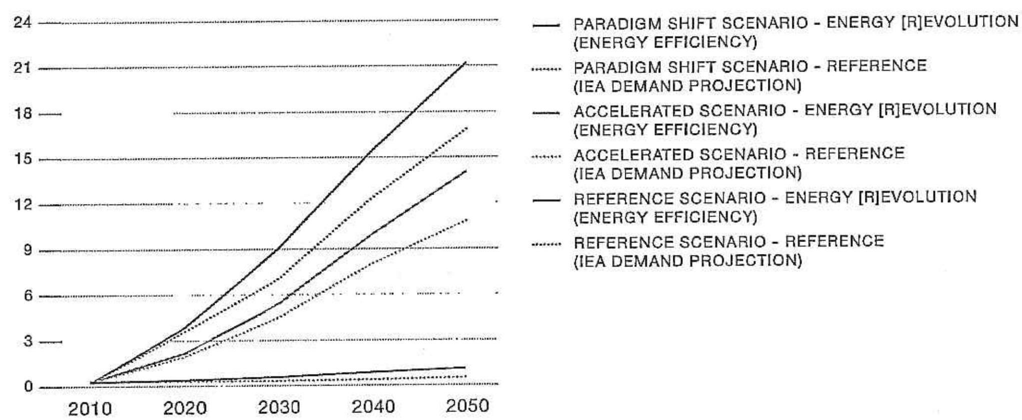
Electricity production

The share of PV in the electricity market will depend on what happens to electricity consumption in light of global efforts to reduce greenhouse gas emissions. PV could provide as much as 11.3% to 21.2% of electricity demand by 2050.

By 2020, the penetration of PV in the world electricity market could reach a global average of 3.9%. However, in Europe the share could be up to 12% in a Paradigm Shift scenario.

"PV electricity could provide over one fifth of the global electricity demand by 2050."

FIGURE 38
AMOUNT OF SOLAR PV ELECTRICITY AS A PERCENTAGE OF WORLD POWER CONSUMPTION
%



Reference Solar market growth - IEA Projection		2010	2020	2030	2040	2050
Solar power penetration of World's electricity in % - Reference (IEA Demand Projection)	%	0.2	0.4	0.7	1.1	1.4
Solar power penetration of World's electricity in % - Energy [R]evolution (Energy Efficiency)	%	0.2	0.4	0.8	1.3	1.8
Accelerated Solar Market growth						
Solar power penetration of World's electricity in % - Reference (IEA Demand Projection)	%	0.2	1.9	4.9	8.2	11.3
Solar power penetration of World's electricity in % - Energy [R]evolution (Energy Efficiency)	%	0.2	2.0	5.7	10.1	14.0
Paradigm Shift Solar Market Growth						
Solar power penetration of World's electricity in % - Reference (IEA Demand Projection)	%	0.2	4.0	7.8	12.6	17.1
Solar power penetration of World's electricity in % - Energy [R]evolution (Energy Efficiency)	%	0.2	4.2	9.1	15.5	21.2

source: Greenpeace/EPIA Solar Generation VI, 2010

c. Employment and investment

As mentioned, 30 FTE jobs are created for each MW of solar power modules produced and installed. Using this assumption, more than 228,000 people are employed in the solar energy sector in 2009. Using the Reference scenario, this figure would fall to around 136,000 jobs in 2015, and rise to 187,000 in 2020 and reach almost 509,000 by 2030.

In the Accelerated scenario, the solar electricity sector would become a powerful jobs motor, providing green-collar employment to almost 1.7 million people by 2020 and 2.63 million by 2030.

The Paradigm Shift scenario would see employment levels in solar electricity as high as 1.37 million as early as 2015, rising to 3.78 million in 2020 and 3.55 million in 2030.

In terms of global investment, the PV industry could attract €79 billion per year in 2020, increasing to €93 billion in 2030 under the Accelerated scenario. With a Paradigm Shift, investment in the world's PV electricity market would attract investment of €129 billion a year by 2020. The scenario foresees that this would level off over the next two decades, reaching €149 billion per year in 2050.

Worker installing PV module, Wesco court, Woking, UK.

"Over 3.5 million people could be employed in the PV sector in 2030."

TABLE 18
INVESTMENT AND EMPLOYMENT POTENTIAL OF SOLAR PV

Reference Scenario	2008	2009	2010	2015	2020	2030	2040	2050
Annual Installation MW	4,940	7,262	7,550	4,117	5,920	18,740	19,928	20,129
Cost €/kW	3,000	2,900	2,800	2,351	2,080	1,703	1,487	1,382
Investment € billion/year	15	21	14	12	13	27	30	28
Employment Job/year	156,965	228,149	237,093	136,329	187,464	508,944	476,114	692,655
Accelerated Scenario								
Annual Installation MW	4,940	7,262	12,091	27,091	59,031	96,171	162,316	174,796
Cost €/kW	3,000	2,900	2,800	1,855	1,340	966	826	758
Investment € billion/year	15	21	34	50	79	93	134	133
Employment Job/year	156,965	228,149	374,319	810,228	1,690,603	2,629,968	4,027,349	4,315,343
Paradigm Shift Scenario								
Annual Installation MW	4,940	7,262	13,625	47,000	135,376	136,833	250,000	250,000
Cost €/kW	3,000	2,900	2,500	1,499	951	744	645	596
Investment € billion/year	15	21	34	70	129	100	161	149
Employment Job/year	156,965	228,149	417,010	1,372,185	3,781,553	3,546,820	5,563,681	5,346,320

source: Greenpeace/EPIA Solar Generation VI, 2010.

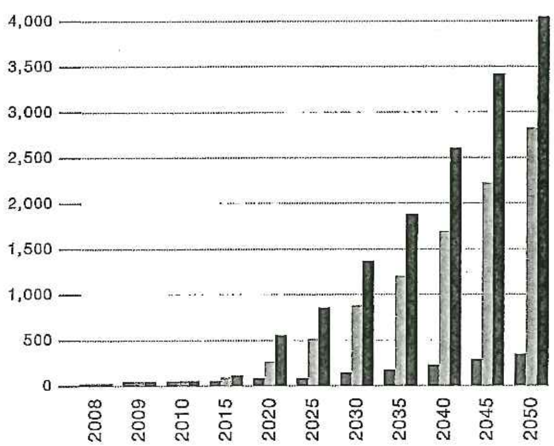
d. CO_2 reduction

Tackling climate change using PV

Under the Paradigm Shift scenario, up to 4,047 million tonnes of CO_2 equivalent would be avoided every year by 2050. The cumulative total from 2003 to 2050 would represent up to 65 billion tonnes of CO_2 equivalent saved. There is no doubt that PV can be an efficient tool to replace conventional power generation and fight climate change.

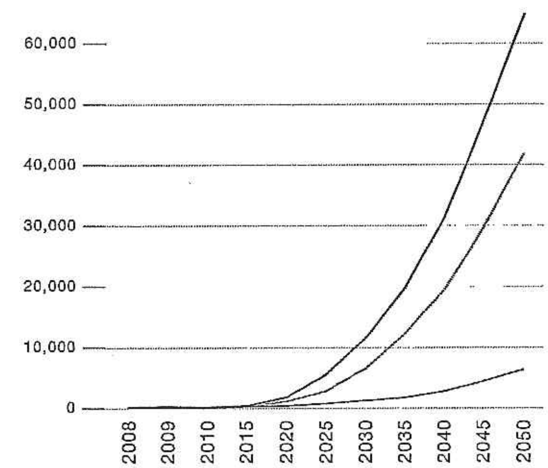
"PV could save over 4 billion tonnes of co2 equivalent in the year 2050."

FIGURE 39
ANNUAL CO_2 REDUCTION
MILLION TONNES CO_2



source: Greenpeace/EPIA Solar Generation VI, 2010.

