OVERVIEW ON SOLAR ELECTRIC POWER IN BUILDINGS WITH APPLICATIONS IN ARMENIA

ASSISTANCE TO ENERGY SECTOR TO STRENGTHEN ENERGY SECURITY AND REGIONAL INTEGRATION

CONTRACT NUMBER EPP-I-08-03-00008-00

JULY 2011

This publication was produced for review by the United States Agency for International Development. It was prepared by Tetra Tech ES, Inc.

Overview on Solar Electric Power in Buildings with Applications in Armenia

ASSISTANCE TO ENERGY SECTOR TO STRENGTHEN ENERGY SECURITY AND REGIONAL INTEGRATION

CONTRACT NUMBER EPP-I-08-03-00008-00

Overview on Solar Electric Power in Buildings with Applications in Armenia

ASSISTANCE TO ENERGY SECTOR TO STRENGTHEN ENERGY SECURITY AND REGIONAL INTEGRATION

CONTRACT NUMBER EPP-I-08-03-00008-00

July 2011

Prepared for: United States Agency for International Development
Armenia Mission
1 American Ave.
Yerevan 0082 Armenia

Prepared by: Tetra Tech ES, Inc.

Tetra Tech ES, Inc.
4601 N. Fairfax Drive
Suite 601
Arlington, VA 22203

Tel: +1 703 387 2100
Fax: +1 703 387 2160
www.tetratech.com,
www.armesri.am

Version: 1.0

TABLE OF CONTENTS

1. SUMMARY

Armenia has a good solar resource, many years of Research and Development (R&D) experience in solar thermal and Photovoltaic (PV) applications, but is in the early stage of its broad commercial utilization. The findings of this report are aimed to assist the government of Armenia with options for continuing solar energy development. Expanding its energy portfolio to include solar, improving the legal and regulatory environment and creating a solar energy development strategy can increase national, energy and economic security, while creating jobs. Most of the countries aggressively pursuing solar installations have less insolation than Armenia.

Without a change in the linkage between Gross Domestic Product (GDP) and energy, projections of total world consumption of energy indicate an increase of 49 percent from 2007 to 2035. The United States Energy Information Administration (EIA) estimates, under their reference case, that the worldwide use of energy will increase 1.4% each year. While projections indicate an increased need for all types of energy, shifting economics may result in a change in the content of the portfolio. Demand for electricity in Armenia has not been growing but is dependent on an old partially disabled nuclear power plant and on increasingly costly imported natural gas. So there is interest in developing indigenous solar and wind resources for energy security and long term economic reasons.

The economics of solar PV are continuing to improve. The price of PV modules has been decreasing, following a learning curve of approximately 20% for over 30 years. In 2010, modules were selling for less than $2/watt. As the price is reduced, niche markets (in outer space and off-grid) have expanded into broader markets (rooftop and power plant). Over the past 3 decades, every time the cumulative average PV production doubles, the cost of a PV module is reduced by 20%. PV installations are continuing to grow in both strong and weak global economies. Production has been increasing by about 45% annually for the past 10 years. In recent years, this growth has been accelerated by Feed-In Tariffs (FIT) offered by various states around the world and by utility Renewable Portfolio Standards (RPS).

The technical performance of the PV modules is continuing to improve. According to the International Energy Agency (IEA), typical commercial flat-plate module efficiencies are expected to increase from 16% in 2010 to 25% in 2030, with the potential of increasing up to 40% in 2050. Several countries have a long history of supporting the advancement of photovoltaics. Steven Chu, Secretary, U.S. Department of Energy, recently announced the SunShot program designed to reduce the cost of PV systems from about $4/watt to $1/watt by 2020. The resulting electricity price will be competitive with utility power at $0.05-0.06/kWh. It is estimated that by 2030, 14% of the U.S.'s power will be generated from solar PV.

In 2008, about 90% of installations were roof top, residential, commercial and industrial. Flat plate PV integrates well into buildings. The International Energy Agency (IEA) projects that in 2050, residential and commercial rooftop installations will still be about 60% of a much larger market. Integrating PV into roofs and facades can increase the economies of the system by offsetting the costing of other building materials, assuring that an unobstructed roof or façade is available, load bearing elements of the building a properly designed from the beginning and the buildings electrical system is organized to accommodate solar PV. This approach may allow technical and financial synergies leading to attractive returns.

Distributed PV power generation can improve grid reliability. Having small and large generators dispersed around a geographic region can lead to a stronger power network, making it less susceptible to natural, economic and human risks. In the event a generator is disrupted or a major transmission line fails, many small solar generators can feed power into the distribution system. This may not supply all of the loads but may be able to serve critical loads, keeping vital functions operating until power can be restored.

