photovoltaics had exceeded all expectations. In 2009 alone, 10600 MWp of capacity was installed. As a result, the support costs had skyrocketed. The legislation introduced a dramatic reduction in photovoltaic tariffs, cutting these between 8 and 13% depending on the installation type, followed by a second cut of 3%. The self-consumption incentive was significantly raised to around 8 cents/kWh and eligibility extended to systems up to 500 kWp. The feed-in rate itself was dependent on the system size and the proportion of demand that was consumed on-site.

2012: EEG Revised
The new EEG sought to advance the dynamic expansion of renewable electricity generation, control the rising costs associated with the scheme, and enhance market and grid integration, while adhering to the principles of a feed-in system. The revised system includes a market premium scheme, the market premium was intended to prepare renewables for the market and to eventually lower their dependence on explicit policy measures. The rising shares of variable renewable generation had led to concerns about the ability of the electricity system to cope. The new act included measures for the grid integration of photovoltaic systems. Grid operators could now limit the feed-in of photovoltaics in times of grid overload, with the plant operators receiving compensation for their loss of revenue.

2013: PV Act
The tariff cuts were up to 30%, with the tariff cuts scheduled in the EEG (2012) for 1 July 2012 advanced and tightened from their original 15%. A hard cap on the total photovoltaic capacity was introduced, set at 52 GWp. The self-consumption privilege was removed for new installations, as grid parity was already met

2014: PV Tendering Scheme
A system of competitive bidding in which generators of renewable power must compete against one another to win contracts from the state. The goal of these competitive bidding laws is to cut the cost of renewable power but the effect has been to dramatically undermine the decentralized and democratic character of the energy transition since small renewables companies and community-based cooperatives generally lack the capital to submit artificially inexpensive bids. The result has been a shocking crash in levels of investment and deployment of renewables.



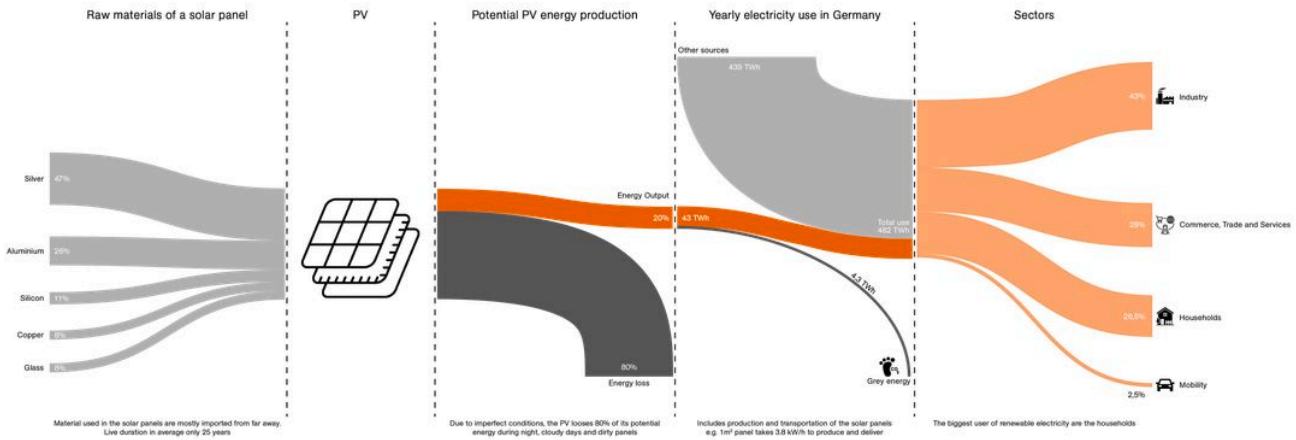
2020

2017: EEG Amendment
After three years of testing and proving its worth, the tendering system is now in place. The government thus has the means to “control” the market and to be able to prevent a too strong increase of solar installations which would influence the stock market.

Is PV Really Renewable?

Through the study of dynamic flow of materials, energy and processes, we observe that most of the materials used for the production of PV systems are not available locally. This leads us to the question of whether PV systems are really renewable or not. If we look at the potential energy that could theoretically be produced with PV systems, it is remarkable to see that 80 % of the potential is lost as energy loss. The 20 % that could be generated therefore only account for 9 % of the electricity demand in Germany. 10 % of this must be deducted to cover the grey energy in order to do justice to the resources used. Silicon for example requires up to 1500 megajoules per kilogram which is an immense amount of energy going mainly for extraction, production and transport.

Speaking of energy loss, there is still a bleak of hope when we observe the technological improvements of PV cells over the years (and the years to come). National Renewable Energy Laboratory (NREL) reveals that although most solar PV arrays currently use vary in efficiency from around 10–20 %, efficiency values as high as 44.4 % have been obtained in experimental settings by Sharp and NREL. Despite most of the high efficiency technologies running under high laboratory supervision and not at full-scale production, all 5 research-cell technologies have efficiency levels that are rising at exponential rates. However, it is critical to note that the majority of efficiencies higher than 25 % belong to large private corporations like Sharp, Boeing and Panasonic. This is heavily attributed to huge financial resources and short-term incentives of maximising profits.



METABOLISM OF PV SOLAR ENERGY FROM EXTRACTION TO USAGE
Source: International Energy Agency (IEA), 2022 [https://www.iea.org/reports/solar-pv-global-supply-chains]

GREY ENERGY AND CARBON FOOTPRINT OF SOLAR ENERGY



ALUMINIUM ORE, GUINEA
Source: Wirtgen Group [https://www.wirtgen-group.com/en-us/news-and-media/wirtgen/2500-sm-bauxit-guinea/?q=ngd]



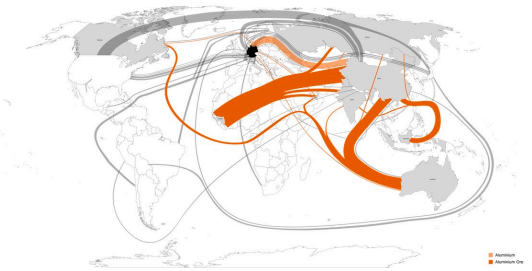
SILVER ORE, PERU
Source: desde adentro [https://www.desdeadentro.pe/2022/04/los-retos-de-construir-las-proximas-minas/]



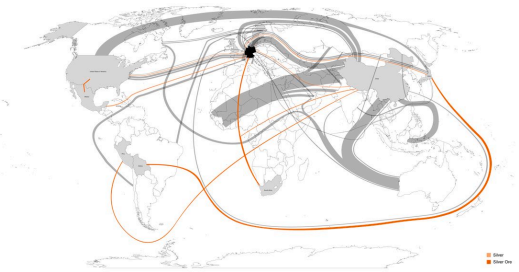
COPPER ORE, CHILI
Source: Codelco
[https://www.flickr.com/photos/codelco/]



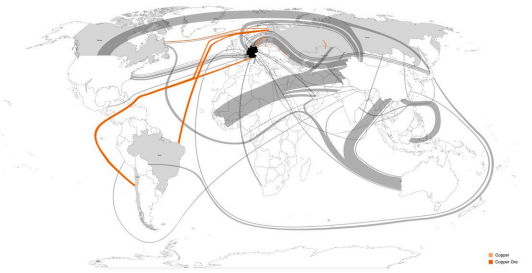
SILICA SAND, USA
Source: Martin Marietta [https://www.at-minerals.com/en/artikel/at_Sand_as_raw_material_a_scarce_commodity__3494944.html]



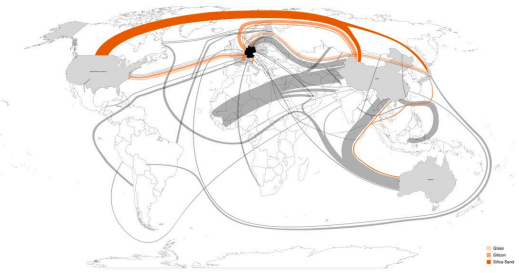
CIRCULATION OF EXTRACTED
ALUMINUM ORE; ALUMINUM PRODUCED
Source: OEC [https://oec.world/en]



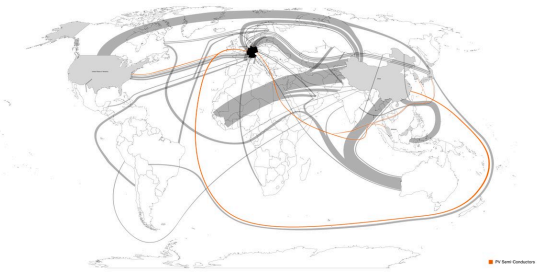
CIRCULATION OF EXTRACTED
SILVER ORE; SILVER PRODUCED
Source: OEC [https://oec.world/en]



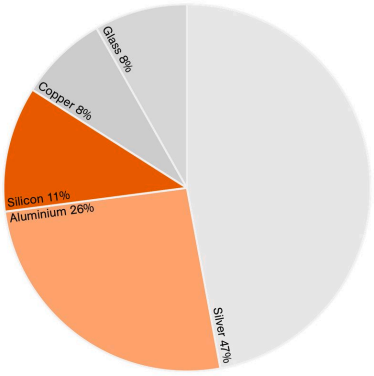
CIRCULATION OF EXTRACTED
COPPER ORE; COPPER PRODUCED
Source: OEC [https://oec.world/en]



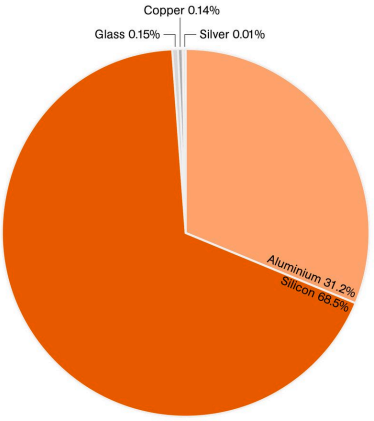
CIRCULATION OF EXTRACTED SILICA
SAND; SILICON AND GLASS PRODUCED
Source: OEC [https://oec.world/en]



CIRCULATION OF MANUFACTURED
PV SEMI-CONDUCTORS
Source: OEC [https://oec.world/en]



COMPOSITION OF PV PANEL RAW MATERIAL



ACTUAL CO_2 FOOTPRINT OF
EACH PV PANEL RAW MATERIAL

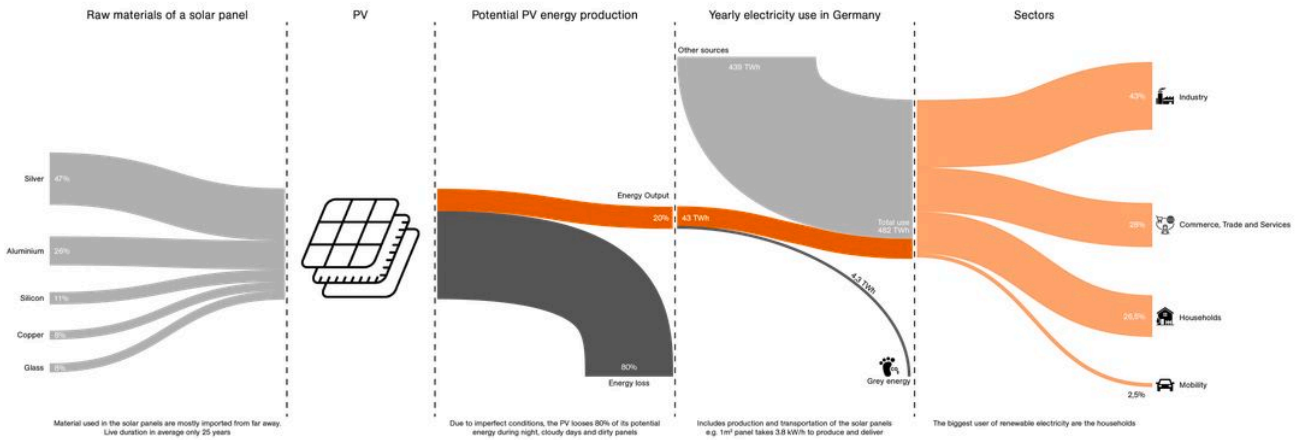
Intensive technological expertise is required to develop a PV semiconductor for the production of these sustainable solutions. As a result, the sourcing of the materials, often mined and excavated from territories in the global south (who do not have the technical capacity to develop PV). Hence, the shipment to Asian countries (where there are the relevant machineries) are prevalent. They are subsequently developed and shipped to Germany. This process is takes aeons and one should start to reflect on the Carbon Footprint it has on the climate as a result of this global shipments.

It is also important to note the changes of apparent and real carbon footprint of each PV panel raw material after considering their respective grey energy factor.

Can the efficiency of solar cells really outweigh the ecological detriments from material production for technological solutions in the long run?