FIGURE 40
CUMULATIVE CO_2 REDUCTION
MILLION TONNES CO_2

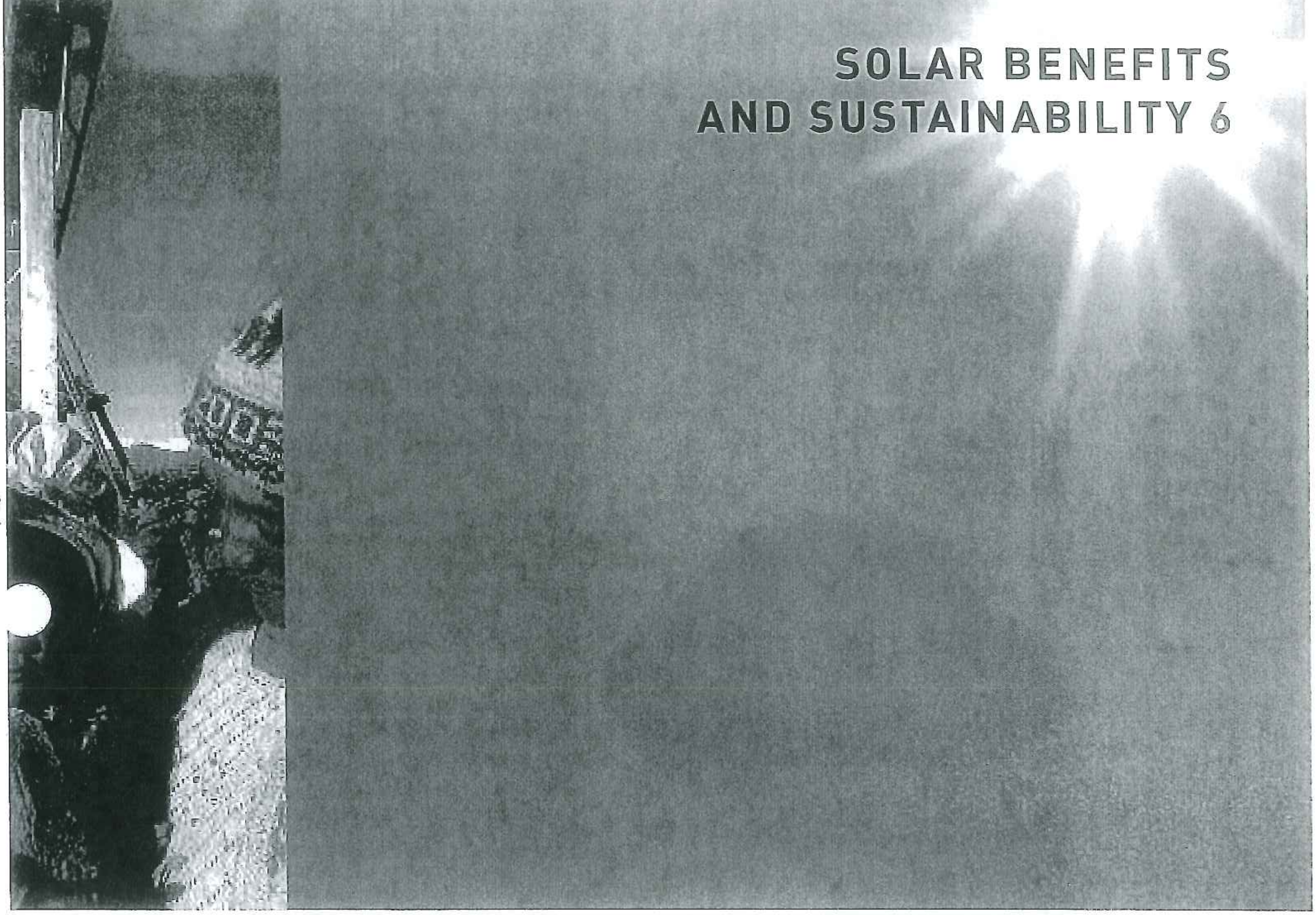


source: Greenpeace/EPIA Solar Generation VI, 2010.

Reference Scenario	2008	2009	2010	2015	2020	2030	2040	2050
CO_2 reduction (with 600g CO_2/kWh) [annual Mio tCO_2]	10	15	19	33	57	123	226	337
Avoided CO_2 since 2003 [cummulative Mio tCO_2]	35	50	69	208	438	1,300	3,031	5,911
Accelerated Scenario								
CO_2 reduction (with 600g CO_2/kWh) [annual Mio tCO_2]	10	15	20	73	254	853	1,693	2,670
Avoided CO_2 since 2003 [cummulative Mio tCO_2]	61	75	95	327	1,160	6,580	19,153	41,460
Paradigm Scenario								
CO_2 reduction (with 600g CO_2/kWh) [annual Mio tCO_2]	5	15	20	113	540	1,358	2,603	4,047
Avoided CO_2 since 2003 [cummulative Mio tCO_2]	56	70	90	404	2,014	11,085	30,559	64,890

source: Greenpeace/EPIA Solar Generation VI, 2010.

SOLAR BENEFITS AND SUSTAINABILITY 6

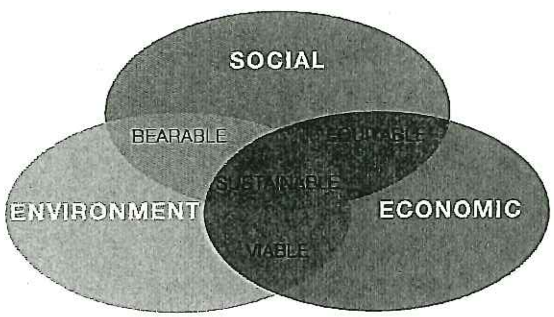


6. SOLAR BENEFITS AND SUSTAINABILITY

Sustainable development can be described as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[37]. The concept of sustainability is based on three pillars: social, environmental and economic sustainability. This chapter summarises how the benefits of PV electricity can contribute to each of these three pillars.

"PV electricity generates a number of economic benefits for the entire society."

FIGURE 41
DEFINITION OF SUSTAINABILITY



source: IUCN – The Future of Sustainability:
Re-thinking Environment and Development in the Twenty-first Century, 2006.

6.1. Economic benefits

Apart from being a clean and reliable source of electricity, PV generates a number of economic benefits for the entire society. The *SET For 2020* study has analysed the net economic benefits of PV to society for the European Union.

Figure 41 illustrates the benefits of PV in Europe expressed in €ct/kWh as calculated in the study. All contributing factors are shortly explained below including the cost of Feed-in Tariffs. It demonstrates that Feed-in Tariffs generate more benefits than what they cost initially to electricity consumers[38].

Support schemes benefits

The Feed-in Tariffs received by PV plant owners are a benefit to them. The overall costs for the Feed-in Tariffs are usually rolled over to final electricity consumers and included in their electricity bills. In practice, Feed-in Tariffs are thus creating an income transfer from the whole society to people that decided to invest in PV. As such, their net effect on society is neutral

A study investigating the effect of the Feed-in Tariff cost on the electricity price in Germany was conducted by Phoenix Solar AG with the consulting firm A. T. Kearney. It shows that the net effect of the penetration of PV on the electricity price in Germany is about 1.28€ct/kWh. This represents about 5% of the current electricity price (23.7€ct/kWh).

Reduction of greenhouse gas emissions

The cost of greenhouse gas emissions from power generation can be easily decreased using PV. The manufacturing of PV systems emits between 15 g and 25 g of CO_2-equivalent per kWh, to be compared with the average 600g that each kWh produced in the world emits. And during their operational lifetime, PV systems do not emit any greenhouse gases. Moreover, the carbon footprint of PV systems is decreasing every year. Currently, the external costs to society incurred from burning fossil fuels are not included in electricity prices.

In Europe 1.2 €ct can be saved for each kWh produced by PV electricity. On a world-wide basis the current electricity mix is even more carbon intensive than in the European Union, which means that savings on a global scale will be even larger. It can be assumed that with the current global electricity mix more than 600g/kWh CO_2 equivalent emissions are emitted. The value of avoided emissions by PV on a world-wide scale can be therefore as high as 2.3€ct/kWh.*

* Assumption on the price of carbon dioxide emissions from fossil fuels: 38€/tonne CO_2.

Reduction of grid losses

PV can be considered as a distributed and decentralised source of energy. Producing electricity near the place where it is consumed implies a reduction in the distribution and transmission losses (costs) which are linked to the distance between the point of generation and the point of use. The *SET For 2020* study shows that with the avoidance of grid losses in Europe, the added value of PV would be of 0.5€ct/kWh.