Armenia has a good solar resource, but low electricity prices and relatively higher cost of PV has delayed its deployment. With changes in the regulatory process and allowing a tariff structured for limited technology demonstration projects, groundwork can be laid for the eventual commercial use of this abundant resource in Armenia. The findings of the report are aimed to assist solar energy deployment in Armenia. Most of the countries aggressively pursuing solar installations have less insolation.

2. INTRODUCTION

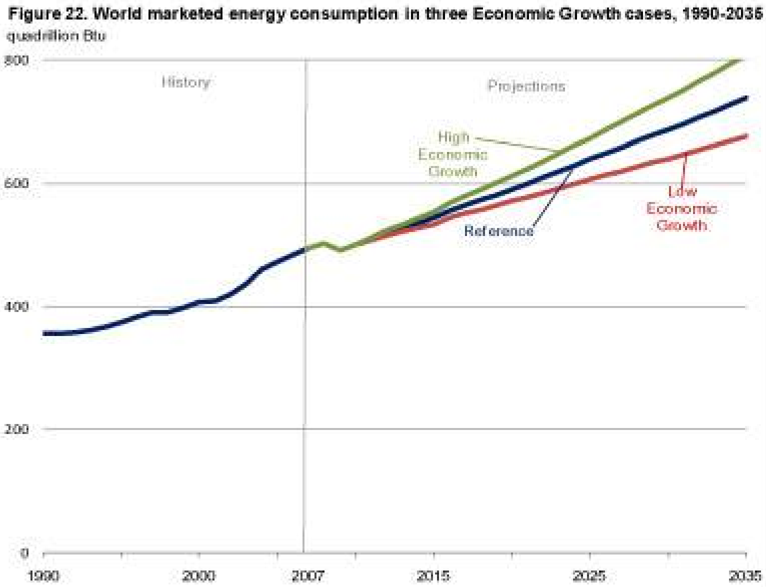
This overview of solar electric power in buildings was prepared to support the United States Agency for International Development's mission to provide assistance to the energy sector to strengthen energy security and regional integration. There is a review of the international energy trends, solar electric economic trends, technical trends and market trends. The increasing international use of PV provides an experience base for Armenia to draw on as it evaluates its energy production portfolio and its options for the future. A survey of solar electric tariffs applied around with illustrative examples. International and local examples of installations are included.

While its use is small today, solar PV power has a particularly promising future. Global PV capacity has been increasing at an average annual growth rate of more than 40% since 2000 and it has significant potential for long-term growth over the next decades. The IEA's technology roadmap envisions that by 2050, PV will provide 11% of global electricity production (4,500 TWh per year), corresponding to 3,000 GW of cumulative installed PV capacity. In addition to contributing to significant greenhouse gas emission reductions, this level of PV will deliver substantial benefits in terms of the security of energy supply and socio-economic development.

This report describes international experience and market trends for solar electric power in buildings in applications that would likely have potential use in Armenia. The findings of the report specify solar electric building technology trends, financial / legal and / regulatory issues, application configurations, approvals and grid connection and cost for solar electric technologies. Emphasis is on practical near-term applications and on options for eliminating or mitigating existing barriers to solar system use in Armenia.

3.1 WORLD ENERGY CONSUMPTION IN THREE ECONOMIC GROWTH CASES, 1990-2035

In the International Energy Outlook (IEO2010) Reference case, world energy consumption increases by 49 percent, or 1.4 percent per year, from 495 quadrillion Btu in 2007 to 739 quadrillion Btu in 2035 (IEO Figure 22) (1 British Thermal Unit, BTU, = 2.93×10^{-4} kWh).



International Energy Outlook 2010: World Energy Demand and Economic Outlook

The global economic recession that began in 2008 and continued into 2009 had a profound impact on world income (as measured by gross domestic product, GDP) and energy use. After expanding at an average annual rate of 4.9 percent from 2003 to 2007, worldwide GDP growth slowed to 3.0 percent in 2008 and contracted by 1.0 percent in 2009. Similarly, growth in world energy use slowed to 1.2 percent in 2008 and then declined by an estimated 2.2 percent in 2009.

Historically, Organization for Economic Cooperation and Development (OECD) member countries have accounted for the largest share of current world energy consumption; however, in 2007—for the first time—energy use among non-OECD nations exceeded that among OECD nations. The discrepancy between OECD and non-OECD energy use grows in the future, given the more rapid growth in energy demand expected for the emerging non-OECD economies.