Through the study of dynamic flow of materials, energy and processes, we observe that most of the materials used for the production of PV systems are not available locally. This leads us to the question of whether PV systems are really renewable or not. If we look at the potential energy that could theoretically be produced with PV systems, it is remarkable to see that 80 % of the potential is lost as energy loss. The 20 % that could be generated therefore only account for 9 % of the electricity demand in Germany. 10 % of this must be deducted to cover the grey energy in order to do justice to the resources used. Silicon for example requires up to 1500 megajoules per kilogram which is an immense amount of energy going mainly for extraction, production and transport.

Speaking of energy loss, there is still a bleak of hope when we observe the technological improvements of PV cells over the years (and the years to come). National Renewable Energy Laboratory (NREL) reveals that although most solar PV arrays currently use vary in efficiency from around 10–20 %, efficiency values as high as 44.4 % have been obtained in experimental settings by Sharp and NREL. Despite most of the high efficiency technologies running under high laboratory supervision and not at full-scale production, all 5 research-cell technologies have efficiency levels that are rising at exponential rates. However, it is critical to note that the majority of efficiencies higher than 25 % belong to large private corporations like Sharp, Boeing and Panasonic. This is heavily attributed to huge financial resources and short-term incentives of maximising profits.



METABOLISM OF PV SOLAR ENERGY FROM EXTRACTION TO USAGE
Source: International Energy Agency (IEA), 2022 [https://www.iea.org/reports/solar-pv-global-supply-chains]

GREY ENERGY AND CARBON FOOTPRINT OF SOLAR ENERGY



ALUMINIUM ORE, GUINEA
Source: Wirtgen Group [https://www.wirtgen-group.com/en-us/news-and-media/wirtgen/2500-sm-bauxit-guinea/?q=ngd]



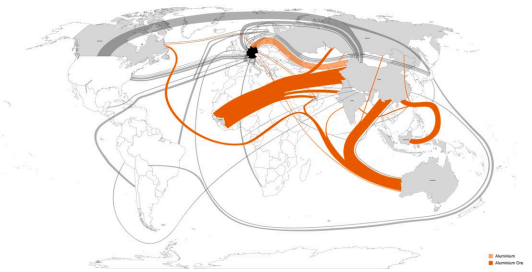
SILVER ORE, PERU
Source: desde adentro [https://www.desdeadentro.pe/2022/04/los-retos-de-construir-las-proximas-minas/]



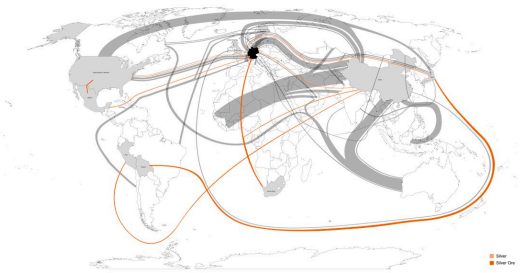
COPPER ORE, CHILI
Source: Codelco
[https://www.flickr.com/photos/codelco/]



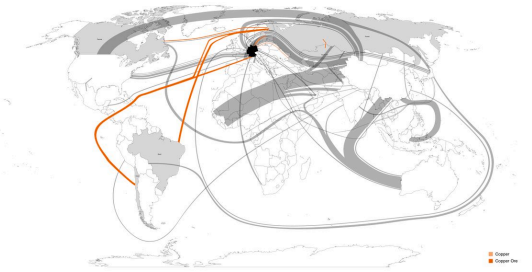
SILICA SAND, USA
Source: Martin Marietta [https://www.at-minerals.com/en/artikel/at_Sand_as_raw_material_a_scarce_commodity__3494944.html]



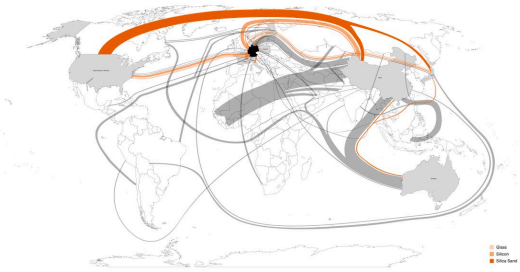
CIRCULATION OF EXTRACTED
ALUMINUM ORE; ALUMINUM PRODUCED
Source: OEC [https://oec.world/en]



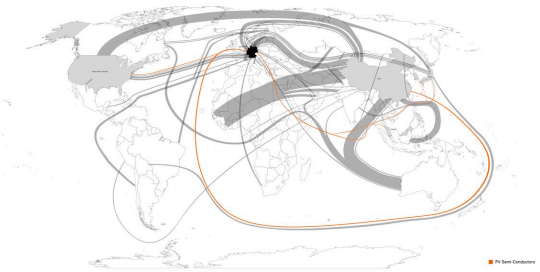
CIRCULATION OF EXTRACTED
SILVER ORE; SILVER PRODUCED
Source: OEC [https://oec.world/en]



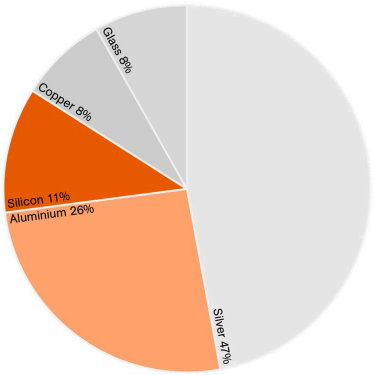
CIRCULATION OF EXTRACTED
COPPER ORE; COPPER PRODUCED
Source: OEC [https://oec.world/en]



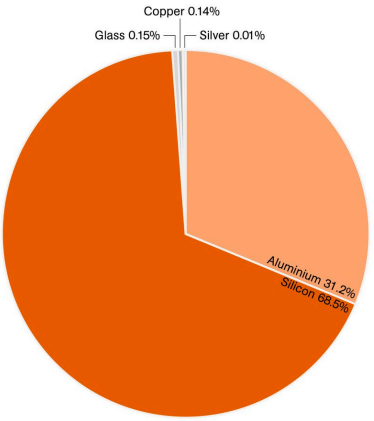
CIRCULATION OF EXTRACTED SILICA
SAND; SILICON AND GLASS PRODUCED
Source: OEC [https://oec.world/en]



CIRCULATION OF MANUFACTURED
PV SEMI-CONDUCTORS
Source: OEC [https://oec.world/en]



COMPOSITION OF PV PANEL RAW MATERIAL



ACTUAL CO_2 FOOTPRINT OF
EACH PV PANEL RAW MATERIAL

Intensive technological expertise is required to develop a PV semiconductor for the production of these sustainable solutions. As a result, the sourcing of the materials, often mined and excavated from territories in the global south (who do not have the technical capacity to develop PV). Hence, the shipment to Asian countries (where there are the relevant machineries) are prevalent. They are subsequently developed and shipped to Germany. This process is takes aeons and one should start to reflect on the Carbon Footprint it has on the climate as a result of this global shipments.

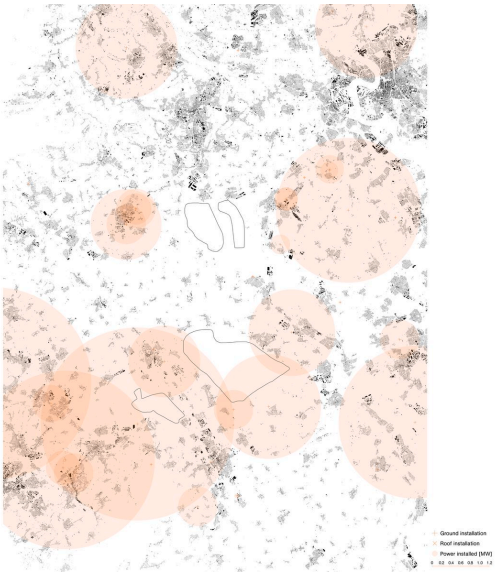
It is also important to note the changes of apparent and real carbon footprint of each PV panel raw material after considering their respective grey energy factor.

Can the efficiency of solar cells really outweigh the ecological detriments from material production for technological solutions in the long run?

Solar Energy Production in the Rheinische Revier: 3 Case Studies



MAP OF ROOF PV INSTALLATION
Source: WMS Erneuerbare Energien NRW, 2022 [http://www.wms.nrw.de/umwelt/erneuerbare_energien_nrw]



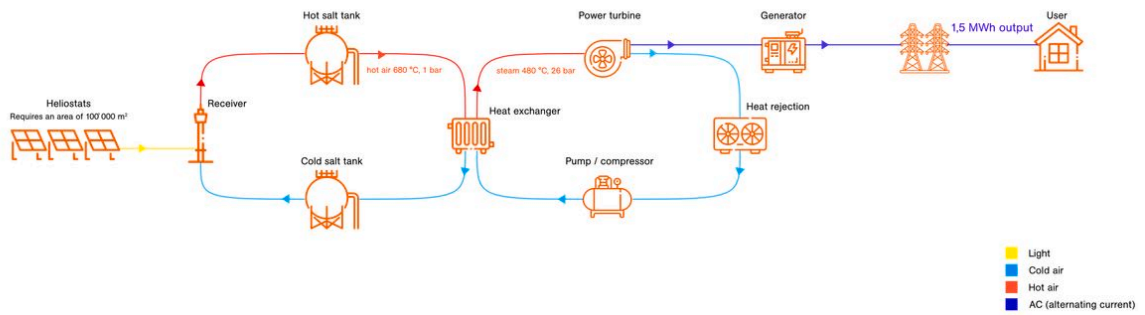
MAP OF GROUND PV INSTALLATION
Ground Installations tend to be large solar plants but are geographically less dense than that roof installed PV panels. Moreover, ground installations produce more energy per household compared to roof installations.
Source: WMS Erneuerbare Energien NRW, 2022 [http://www.wms.nrw.de/umwelt/erneuerbare_energien_nrw]

JÜLICH SOLAR TOWER

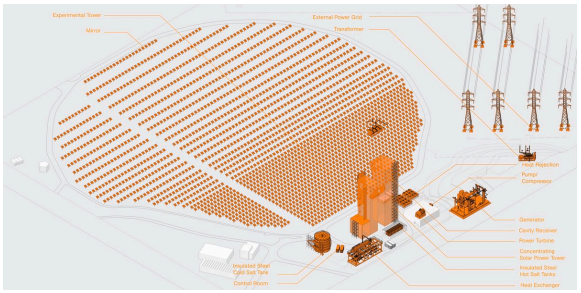
Looking into an unconventional way of harnessing solar energy, Jülich Solar Tower is the first and only German solar power plant utilizing concentrated solar power (CSP), a solar power technology that does not use photovoltaics.

The sun's rays are collected via heliostats distributed over an area of 100 ha and concentrated in the receiver tower. In the process, energy is generated with the help of heat. The Jülich Solar Tower began producing electricity in 2008 and is still used today for experimental and demonstration purposes.

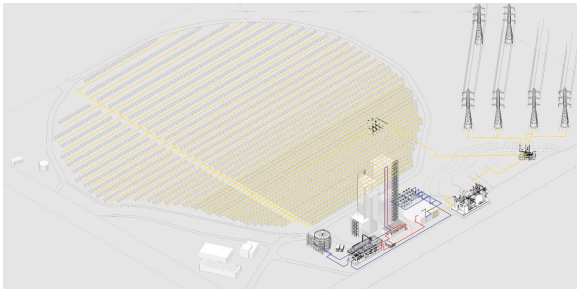
A main field of research at SIJ is the optimisation of absorber structures to achieve the highest possible efficiency and minimise energy loss. In the second tower, however, experiments such as synthesis gas (syngas) on an industrial scale are also being researched and developed.