Energy security (hedging value)

Once installed, a PV system will produce electricity for at least 25 years at a fixed and known cost. Conventional power plants must deal with fluctuating prices for fossil fuels such as oil, gas or coal on the international markets. The certainty of being independent from such fluctuations has been valued for Europe at 1.5 to 3.1€ct/kWh depending on the assumptions of the oil, gas and coal prices evolution.

Operating reserve

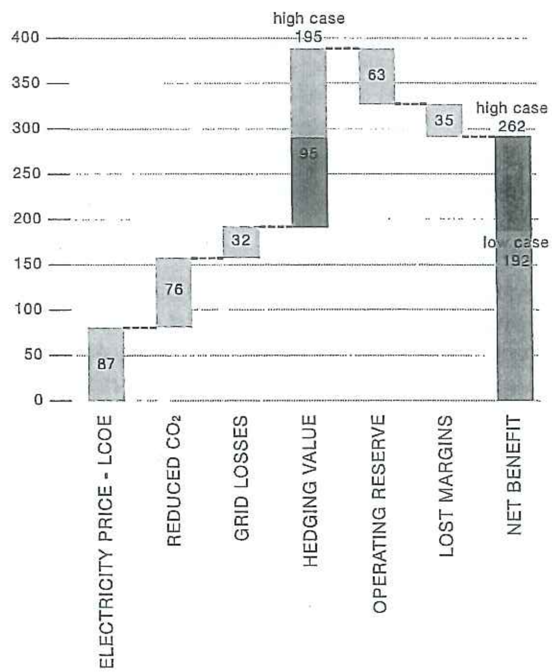
PV requires additional operating reserves to ensure the full reliability of PV electricity systems. This cost is due to the variable nature of PV electricity production and is well-known. In Europe, the additional balancing cost linked to PV operating reserves has been evaluated around 1€ct/kWh.

Lost margins for utilities

Every kWh of PV is produced by a PV plant owner or an Independent Power Producer (IPP) instead of a traditional utility. Therefore, margins of utilities will definitely shrink because of PV. In Europe, this effect has been quantified to be approximately 0.6€ct/kWh.

However, this offers also opportunities for utilities as they will have to adapt their business models transforming into new generation utilities that can take up important tasks in the future electricity grids as aggregators, facilitators and network service providers.

FIGURE 42
EXAMPLE OF CUMULATIVE BENEFITS OF PV (EUROPE, SET FOR 2020 PARADIGM SHIFT SCENARIO).
€Bn



source: EPIA, Set for 2020, 2009.

"PV contribute to reduce gas emissions , grid losses and increase energy security, all these benefits should be quantified."

There are a couple of additional benefits related to PV, apart from those mentioned above. However, it is less straightforward to measure them, as a clear calculation base is lacking.

Industry development

PV requires industrial capacity: raw material providers; module manufacturers; machinery and equipment providers; installers; and other services linked to the electricity system. This generates added value for the community; not only in terms of jobs, but also in terms of industrial development, and business generation.

Moreover, PV contributes to the structural change needed to build an efficient and distributed energy world. PV enables the development of smart grid technology and integrated, innovative applications, such as electric vehicles and energy-positive buildings. It also contributes to the enhancement of competition in the currently rather concentrated power generation market.

Clean and democratic investment

PV can be an alternative, democratic and low-risk investment for all PV plant owners. Instead of investing directly in non-transparent financial funds, PV offers clean and sustainable investment opportunities.

Effects on the electricity generation cost

"PV influences electricity spot prices resulting in lower overall electricity prices."

PV influences the electricity spot prices during periods of peak demand. The spot price for electricity is the highest during such periods. Electricity network operators typically run special power plants during peaks to meet demand. Investing in and operating these highly flexible plants is an expensive practice. As in many countries most of the PV electricity is generated during the periods of high demand, PV electricity generation helps shave the peak-load, thus reducing spot prices. The high correlation between PV generation and prices of electricity on the spot market[39] is a reality, as seen with the German electricity market. In other words, PV lowers the generation cost of electricity.

Value of PV electricity production after the period of support

Feed-in Tariffs are normally granted for a period of 20 years. However, PV modules can generate electricity for at least 25 years. Experiments have even shown that over 30 years of lifetime is feasible. Therefore, PV systems will generate free electricity during a period of at least 5 years after the end of the support schemes payment period.

6.2 Environmental factors

a. Climate change mitigation

The damage we are doing to the climate by using fossil fuels (i.e. oil, coal and gas) for energy and transport is likely to destroy the livelihoods of millions of people, especially in the developing world. It will also disrupt ecosystems and significantly speed up the extinction of species over the coming decades.

International Climate Policies

Recognising these threats, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed the Kyoto Protocol in 1997. The Protocol finally entered into force in early 2005 and since then its member countries meet twice annually to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the agreement made in Kyoto.

The Kyoto Protocol commits its signatories to reduce their greenhouse gas emissions from their 1990 level by 5.2% by the target period of 2008-2012. Nations and regions have adopted a series of reduction targets in order to meet their obligations under the Protocol. In the European Union, for instance, the commitment is to an overall reduction of 8%. To help get there, the EU has agreed to increase its proportion of renewable energy from 6 to 12% by 2010.

International climate negotiations have entered a difficult stage following the Copenhagen Climate Conference (COP 15) which failed to deliver the legally binding international treaty. The treaty would be crucial in providing investment security and a clear direction for the green transformation of the world economy. The Copenhagen Accord, a non-binding letter of political intentions, contains a number of provisions on mid-term targets for developed countries as well as mitigation actions by developing countries. Furthermore, it contains provisions for financial and technological support for developing countries carrying out actions combating climate change. However, the international community is still in search of an internationally accepted formula on how these provisions are to be carried out.

The sixteenth Conference of the Parties (COP 16) took place in Cancun from 29 November to 10 December 2010. After two weeks of talks led by the skilful chairmanship of the Mexican government, delegates at the United Nations Climate Change Conference delivered a balanced package of decisions on adaptation, mitigation technology transfer and finance. The deal reached in Cancun was not rich in content, rather in confidence, especially towards the UNFCCC process. Still, governments have a strict work program ahead to follow through on the Cancun Agreement in order to reach a binding agreement in South Africa on 2011, including major efforts to cut emissions to keep the global temperature rise below 2 degrees, as well as securing fast track and long term finance commitments and the future of the Kyoto Protocol.

EPIA and Greenpeace believe that it is possible to reach a binding deal before the expiration of the end of the first commitment period of the Kyoto Protocol. Such an agreement will need to ensure that industrialized countries reduce their emissions on average by at least 40% by 2020, compared to their 1990 levels. They will need to provide a further $140 billion a year in order to enable developing countries to adapt to climate change, protect their forests and achieve their part of the energy revolution. On the other hand, developing countries themselves need to reduce their greenhouse gas emissions by 15%-30% with regards to their projected growth by 2020 and raise their mitigation ambitions through the Nationally Appropriate Mitigation Actions (NAMAs). NAMAs is a vehicle for the emission reduction actions in developing countries as foreseen in the Bali Action Plan. Thereby a joint commitment from developed and developing economies is needed to limit the growth of greenhouse gas emissions. This is to be done by complying with legally binding emissions reduction obligations and adopting the necessary measures to reduce the use of highly polluting technologies whilst replacing fossil fuel dependency with renewable energy sources.

"EPIA and Greenpeace believe that it is possible to reach a binding deal before the expiration of the Kyoto Protocol."

Greenhouse Effect and Climate Change

The greenhouse effect is a natural process whereby the Earth's atmosphere traps some of the Sun's energy which then warms the planet and controls the climate. However, human activities which produce greenhouse gases have enhanced this effect, thereby artificially raising global temperatures and disrupting our climate. Greenhouse gases include carbon dioxide - produced by burning fossil fuels and through deforestation; methane, -released from agriculture, animals and landfill sites; and nitrous oxide which comes from agricultural production and a variety of industrial chemicals.

The reality of climate change can already be witnessed in the disintegration of polar ice, thawing permafrost, rising sea levels and fatal heat waves. It is not only scientists who are witnessing these changes. From the Inuit of the far north to islanders near the Equator, people are already struggling with impacts of climate change.

An average global warming of more than 2°C threatens millions of people with an increased risk of hunger, disease, flooding in some areas and water shortages in others. Never before has humanity been forced to grapple with such an immense environmental crisis. If we do not take urgent and immediate action to protect the climate, the damage could become irreversible. This can only happen through a rapid reduction in the emission of greenhouse gases into the atmosphere.