In 2007, energy use in non-OECD nations was 1.5 percent higher than that in OECD nations. In the IEO2010 Reference case, non-OECD economies consume 32 percent more energy than OECD economies in 2020 and 63 percent more in 2035. OECD energy use grows slowly over the projection period, averaging 0.5 percent per year from 2007 to 2035, as compared with 2.2 percent per year for the emerging non-OECD economies.

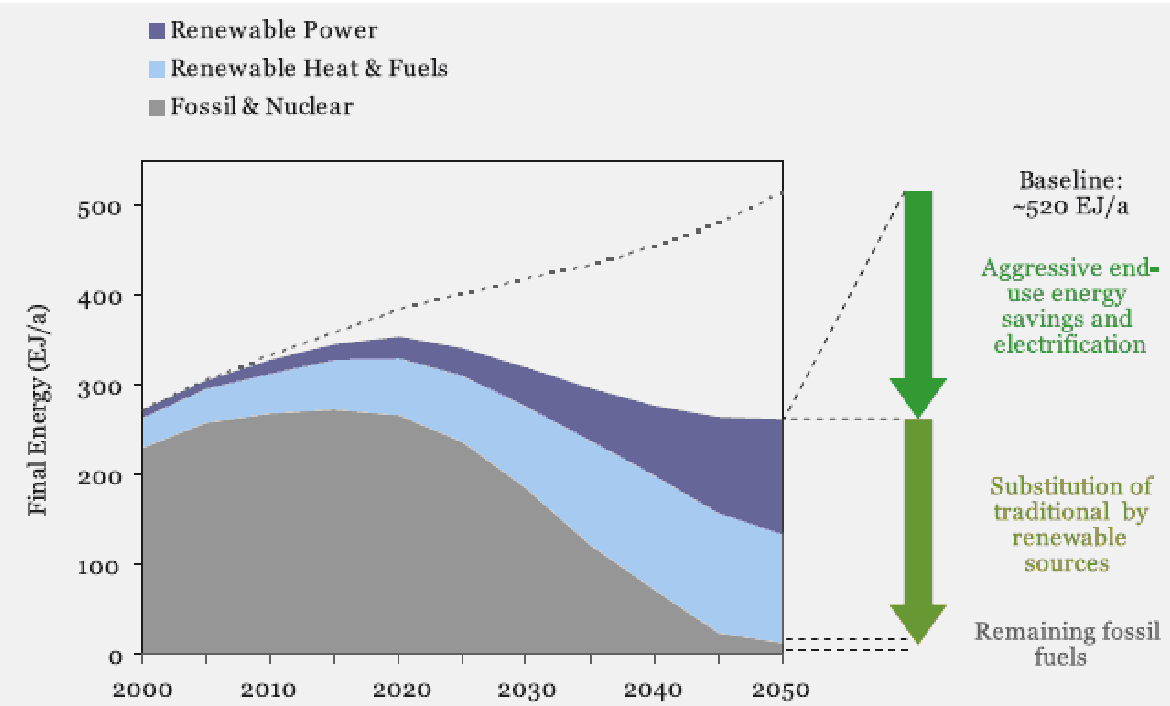
Alternative Economic Growth Cases

Expectations for the future rates of global economic growth are relatively uncertain in the IEO2010 projections. In the High Economic Growth case, 0.5 percentage point is added to the annual growth rate assumed for each country or country grouping in the Reference case. In the Low Economic Growth case, 0.5 percentage point is subtracted from the Reference case annual growth rates. The IEO2010 Reference case shows total world energy consumption reaching 739 quadrillion Btu in 2035—281 quadrillion Btu in OECD countries and 458 quadrillion Btu in non-OECD countries. In the High Growth case, world energy use in 2035 totals 810 quadrillion Btu—71 quadrillion Btu (about 35 million barrels oil equivalent per day) higher than in the Reference case. In the Low Growth case, total world energy use in 2035 is 60 quadrillion Btu (30 million barrels oil equivalent per day) lower than in the Reference case. Thus, the projections for 2035 in the High and Low Economic Growth cases span a range of uncertainty equal to 134 quadrillion Btu (IEO Figure 22).

The High Growth case is consistent with projections for Armenia. In January 2011, in the World Bank annual global economic report, estimates for Armenia were 4.6 percent economic growth in 2011 and continuing at almost 5 percent in 2012.

3.2 A PLAN FOR 100% RENEWABLE ENERGY BY 2050

The World Wildlife fund, along with energy consulting firm Ecofys produced a report detailing how we can meet nearly 100% of global energy needs with renewable sources by 2050. Approximately half of the goal is met through increased energy efficiency to first reduce energy demands, and the other half is achieved by switching to renewable energy sources for electricity production.