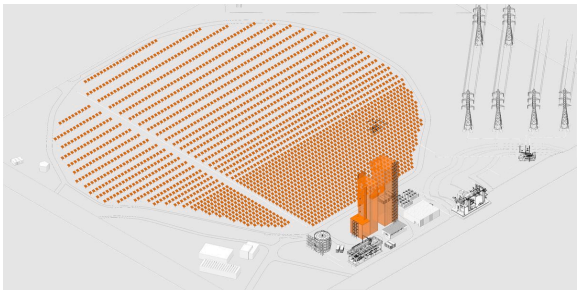
JÜLICH SOLAR TOWER: PROCESS OF ENERGY PRODUCTION



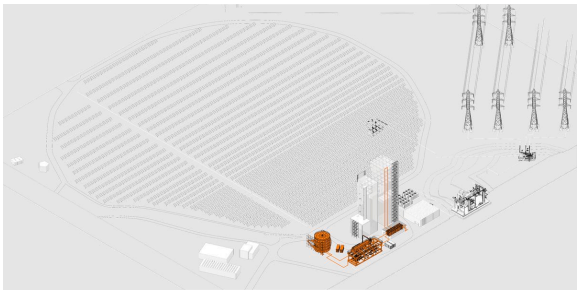
JÜLICH SOLAR POWER
AND ITS INFRASTRUCTURE



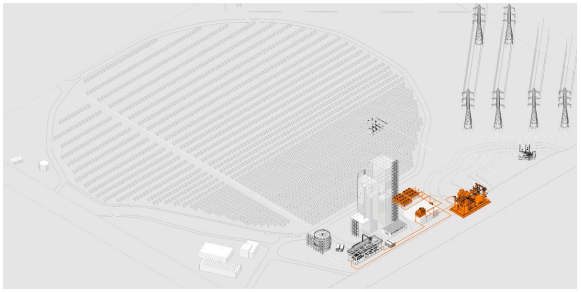
JÜLICH SOLAR TOWER: HOT
STEAM [RED]; COOL AIR [BLUE];
ELECTRICAL CURRENTS [YELLOW]



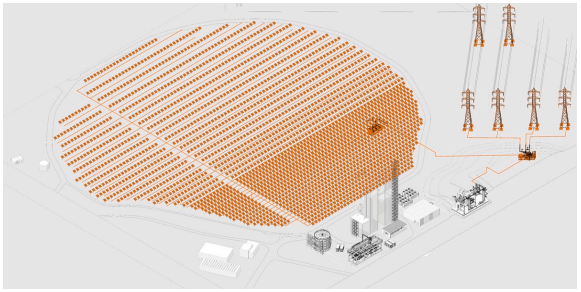
JÜLICH SOLAR TOWER:
CONCENTRATING SOLAR POWER



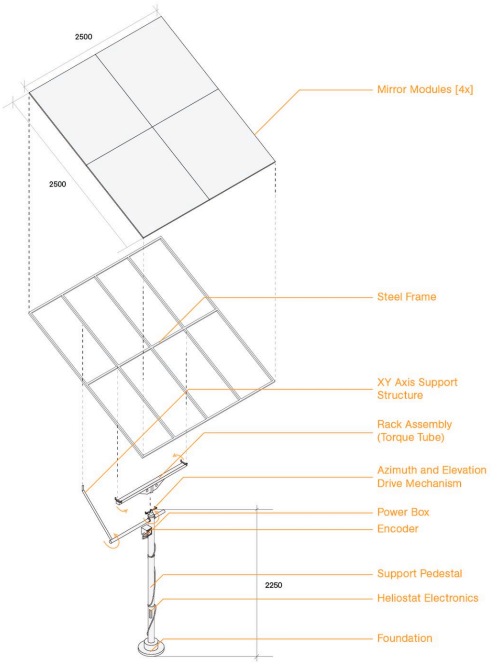
JÜLICH SOLAR TOWER:
THERMAL STORAGE SYSTEM



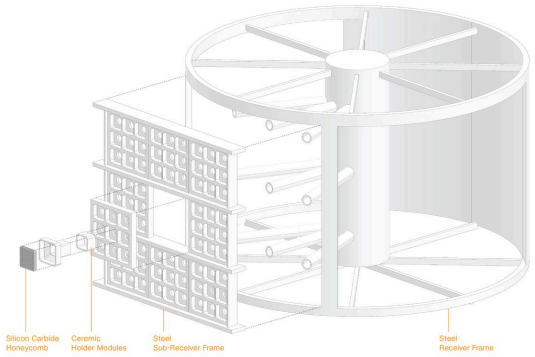
JÜLICH SOLAR TOWER: POWER BLOCK



JÜLICH SOLAR TOWER: ELECTRICAL GRID



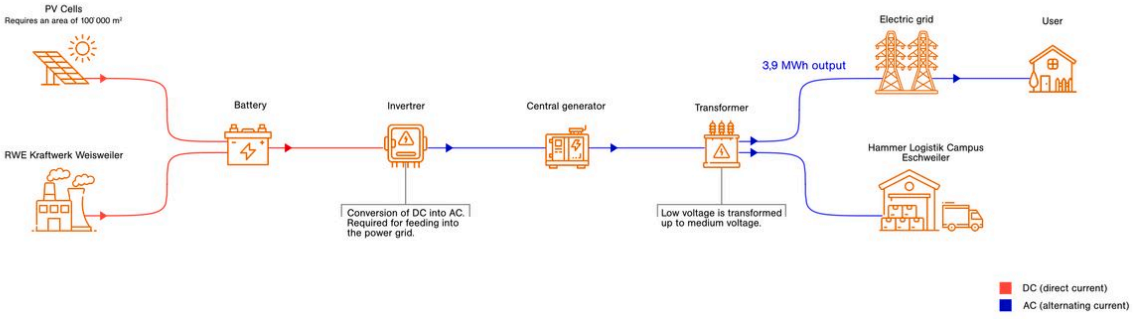
JÜLICH SOLAR TOWER: HELIOSTAT



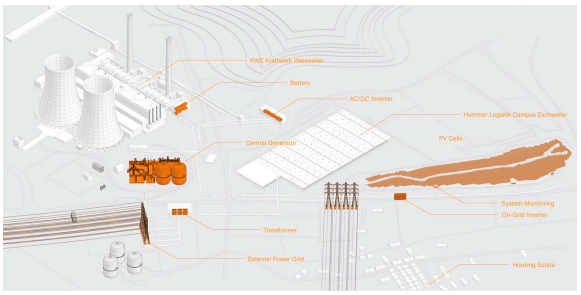
JÜLICH SOLAR TOWER: OPEN VOLUMETRIC AIR RECEIVER

SOLARPARK INDEN

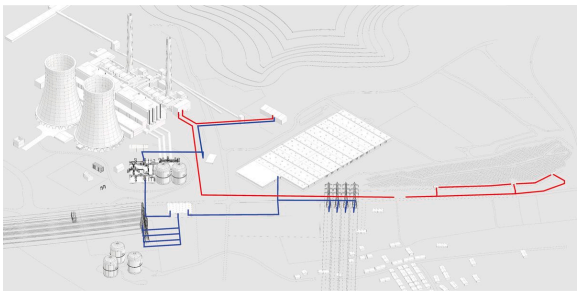
Solarpark Inden is a photovoltaic park with a calculated maximum output of 3.9 MW in the Watt Peak model and was the largest solar power plant in North Rhine-Westphalia as of December 2011. 16,236 solar modules (99×164 cm) were set up on an area of 10 ha, each aligned at an angle of 30 degrees to the south. Within six months, 9.84 million euros were installed here, 57.67 % of which was borne by Rurenergie GmbH (belonging to the district of Düren) and 42.33 % by the company F&S solar concept from Euskirchen.



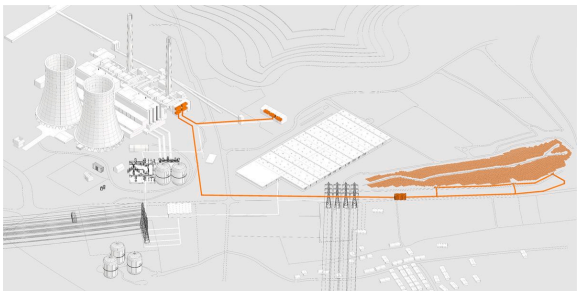
SOLARPARK INDEN: PROCESS OF ENERGY PRODUCTION



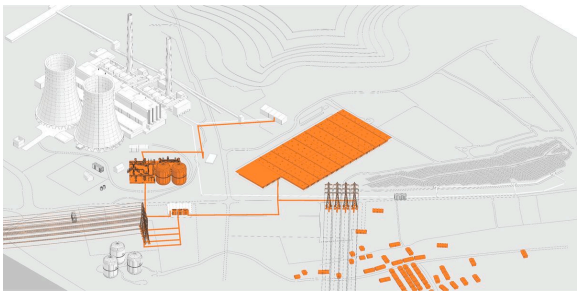
SOLARPARK INDEN AND ITS INFRASTRUCTURE



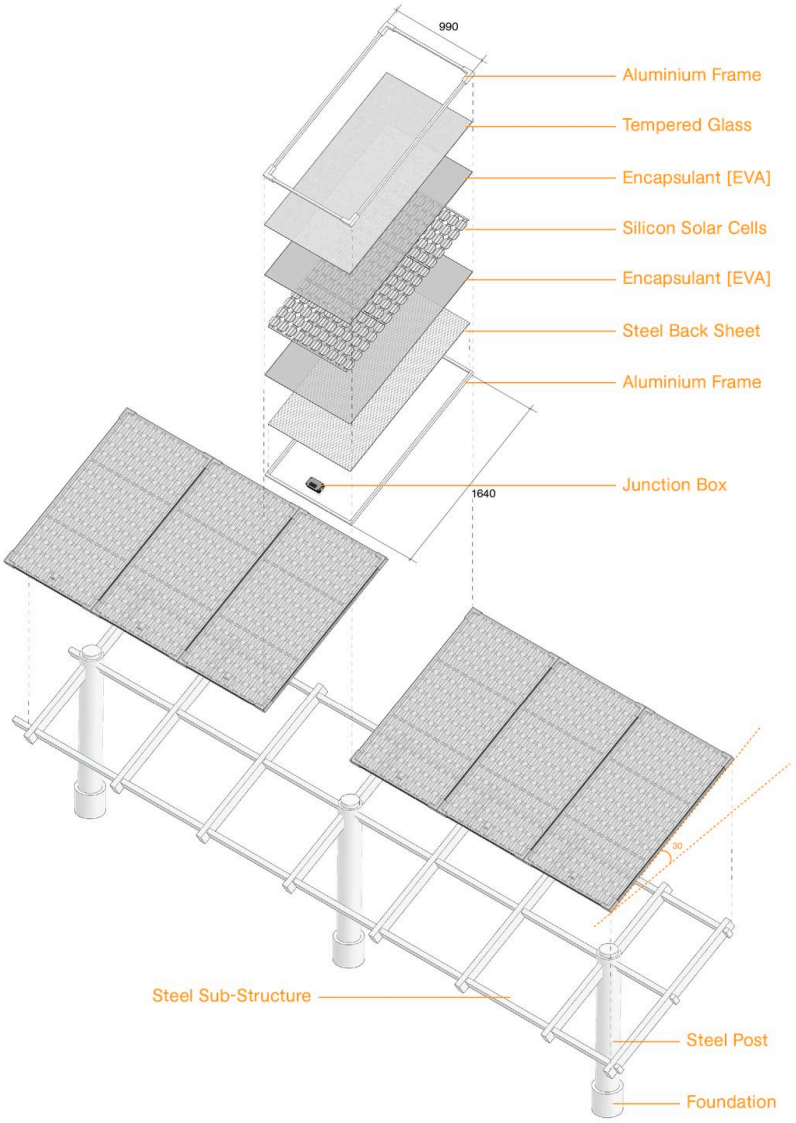
SOLARPARK INDEN: AC [RED]; DC [BLUE]



SOLARPARK INDEN: ENERGY FLOW
FROM SOLAR TO ELECTRICAL ENERGY



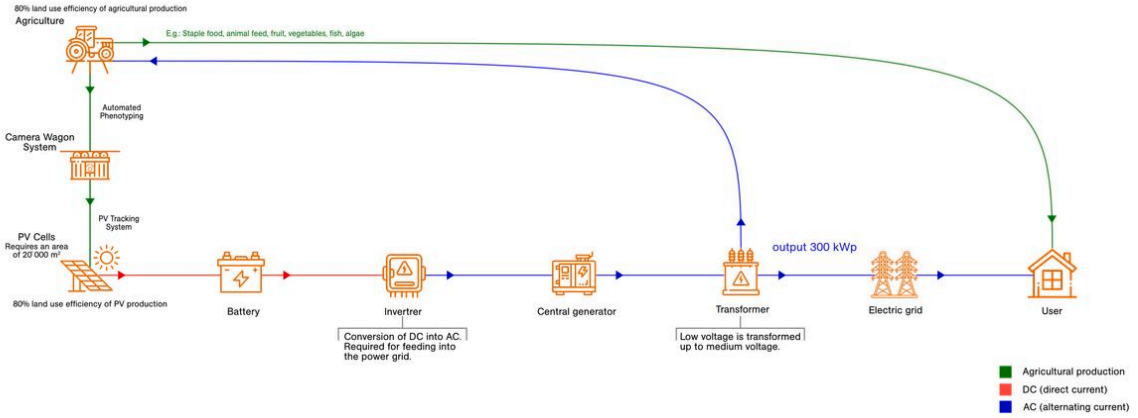
SOLARPARK INDEN: ENERGY FLOW
FROM ELECTRICAL ENERGY TO GRID



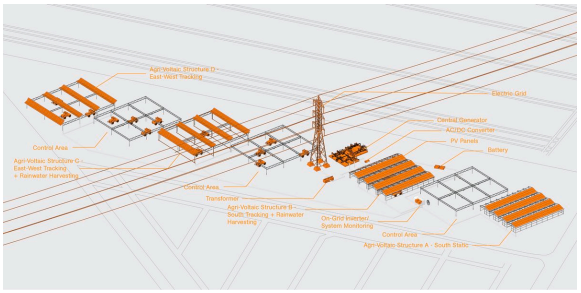
SOLARPARK INDEN: PHOTOVOLTAIC PANELS

SUNFARMING MORSCHENICH-ALT

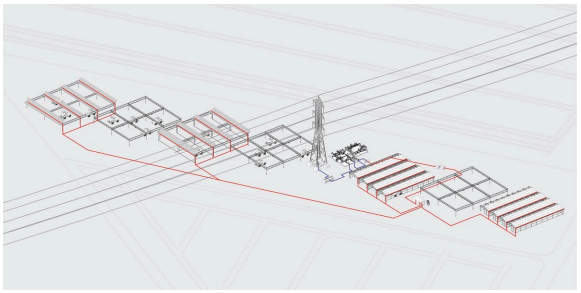
Sunfarming is an Agri-Horti-Photovoltaic research system which includes PV trackers and integrated rainwater harvesting. The system consists of five different structures, by varying orientation and mobility, while a under heavy surveillance of automatic phenotyping. Plowing, sowing and harvesting is performed together with local farmers.