If we allow current trends to continue some of likely effects are:

- Sea levels rising due to melting glaciers and the thermal expansion of the oceans as global temperature increases. Massive releases of greenhouse gases from melting permafrost and dying forests.
- A greater risk of more extreme weather events such as heat waves, droughts and floods. Scarily enough, the global incidence of drought has already doubled over the past 30 years.
- Severe regional impacts such as an increase in river flooding in Europe in addition to coastal flooding, erosion and wetland loss. Low-lying areas in developing countries such as Bangladesh and South China could as well be severely affected by flooding.
- Severe threats to natural systems, including glaciers, coral reefs, mangroves, alpine ecosystems, boreal forests, tropical forests, prairie wetlands and native grasslands.
- Increased risk of species extinction and biodiversity loss.

The greatest impacts will be on poorer countries in sub-Saharan Africa, South and Southeast Asia and Andean South America as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and a decline in agricultural production.

Indeed, policy-makers need to ensure that the green industrial revolution happening in the energy sector will accelerate in the coming decade and fully harness the economic opportunities inherent to the promotion of renewable energies. Photovoltaic energy can play an important role in reducing greenhouse gases while generating electricity and jobs on a global scale. Not only is the sun an unlimited fuel source, it also provides the cleanest form of energy available at any scale, large or small. The photovoltaic industry is ready to provide the technological solutions and capacity to support climate mitigation measures in developing and developed countries alike. The obstacles continue to be political, not technical.

"The main drivers to reduce the EPBT of PV systems are to *reduce*, *reuse* and *replace* materials used."

b. Energy payback time (EPBT)

The production of PV modules requires energy. The energy payback time (EPBT) indicates the number of years a PV system has to operate to compensate for the energy it took to produce, install, dismantle and recycle. The EPBT depends on the level of irradiation (in sunny areas like southern Europe the EPBT is shorter than in areas with relatively low solar irradiance), the type of system (integrated or not, orientation, inclination) and the technology (because of different manufacturing processes and different sensitivities to solar irradiation).

Figure 43 illustrates the EPBT for several PV technologies. The calculation assumes an irradiation of 1,700 kWh/m2/year (southern Europe levels) and that the system is installed on a rooftop benefiting from optimal inclination. The data is extracted from the Ecoinvent database[40], the world's leading database of consistent, transparent, and up-to-date life cycle inventory (LCI) data.

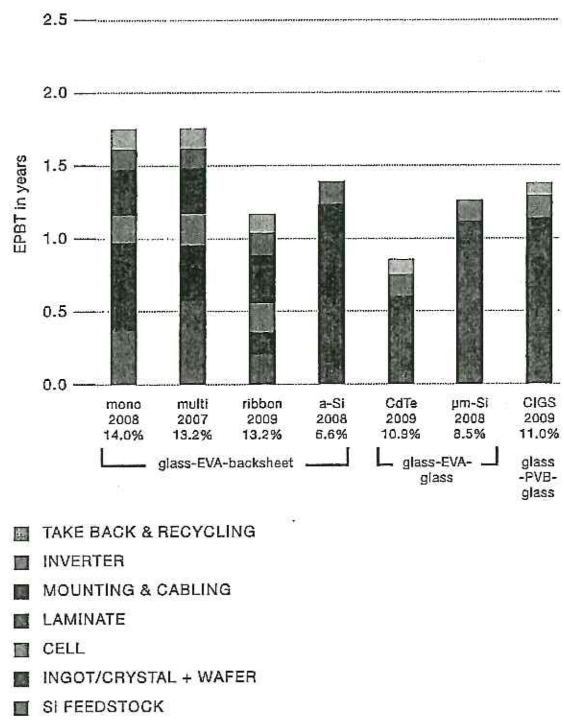
As shown in Figure 43, the production of Si feedstock and ingot is quite energy intensive for c-Si technologies. Hence, new techniques have been developed to reduce energy consumption during these steps of the value chain. This will lead to further decreases in the EPBT of PV systems, improving their sustainability.

TABLE 19
GENERAL INDICATIVE ENERGY PAYBACK TIMES:

EPBT for all PV systems	1 to 3 years
Operational lifetime of PV modules:	25 years (or even more)
Production time for clean electricity:	22 to 24 years (or even more)

source: EPIA.

FIGURE 43
PAY-BACK TIME FOR SEVERAL PV TECHNOLOGIES IN THE SOUTH OF EUROPE



source: Wild-Scholten (ECN) Sustainability: Keeping the Thin Film Industry green, 2nd EPIA International Thin Film Conference Munich, 2009.

The main drivers for further reduction of the EPBT are:

- *Reduce:* using less materials (for example by reducing the thickness of the silicon wafers)
- *Re-use:* recycling of materials
- *Replace:* using materials that generate less CO_2.

Higher system efficiencies for converting solar energy into electricity and continuous improvements in the manufacturing processes will contribute to further decrease the EPBT.

c. Water consumption

The world's population could grow by approximately 25% (from 6 to 8 billion people) by 2030. The demand for water will also increase, but even by about 30%.

Unlike other technologies, PV systems do not require water during their operation. This makes PV a sustainable electricity source in places where water is scarce.

Some water is used during the production process. Approximately 85% of it is used for material extraction and refinement, while module assembly (manufacturing wafers, cells and modules) accounts for the remaining 15%.

Most of the water indirectly used for PV production comes from the electricity consumption of PV factories: conventional power generation uses water, amongst others, for cooling. Hence, an increased share of PV in the electricity mix would lower the water requirements during the production process of PV modules. Moreover, even while water needs for PV are already lower than for other power generation technologies, the industry is working continuously to reduce water consumption during the manufacturing process.

d. Recycling

PV modules are designed to generate clean, renewable energy for at least 25 years. The first significant PV systems were installed in the early 1990s. Full-scale end-of-life recycling is still another ten years away. The PV industry is working to create solutions that reduce the impact of PV on the environment at all stages of the product life cycle: from raw material sourcing through end-of-life collection and recycling.

In 2007, leading manufacturers embraced the concept of producer responsibility and established a voluntary, industry-wide take-back and recycling programme. Now up and running, the PV CYCLE association (www.pvcycle.org) is working towards greater environmental sustainability.

"The PV industry is working to create solutions that reduce the impact of PV on the environment at all stages of the product life cycle."

PV CYCLE's more than 100 members represent over 85% of the total European PV market. They have agreed to implement the collection and recycling system developed by PV CYCLE, which will be operational soon.

Recycling technologies exist for almost all types of photovoltaic products and most manufacturers are engaged in recycling activities.

The environmental benefits and burdens of recycling have been assessed through the Chevetogne (Belgium) recycling pilot project. The project shows that the environmental benefits of recycling clearly outnumber the additional environmental burdens (heat, chemical treatment to recover the basic materials enclosed in the modules) that recycling of the modules demands.

PV CYCLE

For moore information: www.pvcycle.org

6.3. Social aspects

a. Employment

Close to 220,000 people were employed by the solar photovoltaic industry at the beginning of 2010. This number includes employment along the entire value chain world-wide: production of PV products and equipment needed for their production, development and installation of the systems, operation and maintenance as well as financing of solar power plants and R&D.

"Manufacturing jobs are concentrated in some global production hubs while downstream jobs are mainly local."

While manufacturing jobs could be concentrated in some global production hubs, the downstream jobs (related to installation, operation and maintenance, financing and power sales) are, for the moment, still mainly local.

The market expectations for 2010 show that installations could double. This could bring the number of people employed by the PV industry around the world to more than 300,000.

b. Skilled labour and education

PV will provide an increasing number of jobs during the next decades. However, the need for quality installations calls for skilled labour and appropriate education.

Qualifications required will vary, but some of the most relevant qualifications according to the steps of the PV value-chain are the following:

- *Solar module production:* Skilled staff with a clear background in chemistry, physics or related academic studies with a great level of specialisation and knowledge in the PV sector.
- *PV system integrators:* Technicians for the integration of roof-top mounted systems and engineers for the integration of ground-mounted systems. In addition, highly skilled staff is required to provide services such as management, contracting, design and marketing.
- *Installation:* Qualified and certified installers. Ideally; electricians, roofers, plumbers and other construction workers are to bring their knowledge together in a new kind of job description which could be called "solar installer".
- *Operation and maintenance:* No academic or scientific background required.
- *Recycling of PV modules:* Qualified and trained staff in chemistry, physics or related academic studies and with a clear understanding of recycling issues in relation to solar cells, silver, glass, aluminium, foils, electrical components, copper and steel components.
- *Research and development:* Experienced scientists and engineers with a high level of specialisation in PV.