Ecofys projected global energy consumption between 2000 and 2050

To achieve the goal of 100% renewable energy production, Ecofys foresees that global energy demand in 2050 will be 15% lower than in 2005, despite a growing population and continued economic development in countries like India and China. In their scenario:

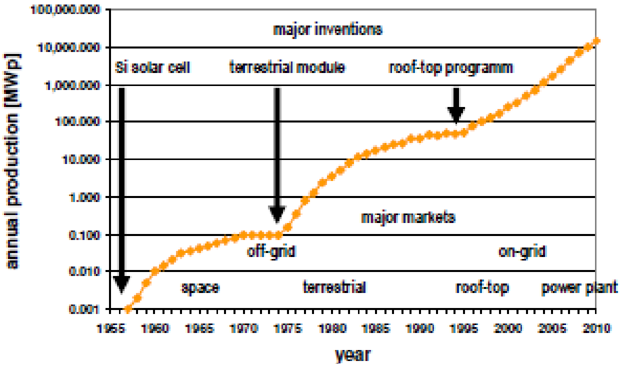
As far as possible, we use electrical energy rather than solid and liquid fuels. Wind, solar, biomass and hydropower are the main sources of electricity, with solar and geothermal sources, as well as ground source heat pumps providing a large share of heat for buildings and industry. Because supplies of wind and solar power vary, “smart” electricity grids have been developed to store and deliver energy more efficiently. To achieve the necessary renewable energy production, Ecofys envisions that solar energy supplies about half of our electricity, half of our building heating, and 15% of our industrial heat and fuel by 2050. This requires an average annual solar energy growth rate much lower than we're currently achieving – an encouraging finding.

Ecofys also envisions using currently existing technology and expertise to create buildings that require less energy for heating or cooling, increased recycling or materials and more efficient transportation. Although energy savings are important, substitution of sustainable renewable energy for traditional sources are key.

4. ECONOMICS

4.1 ROAD TOWARD COST COMPETITIVENESS

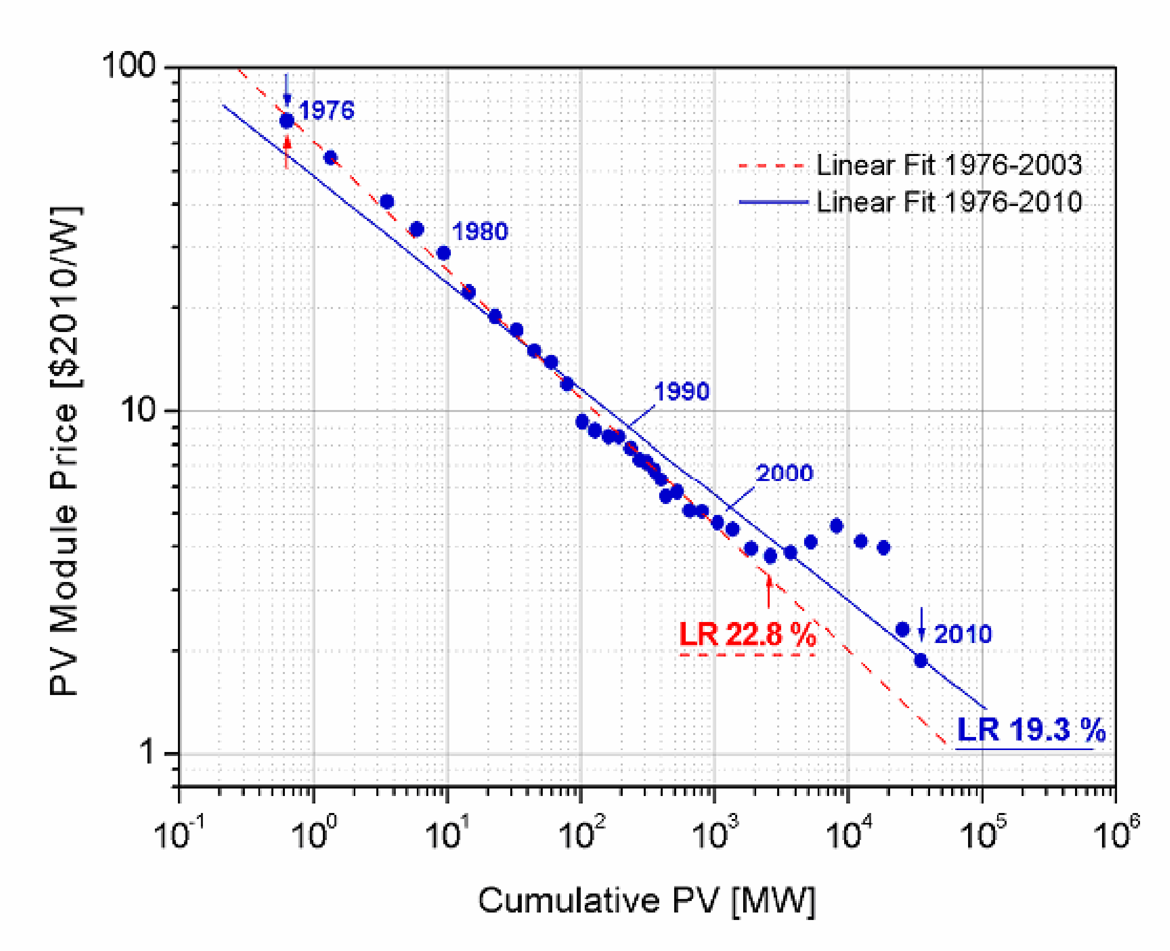
Real market diffusion of PV started immediately after the invention of the silicon (Si) solar cell in 1954 by Darryl Chapin, Calvin Fuller and Gerald Pearson, associates of Bell Labs. The initial application was for powering satellites as the least cost energy option for space applications and induced the first growth phase for early PV industry. In the early 1970s PV as a former space technology was adapted to terrestrial applications by Exxon associate and founder of Solar Power Corp. Elliot Berman, who started the second growth phase of PV for terrestrial off-grid solutions, which showed very strong economics for off-grid decentralized energy supply in developing countries for rural populations. Roof-top programs and Feed-In Tariff (FIT) laws in Japan and Germany started the third high growth regime for PV applications in on-grid markets, which is characterized in its economy by the grid-parity concept. In late 2000s and early 2010s the fourth high growth regime is being started by utility-scale PV power plants now fast gaining ground due to their positive economic impact, best described as driving toward a goal of grid-parity.