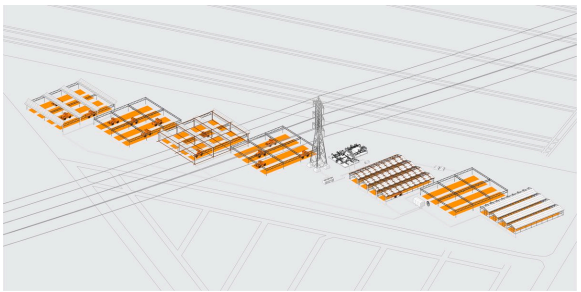
SUNFARMING: PROCESS OF ENERGY PRODUCTION



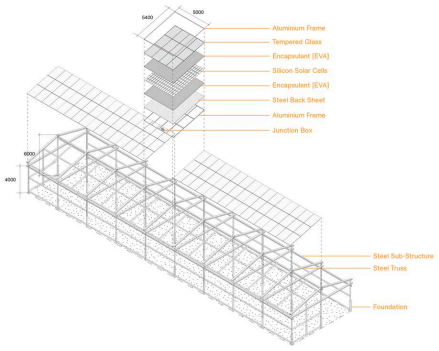
AGRI-HORTI-PHOTOVOLTAIC AND ITS INFRASTRUCTURE



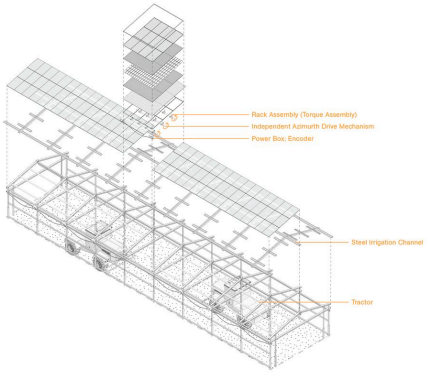
AGRI-HORTI-PHOTOVOLTAIC: DC [RED]; AC [BLUE]



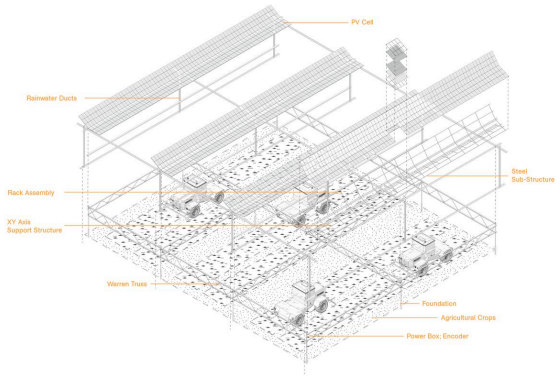
AGRI-HORTI-PHOTOVOLTAIC: AGRICULTURAL ELEMENTS



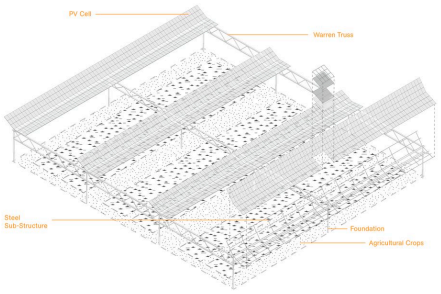
AGRI-VOLTAIC STRUCTURE A: SOUTH STATIC



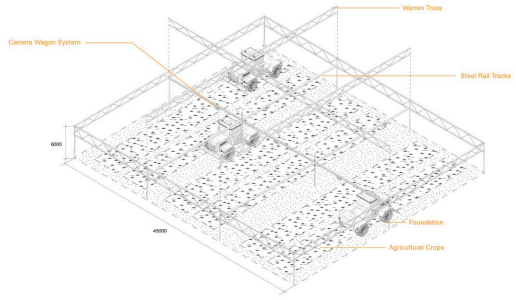
AGRI-VOLTAIC STRUCTURE B: SOUTH TRACKING AND RAINWATER HARVESTING



AGRI-VOLTAIC STRUCTURE C: EAST-WEST TRACKING AND RAINWATER HARVESTING

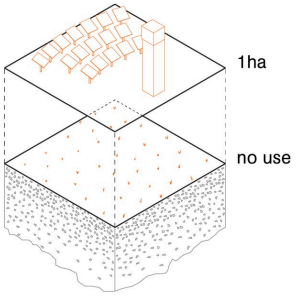


AGRI-VOLTAIC STRUCTURE D: EAST-WEST TRACKING

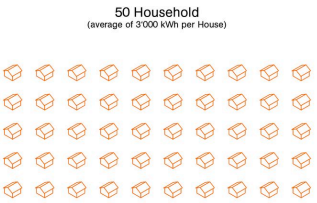


AGRI-VOLTAIC STRUCTURE: CONTROL AREA

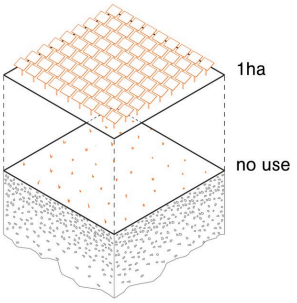
The most tangible parameter determining the effectiveness of solar photovoltaics is the amount of land use. Comparing between the three infrastructures, Jülich Solar Tower is the least efficient in generating electricity. Solarpark on the other hand is efficient but does harness the potential of the land. Sunfarming is relatively efficient and allows hybrid land use.

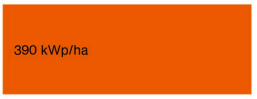


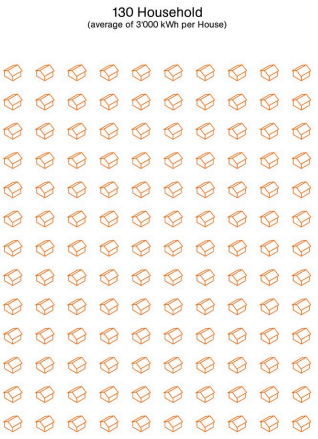




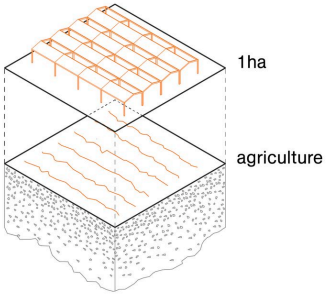
JÜLICH SOLAR TOWER





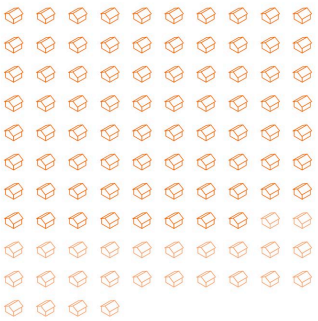


SOLARPARK INDEN

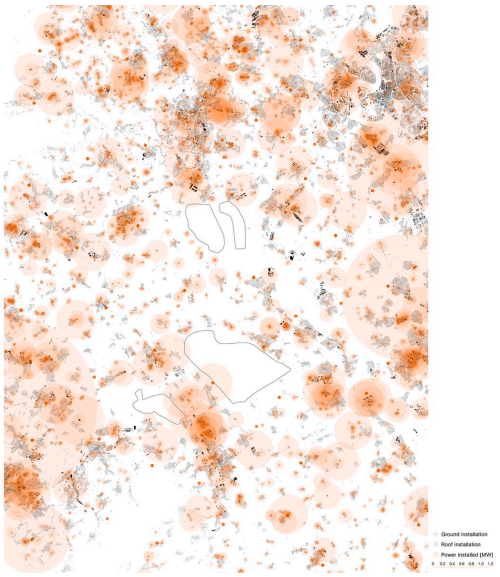




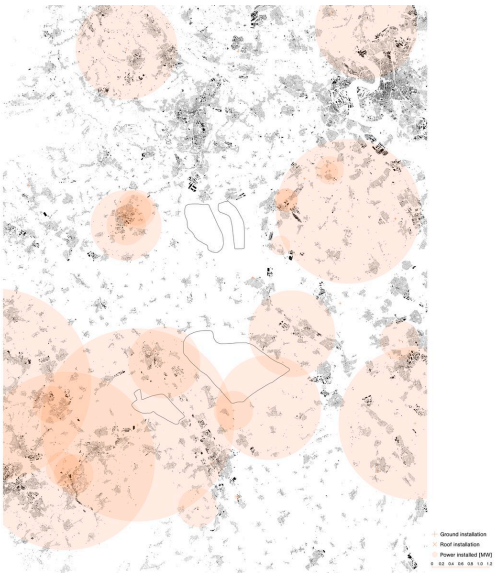
78-104 Household
(average of 3'000 kWh per House)



SUNFARMING AGRI-PV



MAP OF ROOF PV INSTALLATION
Source: WMS Erneuerbare Energien NRW, 2022
[http://www.wms.nrw.de/umwelt/erneuerbare_energien_nrw]



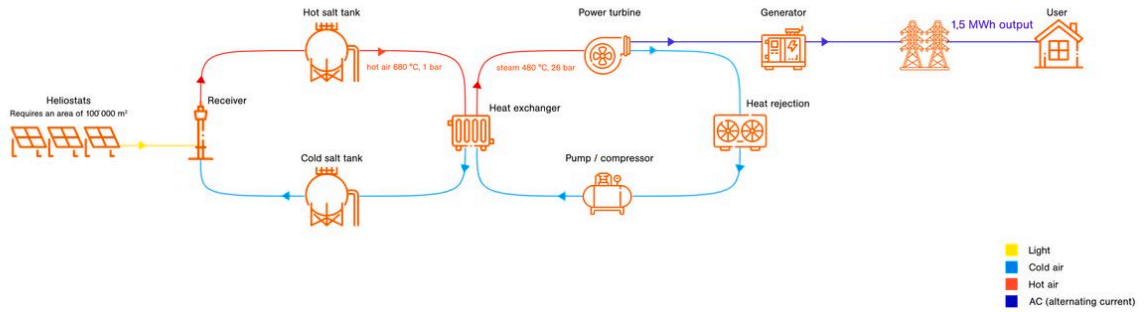
MAP OF GROUND PV INSTALLATION
Ground Installations tend to be large solar plants but are geographically less dense than that roof installed PV panels. Moreover, ground installations produce more energy per household compared to roof installations.
Source: WMS Erneuerbare Energien NRW, 2022
[http://www.wms.nrw.de/umwelt/erneuerbare_energien_nrw]

JÜLICH SOLAR TOWER

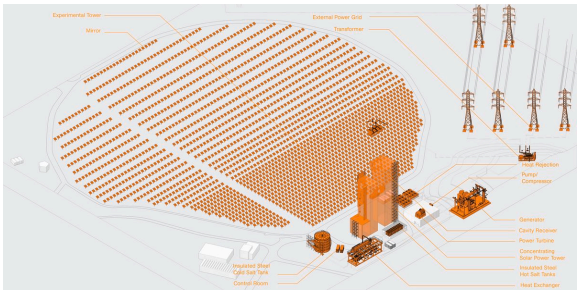
Looking into an unconventional way of harnessing solar energy, Jülich Solar Tower is the first and only German solar power plant utilizing concentrated solar power (CSP), a solar power technology that does not use photovoltaics.

The sun's rays are collected via heliostats distributed over an area of 100 ha and concentrated in the receiver tower. In the process, energy is generated with the help of heat. The Jülich Solar Tower began producing electricity in 2008 and is still used today for experimental and demonstration purposes.

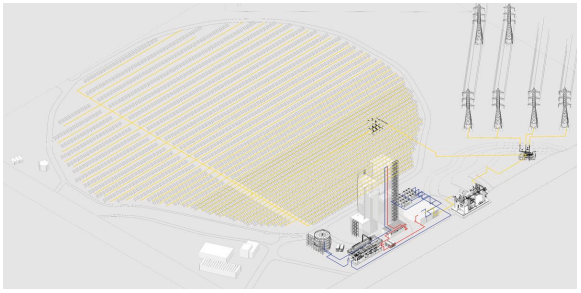
A main field of research at SIJ is the optimisation of absorber structures to achieve the highest possible efficiency and minimise energy loss. In the second tower, however, experiments such as synthesis gas (syngas) on an industrial scale are also being researched and developed.