Capacity building is needed at all levels of education to meet the labour demand. Hence, appropriate programmes and measures are needed from education institutions. They should:

- *Strengthen and adapt the quality of their current curriculum:* Academics and technicians attending the courses need to acquire a high level of specialisation.
- *Increase considerably the offer for specific courses in PV:* This will be necessary to meet demand for 50,000 new direct jobs created annually between 2006 and 2030.

  PV education should ideally be provided in the form of a specialised PV Masters degree, or as additional post-graduate training in photovoltaic energy.

  Experts highlight the importance of early practical training in PV. Project-oriented education, external trainings in the industry, and/or lab courses where practical experience can be obtained, are strongly encouraged.

6.4. Rural electrification

While we advocate for a clean power to alleviate climate change, it is important to recognise that many parts of the world operate with no electricity at all. Solar can help address this, in a more sustainable way than fossil fuel power does.

There are three options available to bring electricity to remote areas:

1. *Extend the national grid*
2. *Provide off-grid technologies*
3. *Create mini-grids with hybrid power*

Extension of the national grid

The huge cost of infrastructure and extra generation capacity prevents many countries from developing their national grids. The demand for electricity in cities is growing due to the increase in population, creating conflicts with utilities that need to stabilise the grid and follow the demand.

According to the World Bank, grid extension prices can vary from $6,340/km in densely populated country such as Bangladesh to $19,070/km in country like Mali[42]), making grid extension a difficult and expensive choice.

Off-grid solutions

Off-grid power generation using renewable energy sources is becoming more competitive in remote communities. It does not suffer the power losses that come with long transmission lines. Energy Home Systems (EHS) are designed to power individual households and are relatively cheap and easy to maintain.

PV is probably the most suitable type of technology for EHS as shown by the hundreds of thousands of solar home systems deployed around the world. PV systems can cover the energy needs of single households, public buildings and commercial units. In rural areas they can replace the candles, kerosene and biomass traditionally used for lighting and run other applications that are usually driven by dry-cell batteries or diesel generators.

The main types of off-grid PV systems which have been widely tested world-wide are found in Table 18 on the following page.

"Solar can help access clean power in non electrified parts of the world."

Energy and Equality

According to the IEA's report on the world's access to energy[41], in 2008 approximately 1.5 billion people or 22% of the world's population did not have access to electricity, with 85% of those people living in rural areas. Energy alone is not sufficient to alleviate poverty; however, it is an important step in any development progress. Access to electricity for significant amounts of people helps towards a number of Millennium Development Goals (MDG), set by the United Nations. Those goals include:

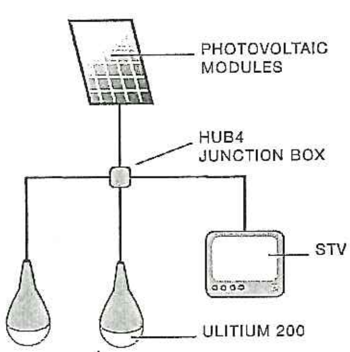
- Reducing hunger by enabling cold food storage (MDG 1)
- Providing access to safe drinking water through pumping systems (MDG1)
- Improving education by providing light and communication tools (MDG2)
- Creating gender equality by relieving women of fuel and water collecting tasks (MDG3)
- Contributing to the reduction of child and maternal mortality, the incidence of disease and the fight against pandemics by providing refrigeration for medication as well as access to modern medical equipment (MDG 4, 5 and 6)
- Using environmentally sound technologies to provide electrical connections in order to contribute to global environmental sustainability (MDG 8).

TABLE 20
MAIN TYPES OF OFF-GRID PV SYSTEMS WHICH HAVE BEEN WIDELY TESTED WORLD-WIDE

New generation of Pico PV systems (PPS)	Classical Solar Home Systems (SHS)	Solar Residential Systems (SRS)
• Used for small loads like highly-efficient LED lamps • Powered by a small solar panel and uses a battery which is often integrated into the lamp itself • Provides a power output of 1 to 10 W, mainly used for lighting and to replace unhealthy and inefficient sources • Depending on the model, can also charge small applications such as mobile phones and radios • User-friendly interface, easy plug-and-play installation, and low investment and maintenance costs.	• Generally cover a power output of up to 250 W. • Normally composed of several independent components such as modules, charge controller and the battery • Technologically mature, has been used for decades and offers more power output than Pico systems • Long-term, reliable source of power for households. • Limited by the need for energy storage which is difficult to improve later. • Require a trained technician for optimum installation and maintenance.	• Off-grid systems with output up to 2,000 W • Usually include a converter, which allows the use of AC loads and usually supply public services or companies • Represent flexible, scalable and adaptable solutions • Stand-alone off-grid PV systems primarily provide electricity for small loads and are not always in use to supply motive

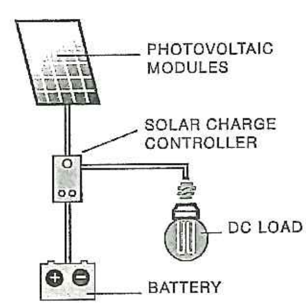
source: Alliance for Rural Electrification.

FIGURE 44
PICO POWER SYSTEM



source: Phaesun.

FIGURE 45
SOLAR HOME SYSTEM



source: Phaesun.

Mini-grid combined with hybrid power

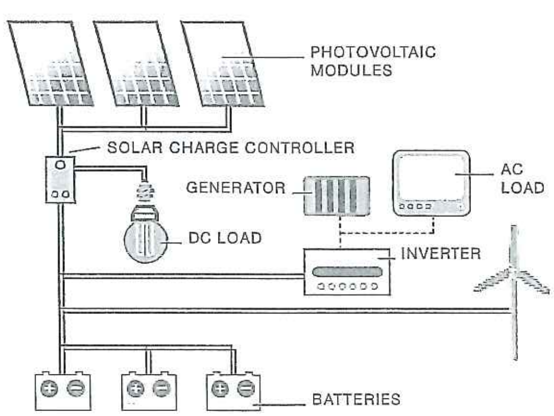
The third approach is a combination of the first two, providing local grids powered by more than one source of generation. PV plays a tremendous role to rural electrification within this approach.

Centralised electricity generation at the local level can power both domestic appliances and local businesses using village-wide distribution networks. They can be driven by fossil fuel or renewable energy sources, or by a combination of both. Backup systems (genset) or battery storage can complement the installation.

Figure 49 shows a village grid that is supplied by a hybrid system. It uses different, but complementary, renewable energy technologies (RET), often with a genset backup and battery storage.

This solution offers many advantages, not only in terms of cost, but also with regard to the availability of energy for small communities. It improves the quality of the electricity delivered and the reliability of the system compared to connections with fluctuating grids. It can be easily scaled up and introduce a large percentage of clean energy into the electricity generation mix. Finally, it can be connected to the national grid when the grid reaches that location.

FIGURE 46
MINI GRID AND HYBRID SYSTEM



source: Phaesun.

Competitiveness of renewable energy in developing countries

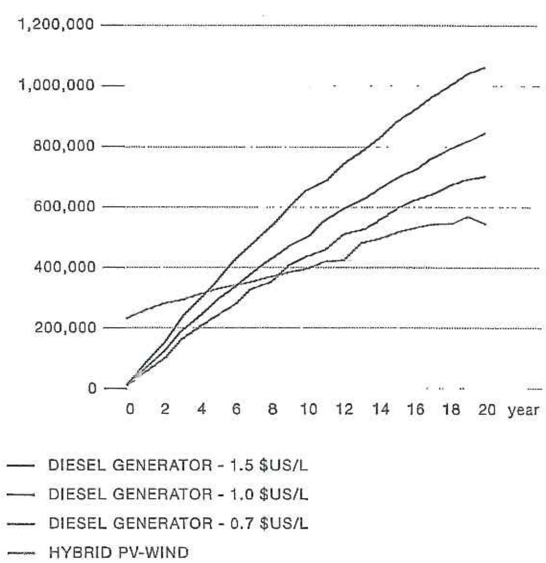
In many cases, off-grid renewable energy solutions offer the lowest generation costs for off-grid electrification with a mini-grid.