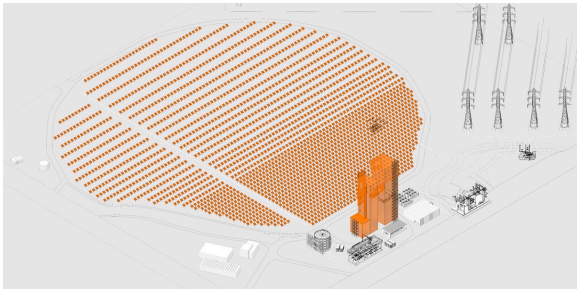
JÜLICH SOLAR TOWER: PROCESS OF ENERGY PRODUCTION



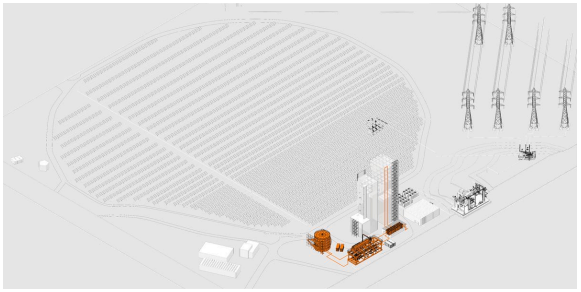
JÜLICH SOLAR POWER
AND ITS INFRASTRUCTURE



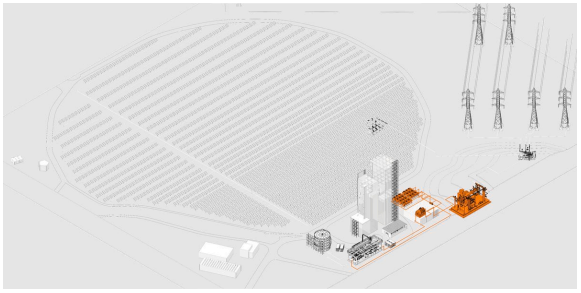
JÜLICH SOLAR TOWER: HOT
STEAM [RED]; COOL AIR [BLUE];
ELECTRICAL CURRENTS [YELLOW]



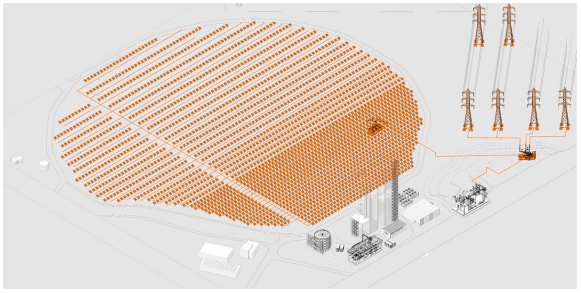
JÜLICH SOLAR TOWER:
CONCENTRATING SOLAR POWER



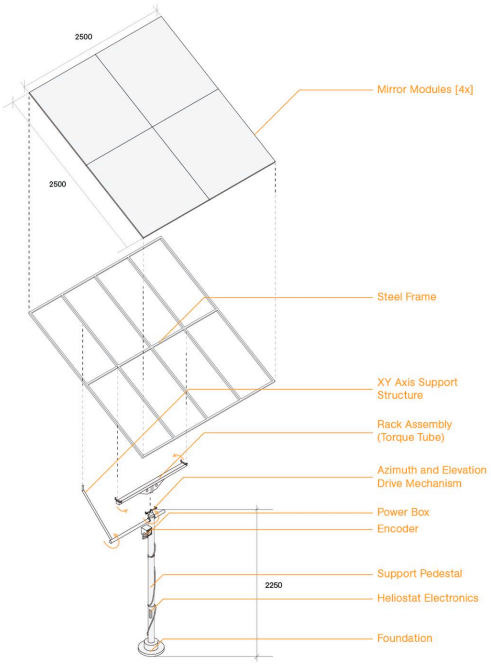
JÜLICH SOLAR TOWER:
THERMAL STORAGE SYSTEM



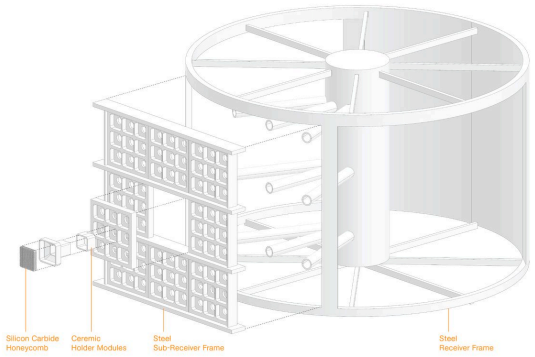
JÜLICH SOLAR TOWER: POWER BLOCK



JÜLICH SOLAR TOWER: ELECTRICAL GRID



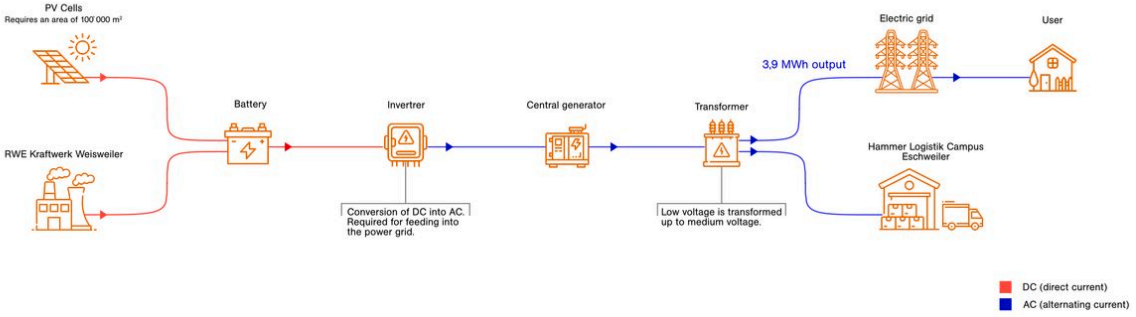
JÜLICH SOLAR TOWER: HELIOSTAT



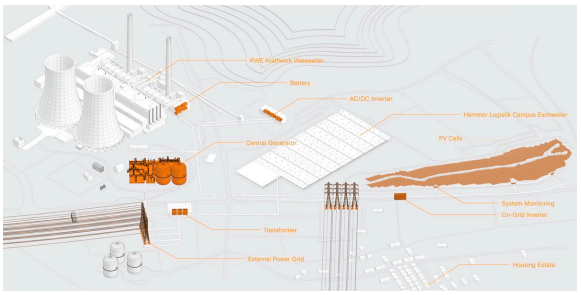
JÜLICH SOLAR TOWER: OPEN VOLUMETRIC AIR RECEIVER

SOLARPARK INDEN

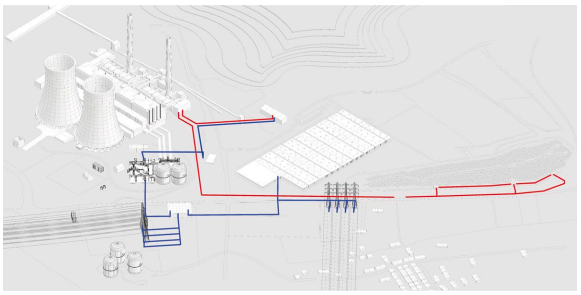
Solarpark Inden is a photovoltaic park with a calculated maximum output of 3.9 MW in the Watt Peak model and was the largest solar power plant in North Rhine-Westphalia as of December 2011. 16,236 solar modules (99×164 cm) were set up on an area of 10 ha, each aligned at an angle of 30 degrees to the south. Within six months, 9.84 million euros were installed here, 57.67 % of which was borne by Rurenergie GmbH (belonging to the district of Düren) and 42.33 % by the company F&S solar concept from Euskirchen.



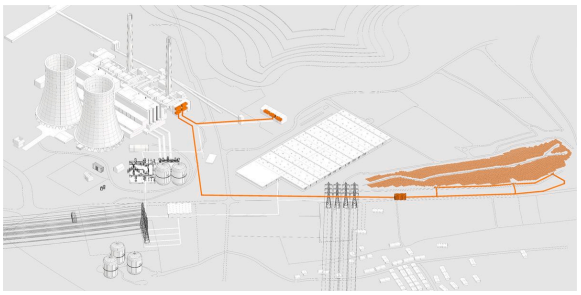
SOLARPARK INDEN: PROCESS OF ENERGY PRODUCTION



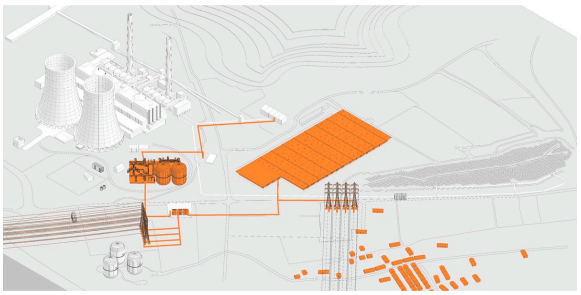
SOLARPARK INDEN AND ITS INFRASTRUCTURE



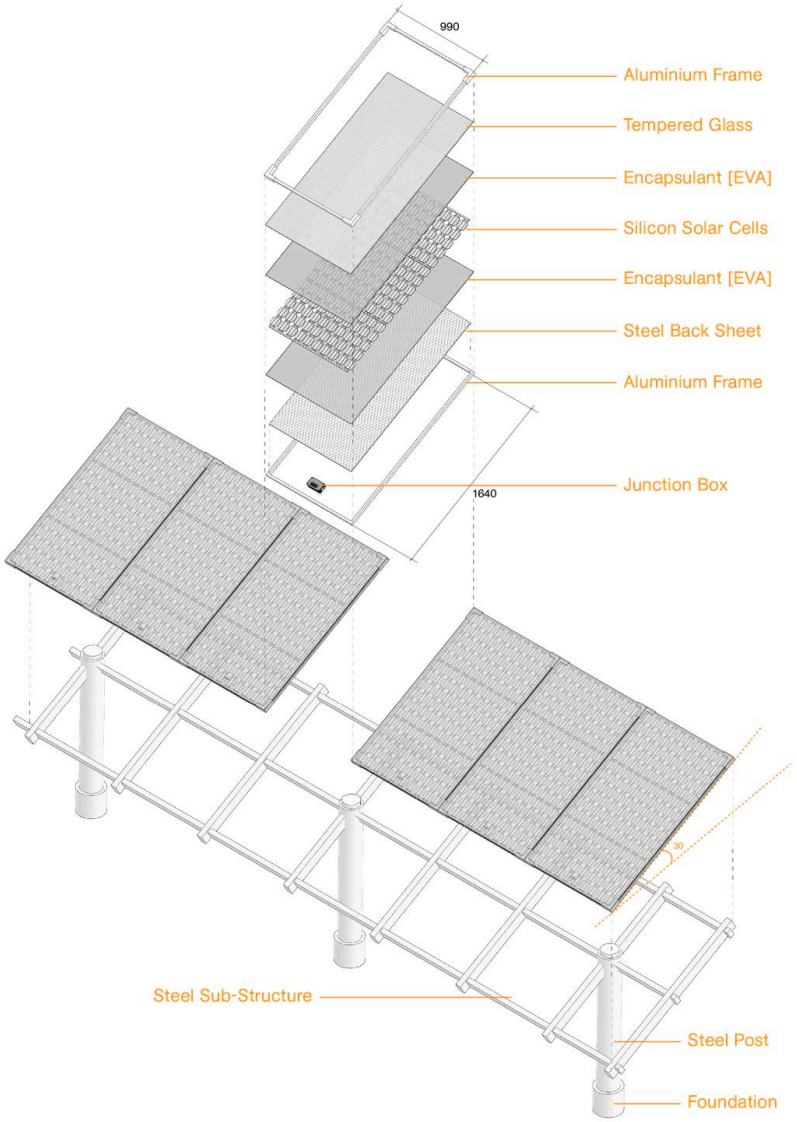
SOLARPARK INDEN: AC [RED]; DC [BLUE]



SOLARPARK INDEN: ENERGY FLOW
FROM SOLAR TO ELECTRICAL ENERGY



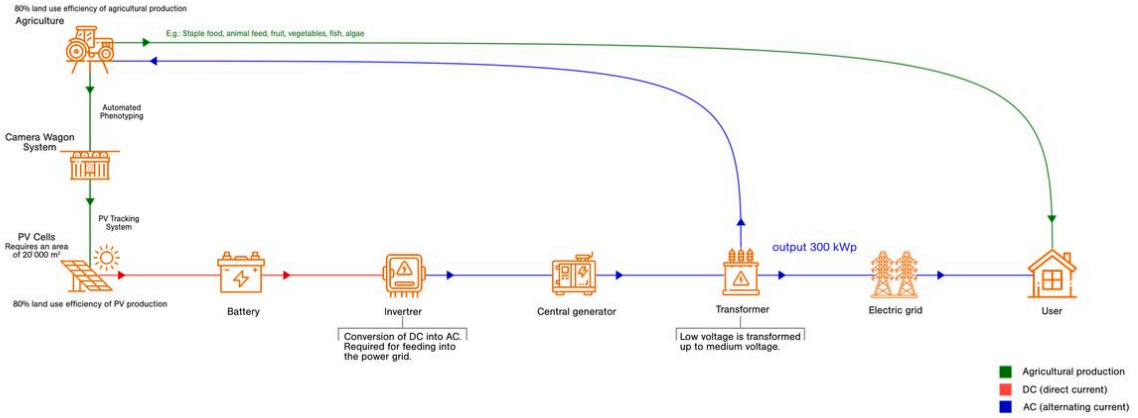
SOLARPARK INDEN: ENERGY FLOW
FROM ELECTRICAL ENERGY TO GRID



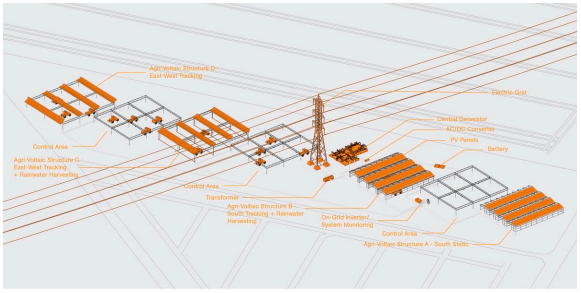
SOLARPARK INDEN: PHOTOVOLTAIC PANELS

SUNFARMING MORSCHENICH-ALT

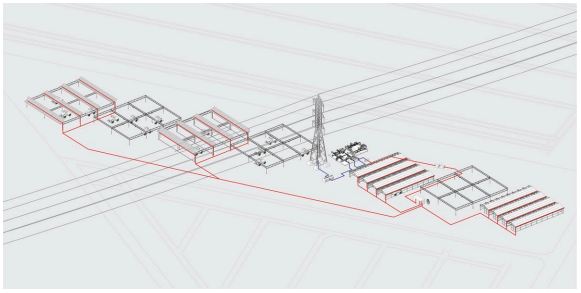
Sunfarming is an Agri-Horti-Photovoltaic research system which includes PV trackers and integrated rainwater harvesting. The system consists of five different structures, by varying orientation and mobility, while a under heavy surveillance of automatic phenotyping. Plowing, sowing and harvesting is performed together with local farmers.



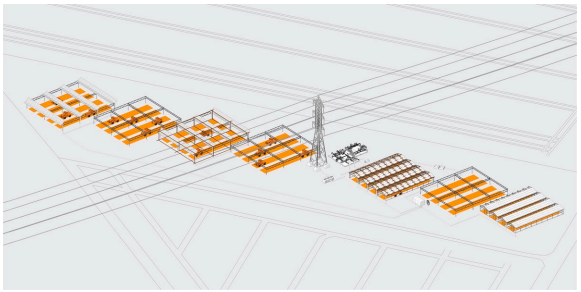
SUNFARMING: PROCESS OF ENERGY PRODUCTION



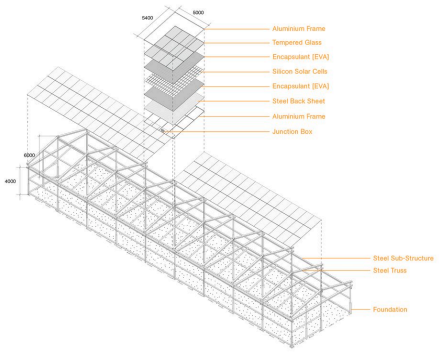
AGRI-HORTI-PHOTOVOLTAIC
AND ITS INFRASTRUCTURE



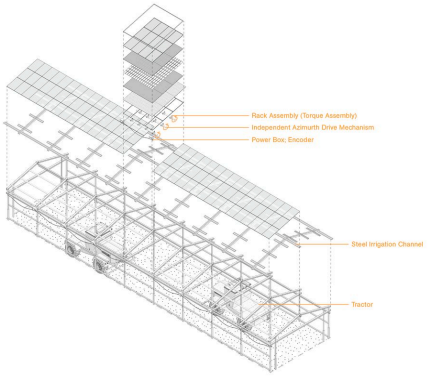
AGRI-HORTI-PHOTOVOLTAIC:
DC [RED]; AC [BLUE]



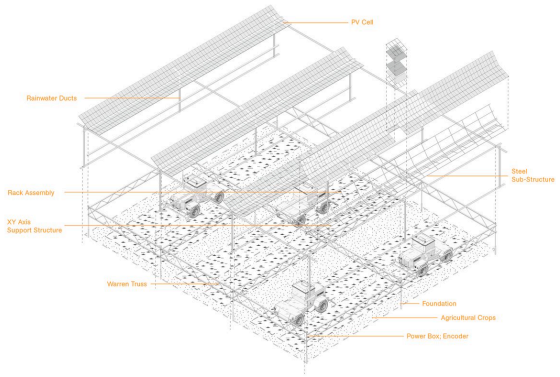
AGRI-HORTI-PHOTOVOLTAIC:
AGRICULTURAL ELEMENTS



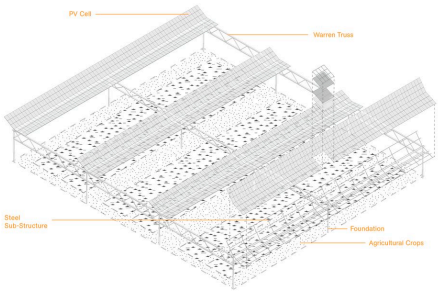
AGRI-VOLTAIC STRUCTURE A: SOUTH STATIC



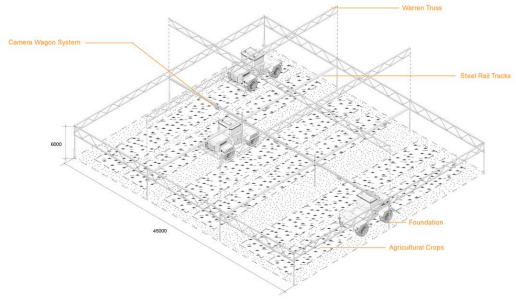
AGRI-VOLTAIC STRUCTURE B: SOUTH
TRACKING AND RAINWATER HARVESTING



AGRI-VOLTAIC STRUCTURE C: EAST-WEST TRACKING AND RAINWATER HARVESTING

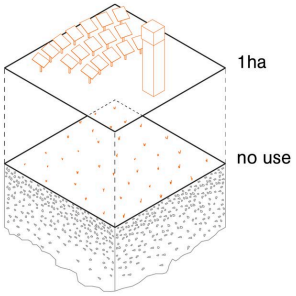


AGRI-VOLTAIC STRUCTURE D: EAST-WEST TRACKING



AGRI-VOLTAIC STRUCTURE: CONTROL AREA

The most tangible parameter determining the effectiveness of solar photovoltaics is the amount of land use. Comparing between the three infrastructures, Jülich Solar Tower is the least efficient in generating electricity. Solarpark on the other hand is efficient but does harness the potential of the land. Sunfarming is relatively efficient and allows hybrid land use.

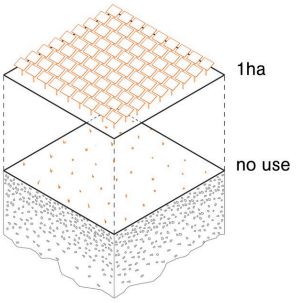


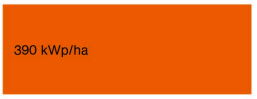


50 Household
(average of 3'000 kWh per House)

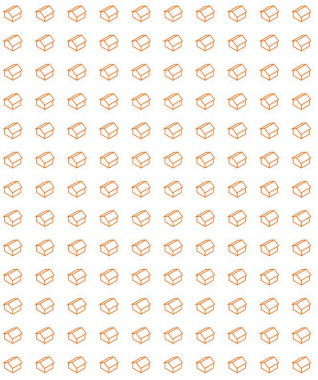


JÜLICH SOLAR TOWER

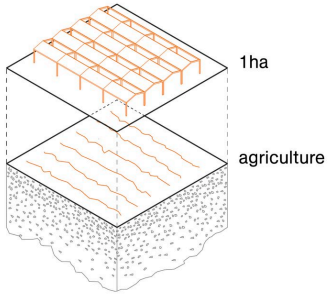




130 Household
(average of 3'000 kWh per House)



SOLARPARK INDEN







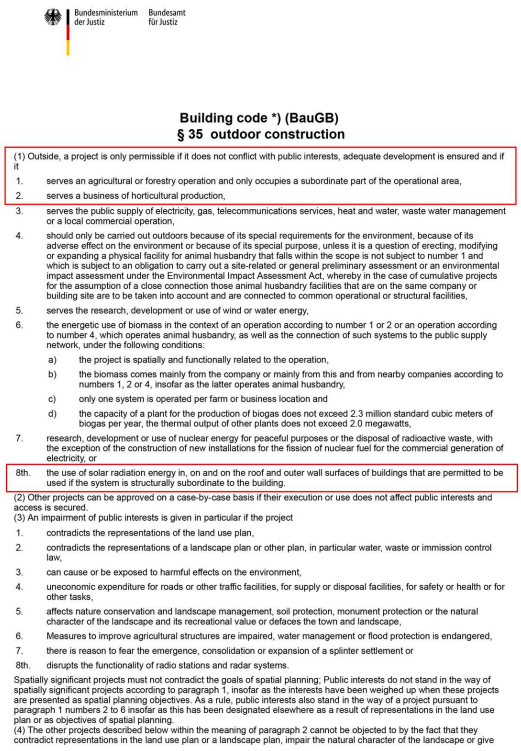
SUNFARMING AGRI-PV

The Potentials and Challenges of Agrivoltaics

Increasingly frequent heat waves in Central Europe have caused the annual irradiation in Germany to increase drastically overtime. This makes it the more favourable for the use of Agrivoltaics as they could not only produce more electrical energy through greater amounts of solar energy absorbed, but also improve crop cultivation by reducing evaporation and protection against intense solar radiation.

While the technical and economic feasibility of Agri-Voltaics has been proven in many countries, the current regulatory framework is probably the greatest hurdle to exploiting its potential. In Germany, for example, the dual use of land for photovoltaics and agriculture is currently not defined in law and the Renewable Energy Sources Act (EEG) does not provide adequate compensation. Is it that regulations should not be so precise at ‘controlling’ machines, but rather consider the typological value as a whole?

THE COMPLEXITY OF LAND USE RIGHTS



Bundesministerium der Justiz Bundesamt für Justiz

Building code *) (BauGB)
§ 35 outdoor construction

(1) Outside, a project is only permissible if it does not conflict with public interests, adequate development is ensured and if it

1. serves an agricultural or forestry operation and only occupies a subordinate part of the operational area,
2. serves a business of horticultural production,
3. serves the public supply of electricity, gas, telecommunications services, heat and water, waste water management or a local commercial operation,
4. should only be carried out outdoors because of its special requirements for the environment, because of its adverse effect on the environment or because of its special purpose, unless it is a question of erecting, modifying or expanding a physical facility for animal husbandry that falls within the scope is not subject to number 1 and which is subject to an obligation to carry out a site-related or general preliminary assessment or an environmental impact assessment under the Environmental Impact Assessment Act, whereby in the case of cumulative projects for the assumption of a close connection those animal husbandry facilities that are on the same company or building site are to be taken into account and are connected to common operational or structural facilities,
5. serves the research, development or use of wind or water energy,
6. the energetic use of biomass in the context of an operation according to number 1 or 2 or an operation according to number 4, which operates animal husbandry, as well as the connection of such systems to the public supply network, under the following conditions:
   a) the project is spatially and functionally related to the operation,
   b) the biomass comes mainly from the company or mainly from this and from nearby companies according to numbers 1, 2 or 4, insofar as the latter operates animal husbandry,
   c) only one system is operated per farm or business location and
   d) the capacity of a plant for the production of biogas does not exceed 2.3 million standard cubic meters of biogas per year, the thermal output of other plants does not exceed 2.0 megawatts,
7. research, development or use of nuclear energy for peaceful purposes or the disposal of radioactive waste, with the exception of the construction of new installations for the fission of nuclear fuel for the commercial generation of electricity, or

8th. the use of solar radiation energy in, on and on the roof and outer wall surfaces of buildings that are permitted to be used if the system is structurally subordinate to the building.

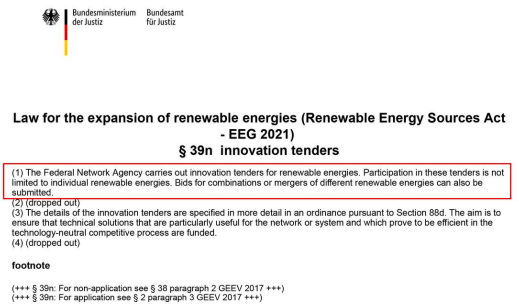
(2) Other projects can be approved on a case-by-case basis if their execution or use does not affect public interests and access is secured.
(3) An impairment of public interests is given in particular if the project

1. contradicts the representations of the land use plan,
2. contradicts the representations of a landscape plan or other plan, in particular water, waste or immission control law,
3. can cause or be exposed to harmful effects on the environment,
4. uneconomic expenditure for roads or other traffic facilities, for supply or disposal facilities, for safety or health or for other tasks,
5. affects nature conservation and landscape management, soil protection, monument protection or the natural character of the landscape and its recreational value or defaces the town and landscape,
6. Measures to improve agricultural structures are impaired, water management or flood protection is endangered,
7. there is reason to fear the emergence, consolidation or expansion of a splinter settlement or

8th. disrupts the functionality of radio stations and radar systems.