If public money and support mechanisms can play an important role in accelerating energy access and supporting renewable systems, some companies already develop and operate large systems without any support, such as in Laos[43] or Gambia[44]. Off-grid renewables are not only a clean and sustainable solution, but they are also economically sound.

> "off-grid renewable energy solutions offer the lowest generation costs for off-grid electrification with a mini-grid."

Figure 47 shows the cost comparison of several power systems over 20 years, starting in 2010. While the investment in PV systems is higher than in diesel generators, the cost evolution quickly favours the hybrid PV-Wind system.

FIGURE 47
COST COMPARISONS OF ENERGY POWER SYSTEMS ON A LIFECYCLE BASIS[45]
$US



source: the Alliance for Rural Electrification
Projections made from a case study based in Ecuador with real natural conditions.

Challenges

While renewable energy in off-grid and mini-grid solutions is often the most competitive solution, major challenges exist which include:

- Complex financial and organisational questions
- Bottlenecks in the financing, management, business models, sustainable operations and maintenance
- Local social and economic conditions.

"Long term sustainable energy policy strategies are a key challenge for developing countries."

Solutions that are being tried and tested at the minute include:

- Providing stand-alone solutions such as solar home systems with micro credits or a fee for service
- Installing mini-grids via a different business model, using capital subsidies and cost recovery via tariffs.

Policy changes are another challenge that developing countries have to face. Energy policies are often short sighted. Many countries remain focused on grid extension, urban electrification or on large hydro, gas or coal power plants without any long-term strategy for sustainability and supply. When demand outstrips supply, this approach is costly (power shortages, losses for the economic sector) and shows how much diversified electricity generation capacities, especially in rural areas where off-grid technologies can bring reliable electricity, is needed.

More information

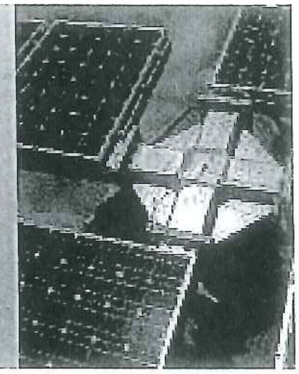
The Alliance for Rural Electrification (ARE – www.ruralelec.org) is the key partner of EPIA regarding the development of off-grid PV in developing countries. ARE is the only renewable energy industry association in the world exclusively working for the development of off-grid renewable energy markets in developing countries. They represent companies, organisations, research institutes and unite all relevant private actors in order to speak with one voice about renewable energies in developing countries.

Alliance for Rural Electrification
Shining a Light for Progress

More information: www.ruralelec.org

Solar helps provide access to energy.

LIST OF ACRONYMS

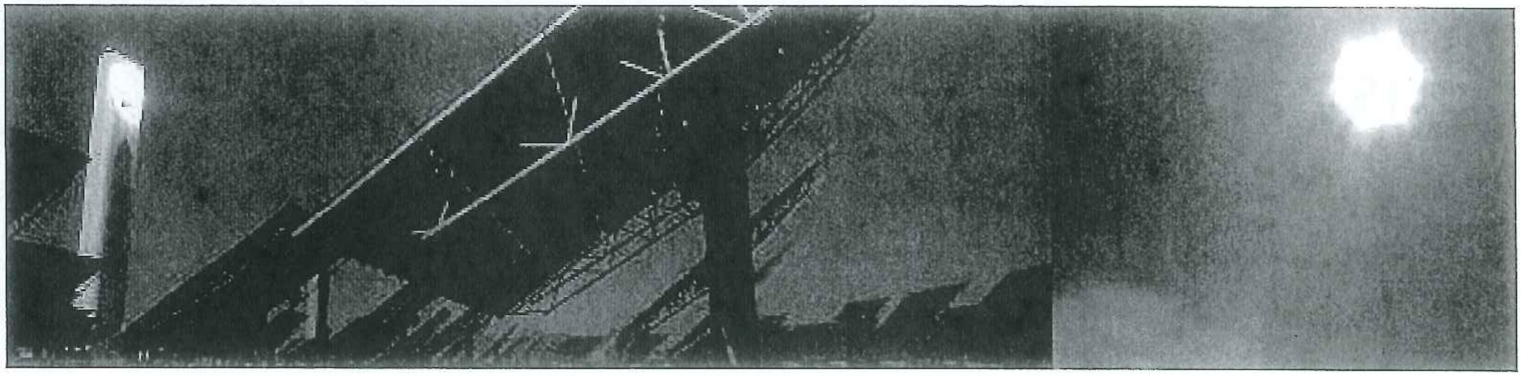


LIST OF FIGURES

µc-Si micro-crystalline silicon
AC alternating current
ARE Alliance for Rural Electrification
a-Si amorphous silicon
BAPV building adapted photovoltaic system (built on top of a roof)
BIPV building integrated photovoltaic system (forms part of a building)
BOS balance of system
CdS cadmium sulphide
CdTe cadmium telluride
CHP combined heat and power (system)
CIGS copper, indium, gallium, (di)selenide/(di)sulphide
CIS copper, indium, (di)selenide/(di)sulphide
CPV concentrating photovoltaic
c-Si crystalline silicon
DC direct current
DSM demand-side management
DSO distribution system operator
DSSC dye-sensitised solar cells
EC European Commission
EEG German Feed-in Law
EHS energy home system
EPBD Energy Performance of Buildings Directive (EC)
EPBT energy payback time
EPC engineering, procurement and construction (of PV systems)
EPIA European Photovoltaic Industry Association
ESTELA European Solar Thermal Electricity Association
ETS Emissions Trading Scheme (EU)
EU European Union
EU-27 Twenty-seven member countries of the European Union
EU-OEA European Ocean Energy Association
EV electric vehicle
EVA ethyl vinyl acetate
EWEA European Wind Energy Association
FiT Feed-in Tariff
FTE full-time equivalent
FTSM FiT Support Mechanism
FTSM FiT Support Mechanism
GaA gallium arsenide
GDP gross domestic product
GW gigawatt
IEA International Energy Agency
IEA-PVPS IEA Photovoltaic Power Systems Programme

LIST OF ACRONYMS & REFERENCES

IRR	internal rate of return
JRC	European Joint Research Centre
km	kilometre
kW	kilowatt
kWh	kilowatt hour
kWp	kilowatt-peak units
LCI	life-cycle inventory
LCOE	levelised cost of energy
mc-Si	mono-crystalline silicon
MDG	Millennium Development Goals (UN programme)
METI	Ministry of Energy, Trade and Industry (Japan)
MW	megawatt
NEA	National Energy Authority (China)
NEDO	New Energy and Industrial Technology Development Organisation (Japan)
OPV	organic photovoltaic
PACE	property-assessed clean energy programme
pc-Si	photo-crystalline (multi-crystalline) silicon
PHEV	petrol-hybrid electric vehicle
p-n junction	potential difference junction
PPS	Pico PV system
PV	photovoltaic
PVB	polyvinyl butyral
PVPS	See IEA-PVPS.
R&D	research and development
R2R	roll-to-roll (manufacturing process)
REC	renewable energy credit
RET	renewable energy technology
RPS	renewable portfolio standard
SET-Plan	Strategic Energy Technology Plan
SHS	solar home system
SME	small- to medium-sized enterprise
SRS	solar residential system
TCO	transparent conducting layer
TPV	thermo-photovoltaics
TSO	transport system operator
TWh	terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
V2G	vehicle to grid
VPP	virtual power plant
WEO 2009	*World Energy Outlook 2009* (IEA report)
Wp	watt-peak. A measure of the nominal power of a photovoltaic solar energy device



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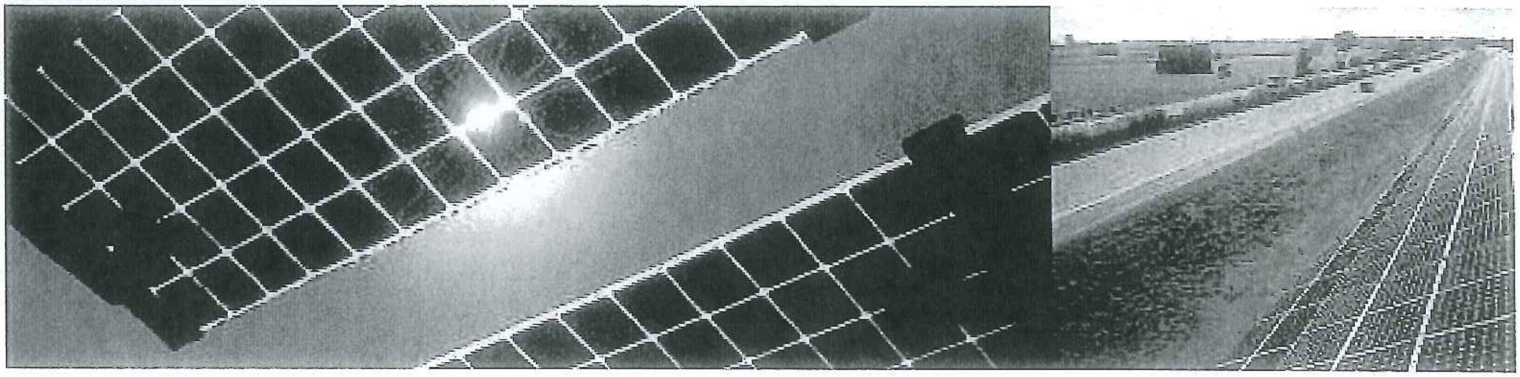

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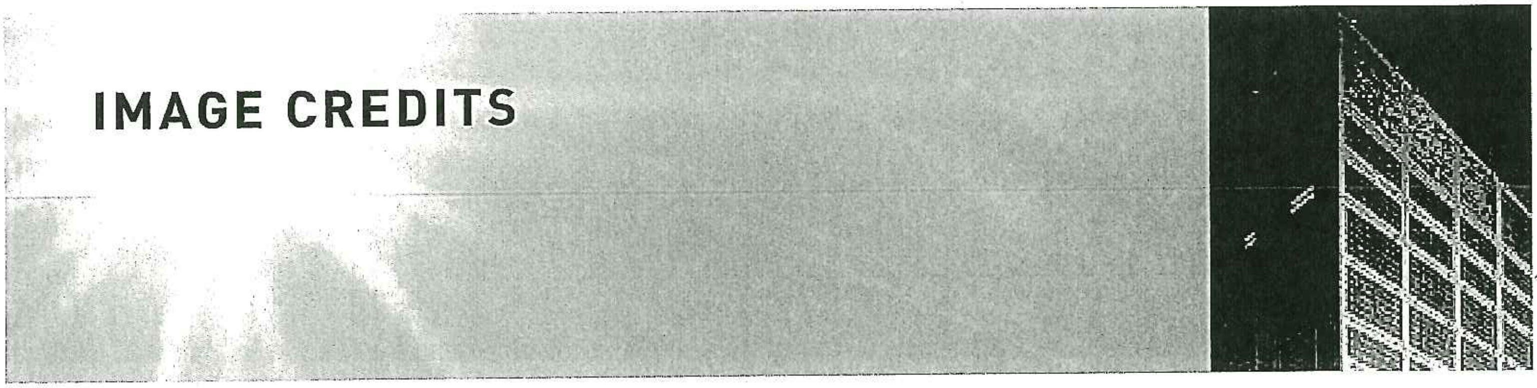

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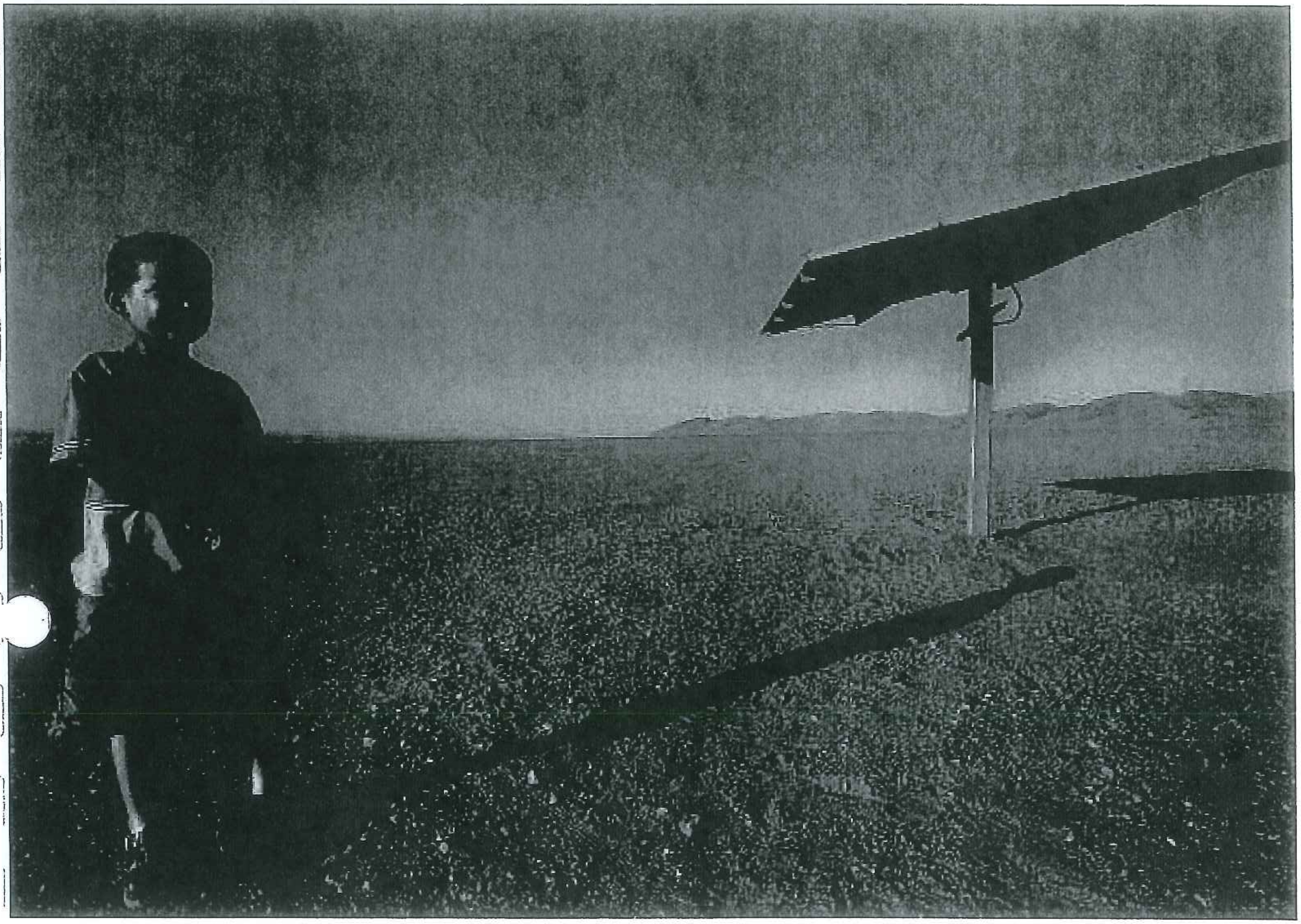


SOLAR GENERATION 6

SOLAR PHOTOVOLTAIC ELECTRICITY EMPOWERING THE WORLD

2011

About EPIA

With over 230 Members drawn from across the entire solar photovoltaic sector, the European Photovoltaic Industry Association is the world's largest photovoltaic industry association and represents about 95% of the European photovoltaic industry. EPIA Members are present throughout the whole value-chain: from silicon, cells and module production to systems development and PV electricity generation as well as marketing and sales.