Spatially significant projects must not contradict the goals of spatial planning; Public interests do not stand in the way of spatially significant projects according to paragraph 1, insofar as the interests have been weighed up when these projects are presented as spatial planning objectives. As a rule, public interests also stand in the way of a project pursuant to paragraph 1 numbers 2 to 6 insofar as this has been designated elsewhere as a result of representations in the land use plan or as objectives of spatial planning.
(4) The other projects described below within the meaning of paragraph 2 cannot be objected to by the fact that they contradict representations in the land use plan or a landscape plan, impair the natural character of the landscape or give

§35 FEDERAL BUILDING CODE (BauGB)
Source: Gesetze im Internet, 2022
[https://www.gesetze-im-internet.de/bbaug/__35.html]



Bundesministerium der Justiz Bundesamt für Justiz

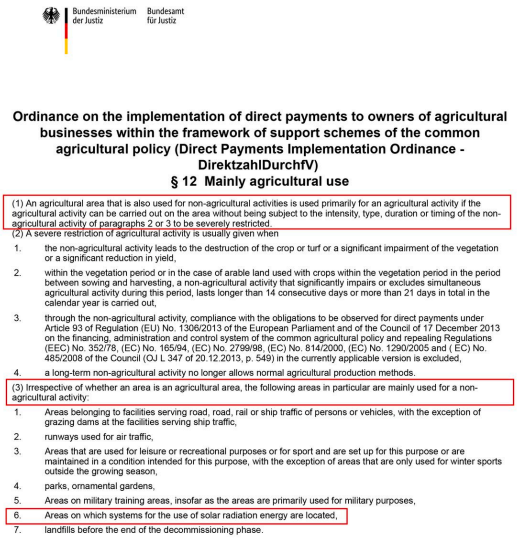
Law for the expansion of renewable energies (Renewable Energy Sources Act - EEG 2021)
§ 39n innovation tenders

(1) The Federal Network Agency carries out innovation tenders for renewable energies. Participation in these tenders is not limited to individual renewable energies. Bids for combinations or mergers of different renewable energies can also be submitted.
(2) (dropped out)
(3) The details of the innovation tenders are specified in more detail in an ordinance pursuant to Section 88d. The aim is to ensure that technical solutions that are particularly useful for the network or system and which prove to be efficient in the technology-neutral competitive process are funded.
(4) (dropped out)

footnote

(+++ § 39n: For non-application see § 38 paragraph 2 GEEV 2017 +++)
(+++ § 39n: For application see § 2 paragraph 3 GEEV 2017 +++)

§39n RENEWABLE ENERGY SOURCES ACT (EEG 2021)
Source: Gesetze im Internet, 2022
[https://www.gesetze-im-internet.de/eeg_2014/__39n.html]



Bundesministerium der Justiz Bundesamt für Justiz

Ordinance on the implementation of direct payments to owners of agricultural businesses within the framework of support schemes of the common agricultural policy (Direct Payments Implementation Ordinance - DirektzahlDurchfV)

§ 12 Mainly agricultural use

(1) An agricultural area that is also used for non-agricultural activities is used primarily for an agricultural activity if the agricultural activity can be carried out on the area without being subject to the intensity, type, duration or timing of the non-agricultural activity of paragraphs 2 or 3 to be severely restricted.

(2) A severe restriction of agricultural activity is usually given when

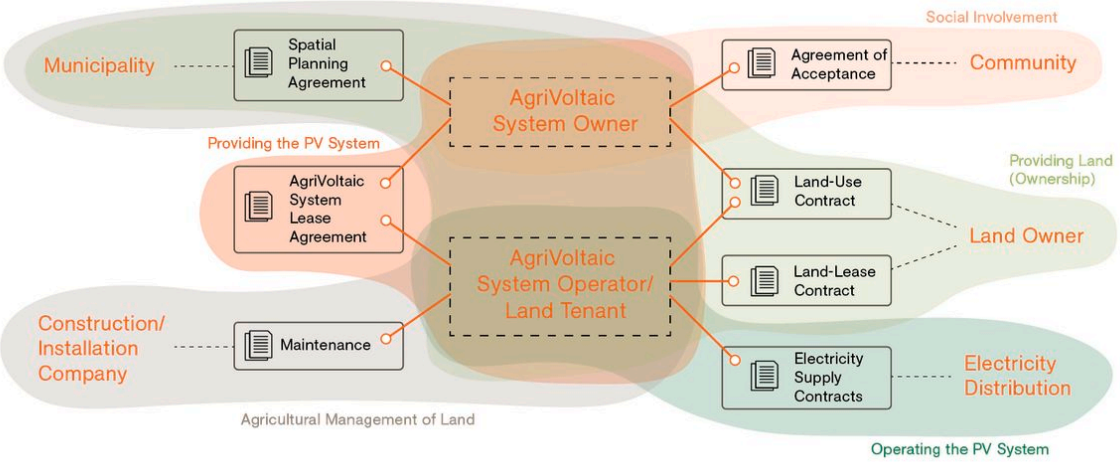
1. the non-agricultural activity leads to the destruction of the crop or turf or a significant impairment of the vegetation or a significant reduction in yield,
2. within the vegetation period or in the case of arable land used with crops within the vegetation period in the period between sowing and harvesting, a non-agricultural activity that significantly impairs or excludes simultaneous agricultural activity during this period, lasts longer than 14 consecutive days or more than 21 days in total in the calendar year is carried out,
3. through the non-agricultural activity, compliance with the obligations to be observed for direct payments under Article 93 of Regulation (EU) No. 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, administration and control system of the common agricultural policy and repealing Regulations (EEC) No. 352/78, (EC) No. 165/94, (EC) No. 2799/98, (EC) No. 814/2000, (EC) No. 1290/2005 and (EC) No. 485/2008 of the Council (OJ L 347 of 20.12.2013, p. 549) in the currently applicable version is excluded,
4. a long-term non-agricultural activity no longer allows normal agricultural production methods.

(3) Irrespective of whether an area is an agricultural area, the following areas in particular are mainly used for a non-agricultural activity:

1. Areas belonging to facilities serving road, road, rail or ship traffic of persons or vehicles, with the exception of grazing dams at the facilities serving ship traffic,
2. runways used for air traffic,
3. Areas that are used for leisure or recreational purposes or for sport and are set up for this purpose or are maintained in a condition intended for this purpose, with the exception of areas that are only used for winter sports outside the growing season,
4. parks, ornamental gardens,
5. Areas on military training areas, insofar as the areas are primarily used for military purposes,
6. Areas on which systems for the use of solar radiation energy are located,
7. landfills before the end of the decommissioning phase.

§12 DIRECT PAYMENTS IMPLEMENTATION ORDINANCE (DirektZahlDurchfV)
Source: Gesetze im Internet, 2022 [https://www.gesetze-im-internet.de/direktzahldurchfv/__12.html]

THE COMPLEXITY OF THE DIVERSITY OF ACTORS



STAKEHOLDERS AND CONTRACT MODELS OF AGRIVOLTAICS
The existing multifaceted structure of stakeholders is interwoven and heavily dependent on each other. Hence it should be taken with care, should we decide to expand this system to generate more layers as the process would get increasingly complex.

Increasingly frequent heat waves in Central Europe have caused the annual irradiation in Germany to increase drastically overtime. This makes it the more favourable for the use of Agrivoltaics as they could not only produce more electrical energy through greater amounts of solar energy absorbed, but also improve crop cultivation by reducing evaporation and protection against intense solar radiation.

While the technical and economic feasibility of Agri-Voltaics has been proven in many countries, the current regulatory framework is probably the greatest hurdle to exploiting its potential. In Germany, for example, the dual use of land for photovoltaics and agriculture is currently not defined in law and the Renewable Energy Sources Act (EEG) does not provide adequate compensation. Is it that regulations should not be so precise at ‘controlling’ machines, but rather consider the typological value as a whole?

THE COMPLEXITY OF LAND USE RIGHTS

Bundesministerium der Justiz Bundesamt für Justiz

Building code *) (BauGB)
§ 35 outdoor construction

(1) Outside, a project is only permissible if it does not conflict with public interests, adequate development is ensured and if it

1. serves an agricultural or forestry operation and only occupies a subordinate part of the operational area,
2. serves a business of horticultural production,
3. serves the public supply of electricity, gas, telecommunications services, heat and water, waste water management or a local commercial operation,
4. should only be carried out outdoors because of its special requirements for the environment, because of its adverse effect on the environment or because of its special purpose, unless it is a question of erecting, modifying or expanding a physical facility for animal husbandry that falls within the scope is not subject to number 1 and which is subject to an obligation to carry out a site-related or general preliminary assessment or an environmental impact assessment under the Environmental Impact Assessment Act, whereby in the case of cumulative projects for the assumption of a close connection those animal husbandry facilities that are on the same company or building site are to be taken into account and are connected to common operational or structural facilities,
5. serves the research, development or use of wind or water energy,
6. the energetic use of biomass in the context of an operation according to number 1 or 2 or an operation according to number 4, which operates animal husbandry, as well as the connection of such systems to the public supply network, under the following conditions:
   a) the project is spatially and functionally related to the operation,
   b) the biomass comes mainly from the company or mainly from this and from nearby companies according to numbers 1, 2 or 4, insofar as the latter operates animal husbandry,
   c) only one system is operated per farm or business location and
   d) the capacity of a plant for the production of biogas does not exceed 2.3 million standard cubic meters of biogas per year, the thermal output of other plants does not exceed 2.0 megawatts,
7. research, development or use of nuclear energy for peaceful purposes or the disposal of radioactive waste, with the exception of the construction of new installations for the fission of nuclear fuel for the commercial generation of electricity, or

8th. the use of solar radiation energy in, on and on the roof and outer wall surfaces of buildings that are permitted to be used if the system is structurally subordinate to the building.

(2) Other projects can be approved on a case-by-case basis if their execution or use does not affect public interests and access is secured.
(3) An impairment of public interests is given in particular if the project

1. contradicts the representations of the land use plan,
2. contradicts the representations of a landscape plan or other plan, in particular water, waste or immission control law,
3. can cause or be exposed to harmful effects on the environment,
4. uneconomic expenditure for roads or other traffic facilities, for supply or disposal facilities, for safety or health or for other tasks,
5. affects nature conservation and landscape management, soil protection, monument protection or the natural character of the landscape and its recreational value or defaces the town and landscape,
6. Measures to improve agricultural structures are impaired, water management or flood protection is endangered,
7. there is reason to fear the emergence, consolidation or expansion of a splinter settlement or

8th. disrupts the functionality of radio stations and radar systems.

Spatially significant projects must not contradict the goals of spatial planning; Public interests do not stand in the way of spatially significant projects according to paragraph 1, insofar as the interests have been weighed up when these projects are presented as spatial planning objectives. As a rule, public interests also stand in the way of a project pursuant to paragraph 1 numbers 2 to 6 insofar as this has been designated elsewhere as a result of representations in the land use plan or as objectives of spatial planning.
(4) The other projects described below within the meaning of paragraph 2 cannot be objected to by the fact that they contradict representations in the land use plan or a landscape plan, impair the natural character of the landscape or give

§35 FEDERAL BUILDING CODE (BauGB)
Source: Gesetze im Internet, 2022
[https://www.gesetze-im-internet.de/bbaug/__35.html]

Bundesministerium der Justiz Bundesamt für Justiz

Law for the expansion of renewable energies (Renewable Energy Sources Act - EEG 2021)
§ 39n innovation tenders

(1) The Federal Network Agency carries out innovation tenders for renewable energies. Participation in these tenders is not limited to individual renewable energies. Bids for combinations or mergers of different renewable energies can also be submitted.
(2) (dropped out)
(3) The details of the innovation tenders are specified in more detail in an ordinance pursuant to Section 88d. The aim is to ensure that technical solutions that are particularly useful for the network or system and which prove to be efficient in the technology-neutral competitive process are funded.
(4) (dropped out)

footnote

(+++ § 39n: For non-application see § 38 paragraph 2 GEEV 2017 +++)
(+++ § 39n: For application see § 2 paragraph 3 GEEV 2017 +++)

§39n RENEWABLE ENERGY SOURCES ACT (EEG 2021)
Source: Gesetze im Internet, 2022
[https://www.gesetze-im-internet.de/eeg_2014/__39n.html]

Bundesministerium der Justiz Bundesamt für Justiz

Ordinance on the implementation of direct payments to owners of agricultural businesses within the framework of support schemes of the common agricultural policy (Direct Payments Implementation Ordinance - DirektzahlDurchfV)
§ 12 Mainly agricultural use

(1) An agricultural area that is also used for non-agricultural activities is used primarily for an agricultural activity if the agricultural activity can be carried out on the area without being subject to the intensity, type, duration or timing of the non-agricultural activity of paragraphs 2 or 3 to be severely restricted.
(2) A severe restriction of agricultural activity is usually given when

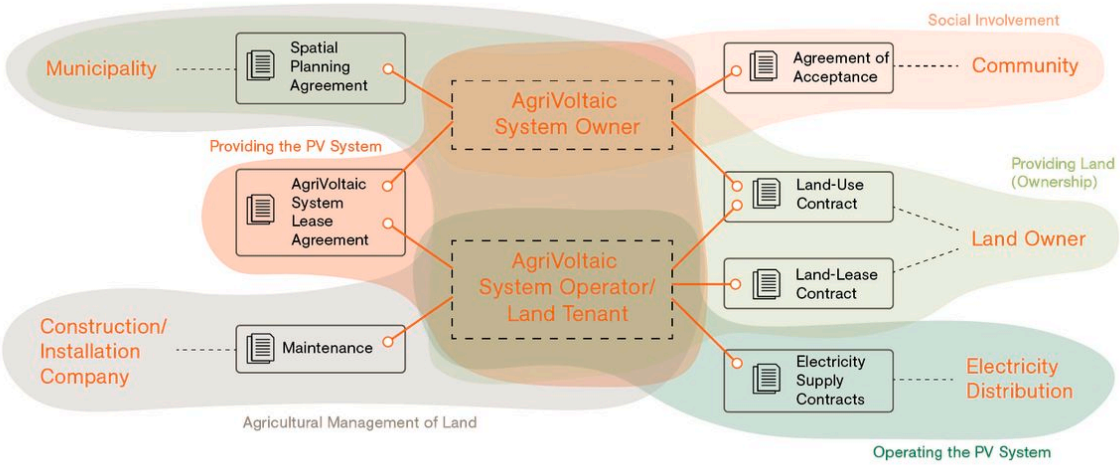
1. the non-agricultural activity leads to the destruction of the crop or turf or a significant impairment of the vegetation or a significant reduction in yield,
2. within the vegetation period or in the case of arable land used with crops within the vegetation period in the period between sowing and harvesting, a non-agricultural activity that significantly impairs or excludes simultaneous agricultural activity during this period, lasts longer than 14 consecutive days or more than 21 days in total in the calendar year is carried out,
3. through the non-agricultural activity, compliance with the obligations to be observed for direct payments under Article 93 of Regulation (EU) No. 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, administration and control system of the common agricultural policy and repealing Regulations (EEC) No. 352/78, (EC) No. 165/94, (EC) No. 2799/98, (EC) No. 814/2000, (EC) No. 1290/2005 and (EC) No. 485/2008 of the Council (OJ L 347 of 20.12.2013, p. 549) in the currently applicable version is excluded,
4. a long-term non-agricultural activity no longer allows normal agricultural production methods.

(3) Irrespective of whether an area is an agricultural area, the following areas in particular are mainly used for a non-agricultural activity:

1. Areas belonging to facilities serving road, road, rail or ship traffic of persons or vehicles, with the exception of grazing dams at the facilities serving ship traffic,
2. runways used for air traffic,
3. Areas that are used for leisure or recreational purposes or for sport and are set up for this purpose or are maintained in a condition intended for this purpose, with the exception of areas that are only used for winter sports outside the growing season,
4. parks, ornamental gardens,
5. Areas on military training areas, insofar as the areas are primarily used for military purposes,
6. Areas on which systems for the use of solar radiation energy are located,
7. landfills before the end of the decommissioning phase.

§12 DIRECT PAYMENTS IMPLEMENTATION ORDINANCE (DirektZahlDurchfV)
Source: Gesetze im Internet, 2022
[https://www.gesetze-im-internet.de/direktzahldurchfv/__12.html]

THE COMPLEXITY OF THE DIVERSITY OF ACTORS



STAKEHOLDERS AND CONTRACT MODELS OF AGRIVOLTAICS

The existing multifaceted structure of stakeholders is interwoven and heavily dependent on each other. Hence it should be taken with care, should we decide to expand this system to generate more layers as the process would get increasingly complex.

SOURCES

- Alessandra Scognamiglio, ENEA. “Agrivoltaic Systems Design and Assessment: A Critical Review, and a Descriptive Model towards a Sustainable Landscape Vision (Three-Dimensional Agrivoltaic Patterns)”. June 2021. https://www.researchgate.net/publication/352516111_Agrivoltaic_Systems_Design_and_Assessment_A_Critical_Review_and_a_Descriptive_Model_towards_a_Sustainable_Landscape_Vision_Three-Dimensional_Agrivoltaic_Patterns.
- Aluminium ore mine, Guinea (image). https://www.wirtgen-group.com/en-us/news-and-media/wirtgen/2500-sm-bauxit-guinea/?q=ngd
- A marine beacon (image). http://www.estrancitedelamer.fr/pages-thematiques/le-balisage-maritime
- A professor showing a solar panel in New Mexico in 1974 (image). https://en.wikipedia.org/wiki/Timeline_of_solar_cells#/media/File:DR._R.L._SAN_MARTIN,_NEW_MEXICO_STATE_UNIVERSITY_CLOSED_COIL_TYPE_SOLAR_HEATING_PANEL_-_555293_(cropped).jpg
- Biking on the highway (image). http://crudeoilpeak.info/oil-crisis-1973
- Book *Energiewende* (image). https://industriemuseum.lvr.de/de/sammlung/sammlung_entdecken/oekologie___recycling/buch_energiewende/BuchEnergieWende.html
- Chernobyl nuclear power plant after the disaster (image). https://www.lefigaro.fr/sciences/2016/04/26/01008-20160426ARTFIG00012-trente-ans-apres-tchernobyl-en-dix-questions.php
- Copper ore mine, Chili (image). https://www.flickr.com/photos/codelco/
- Data overview of the commune of Titz – GEOfy, 2022. https://geofy.de/en/titz/landuse/2756
- Direct payments implementation ordinance (DirectZahlDurchV) §12 – Gesetze im Internet, 2022. https://www.gesetze-im-internet.de/direktzahldurchfv/__12\.html
- Dr. Harry Wirth, Fraunhofer ISE. Aktuelle Fakten zur Photovoltaik in Deutschland. 2022. https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf
- EEG illustration (image). https://www.cleanenergywire.org/news/germany-stops-landmark-mechanism-funded-renewables-expansion-power-bills
- Energy-Charts. 2022. https://www.energy-charts.info/index.html?l=en&c=DE
- Evolution of the different types of solar energy infrastructure – Fraunhofer ISE, 2022. https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html Evolution of the different types of solar energy infrastructure – MaStR, 2022. https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht
- Evolution of the duration of sunshine per year – Deutscher Wetterdienst (DWD), 2022. https://www.dwd.de/EN/ourservices/solarenergy/maps_globalradiation_sum_new.html
- Evolution of the efficiency of solar PV technology – National Renewable Energy Laboratory (NREL), 2022. https://www.nrel.gov/pv/cell-efficiency.html
- Evolution of the MWp installed and the average price of PV modules – Bundesministerium für Wirtschaft und Klimaschutz, 2022. https://www.bmwk.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html Fraunhofer ISE, 2022. https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html
- Explosion of nuclear reactor in Fukushima (image). https://www.tempo.com/noticias/actualidade/revelando-estudo-10-anos-apos-o-acidente-nuclear-de-fukushima-radiacao.html
- Federal building code (BauGB) §35 – Gesetze im Internet, 2022. https://www.gesetze-im-internet.de/bbaug/__35\.html
- Fraunhofer Institute for Solar Energy Systems ISE. “Agrivoltaics: Opportunities for Agriculture and the Energy Transition, A Guideline for Germany”. October 2022. https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/APV-Guideline.pdf.
- *Gesetzesbechluss* (image). https://www.clearingstelle-eeg-kwkg.de/sites/default/files/2021-03/4-Gesetzesbeschluss_BR-Ds_660-90\.pdf
- Global cumulative PV Power by Region – International Renewable Energy Agency (IRENA), 2022. https://www.irena.org/Data/View-data-by-topic/Capacity-and-Generation/Country-Rankings
- International Renewable Energy Agency. Statistical Profiles. 2022. https://www.irena.org/Data/Energy-Profiles

- Kelsey Horowitz, Vignesh Ramasamy, Jordan Macknick, Robert Margolis. National Renewable Energy Laboratory (NREL). “Capital Costs fur Dual-Use Photovoltaic Installations: 2020 Benchmark for Ground-Mounted PV Systems with Pollinator-Friendly Vegetation, Grazing, and Crops”. December 2020. https://www.nrel.gov/docs/fy21osti/77811\.pdf
- Konstantin Geimer, Markus Sauerborn, Bernhard Hoffschmidt, Mark Schmitz, Joachim Göttsche. “Test Facility for Absorber Specimens of Solar Tower Power Plants”. October 2010. https://www.scientific.net/AST.74\.266\.
- Map of the different type of insfrastructure – WMS Erneuerbare Energien NRW, 2022. http://www.wms.nrw.de/umwelt/erneuerbare_energien_nrw
- Map of the photovoltaic power potential – Solargis. https://solargis.com/maps-and-gis-data/download/germany
- Materials flows https://oec.world/en
- Metabolism of PV solar energy from extraction to usage – International Energy Agency (IEA), 2022. https://www.iea.org/reports/solar-pv-global-supply-chains
- National Energy Sources and Use – Umweltbundesamt auf Basis AG Energiebilanzen, 2022. https://www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#allgemeine-entwicklung-und-einflussfaktoren
- PV installation in Bremen (image). https://de.wikipedia.org/wiki/1000-Dächer-Programm#/media/Datei:Fotovoltaikanlge-1000-Daecher-PRG-Bremen-k.jpg
- PV power installed in Germany – MaStR, 2022. https://www.marktstammdatenregister.de/MaStR/Einheit/Einheiten/OeffentlicheEinheitenuebersicht PV power installed in Germany – Solarbranche.de, 2022. https://www.solarbranche.de/ausbau/kreise-photovoltaik
- Renewable energy sources act (EEG 2021) §39n – Gesetze im Internet, 2022. https://www.gesetze-im-internet.de/eeg_2014/__39n.html
- R.P. Merchán, M.J. Santos, A. Medina, A. Calvo Hernández. “High Temperature Central Tower Plants for Concentrated Solar Power: 2021 Overview”. 2022. https://gredos.usal.es/bitstream/handle/10366/147586/1-s2\.0-S1364032121010923-main.pdf?sequence=1&isAllowed=y.
- Share of Electricity Production in Germany – Statistisches Bundesamt (Destatis), 2022. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/_Grafik/_Interaktiv/bruttostromerzeugung-erneuerbare-energien.html;jsessionid=23C692346F45D0E75EF0BE6A2650C4F3\.live731
- Silica sand mine, USA (image). https://www.at-minerals.com/en/artikel/at_Sand_as_raw_material_a_scarce_commodity__3494944\.html
- Silver ore mine, Peru (image). https://www.desdeadentro.pe/2022/04/los-retos-de-construir-las-proximas-minas/
- Solarpark Inden, RURENERGIE. 2022. https://www.rurenergie.de/projekte.html
- SolarReviews. “Where is solar power used the most?”. 2022 https://www.solarreviews.com/blog/where-is-solar-power-used-the-most
- “Sunfarming Group Develops and Implements Innovative Agri-Solar Systems in the Rhineland”. SUNfarmingde, 2022. https://sunfarming.de/en/blog/sunfarming-group-develops-and-implements-innovative-agri-solar-systems-in-the-rhineland.
- Tobias Hirsch, Nils Ahlbrink, Jan Gall, Vera Nolte. “vICERP: Virtual Institute of Central Receiver Power Plants”. March 2012. https://www.researchgate.net/publication/259896543_vICERP_Virtual_Institute_of_Central_Receiver_Power_Plants
- TrendEconomy. World Merchandise Exports and Imports by Commodity (HS). 2022. https://trendeconomy.com/data/commodity_h2/250510
- Wenjin Ding, Thomas Bauer. “Progress in Research and Development of Molten Chloride Salt Technology for Next Generation Concentrated Solar Power Plants”. March 2021. https://www.sciencedirect.com/science/article/pii/S2095809921000473\.

This work by Bastien Terrettaz, Eu Juin Toh, and Esad Mujanovic was created as part of the design studio Power to the People at ETH Zurich in Fall 2022. The PDF is intended for educational purposes only. Its commercial distribution is strictly forbidden.

© 2024, Architecture of Territory

Architecture of Territory
Professor Milica Topalović

TEACHING TEAM
Muriz Djurdjevic
Dorothee Hahn
Milica Topalović
Jan Westerheide

Prof. Milica Topalović
ETH Zurich
ONA G41
Neunbrunnenstrasse 50
8093 Zurich
Switzerland
+41 (0)44 633 86 88
www.topalovic.arch.ethz.ch