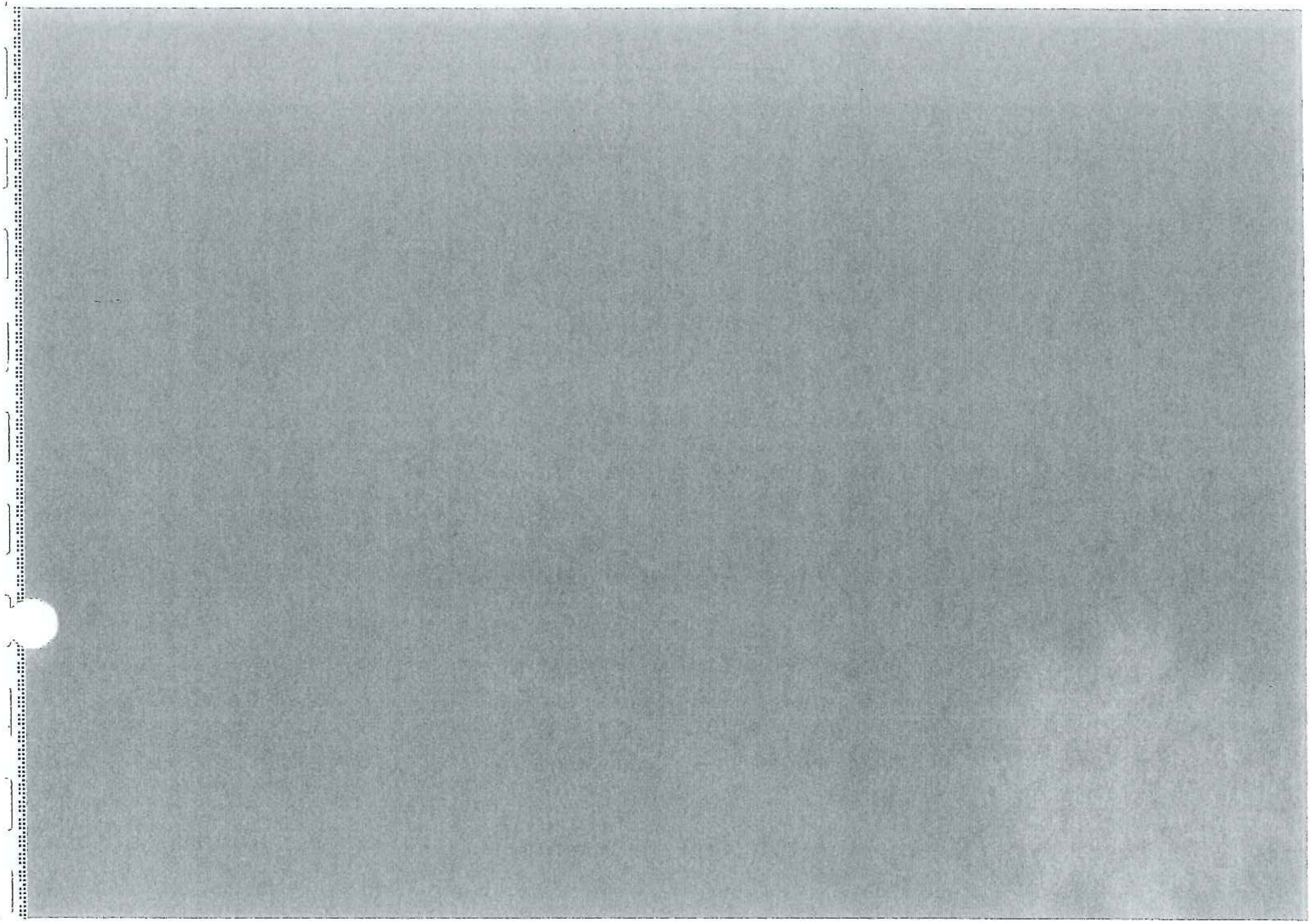
About Greenpeace

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Asia and the Pacific. It speaks for 2.8 million supporters worldwide and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

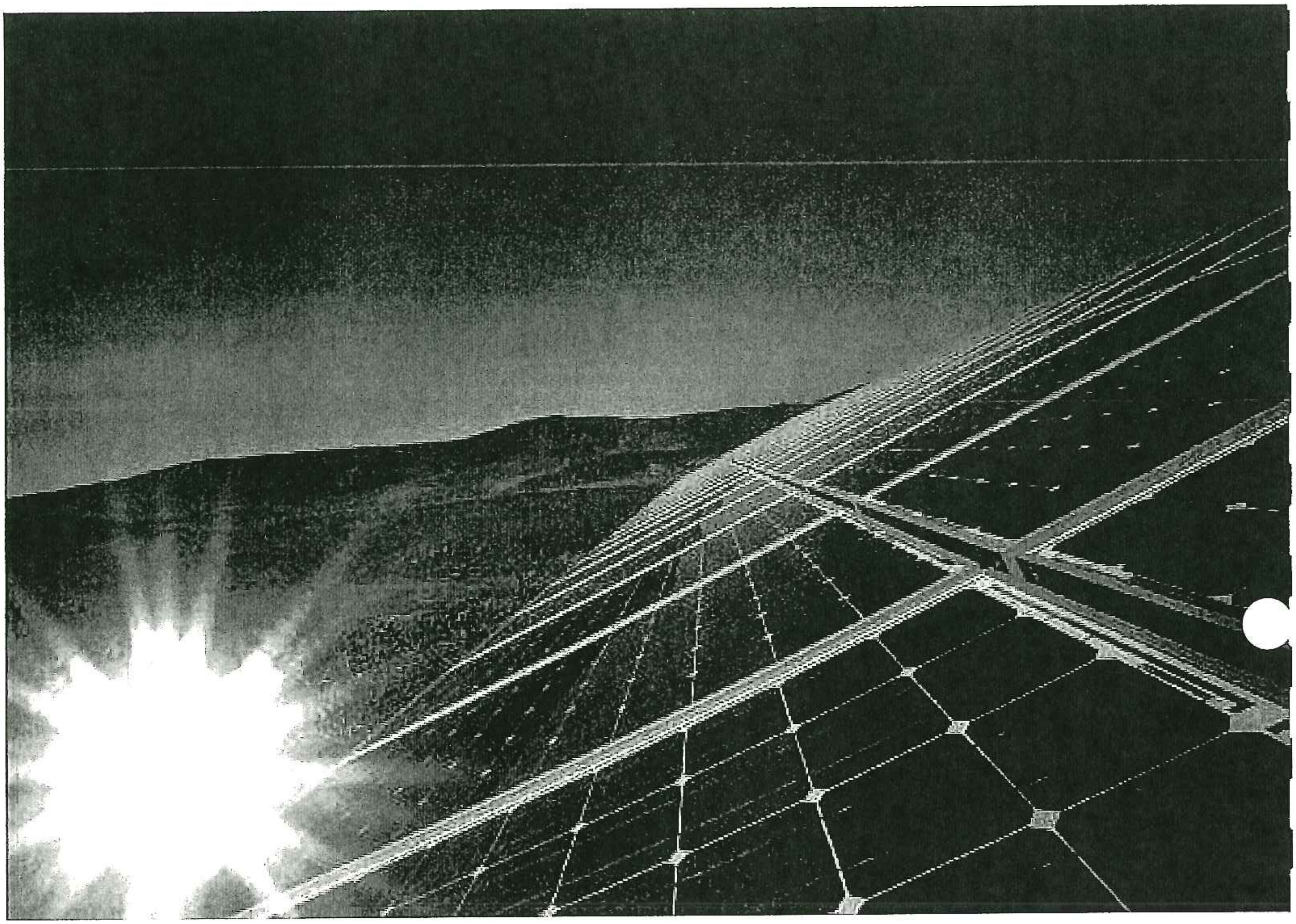
Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area north of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today and ships are an important part of all its campaign work.

PHOTOVOLTAICS
YOUR SUN YOUR ENERGY™

Your Sun Your Energy Campaign is promoting the advantages of photovoltaics and demonstrating what the virtually infinite power of the sun can offer. This wide-spanning campaign endeavours to illustrate how people can, through their daily activities, brighten their life thanks to photovoltaics. More information on **www.yoursunyourenergy.org**



Scenario by: Sven Teske (Greenpeace International), Gaetan Masson (EPIA). **Text edited by:** EPIA: Monika Antal, Giorgia Concas, Eleni Despotou, Adel El Gammal, Daniel Fraile Montoro, Marie Latour, Paula Llamas, Sophie Lenoir, Gaëtan Masson, Pieterjan Vanbuggenhout. Greenpeace: Sven Teske. External contributions: Simon Rolland (Alliance for Rural Electrification), Rebecca Short. **Design by:** Onehemisphere, Sweden.



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