Historic PV production independent of major inventions and market segments. Notably, annual growth rates increased from about 33%, in space age and during off-grid diffusion, to 45% for the last 15 years during on-grid diffusion. C. Breyer, et al., Research and Development Investments in PV—A limiting factor for a fast PV diffusion? 25th EU PVSEC/WCPEC-5, Valencia, 6-10 September 2010

The three diffusion phases are marked by three major inventions, Si solar cell, terrestrial PV module and rooftop programs. Off-grid space applications dominated the first diffusion phase from 1957 – 1973 and showed average annual growth rates of about 33%. Terrestrial off-grid applications dominated the second diffusion phase from 1973 – 1995 and generated average annual growth rates of about 33%. Grid connected roof-top systems dominate the third diffusion phase and show average annual growth rates as high as 45%, whereas first utility-scale plants start the next diffusion phase right now. Off-grid PV markets have been growing at a constant high rate of about 15-20% in the years from mid1990s to today but due to much higher growth rates of on-grid markets, the relative proportion of global off-grid installations declined to about 5% of total installed PV capacity. Still, annual average growth rates for PV have been exceeding 30% for more than five decades and have been even increased by serving new markets. PV seems to tend to become the least cost option in every market segment, which has already happened for space applications and shown for off-grid solutions for rural energy supply in developing countries.

4.2 PV LEARNING CURVE



Source: C. Breyer, et al., Research and Development Investments in PV—A limiting factor for a fast PV diffusion? 25th EU PVSEC/WCPEC-5, Valencia 2010, September 6-10

The above learning curve for PV modules for the mid-1970s – 2010 indicates that long-term cost trend of reducing PV module cost by 20% per doubling of historic cumulative average production and installations has been stable for the entire period.The price curve is the best approximation for the cost information. Discontinuities in this trend are mainly caused by technology changes and varying PV industry market dynamics and therefore profit margins, documented by applying different learning rates of 22.8 and 19.3% for the periods 1976 – 2003 and 1976 – 2010, respectively.

Generally, industrial cost reduction follows the empirical law of learning curves, first found in the aviation and shipbuilding industry. Mathematical description adapted to PV can be found elsewhere. Driving force for cost reduction is the growth rate and the so called learning rate. Both parameters are very high for PV, i.e. growth rates above 30% and learning rates at a constant 20% level for each doubling of historic cumulated installed capacity. All other energy technologies show either lower long-term growth rates or lower learning rates, and typically both driving forces are lower. Even long-term negative learning rates are reported for nuclear power plants, i.e. every new power plant generation is more expensive per kW than the previous one.

PV learning curve characteristics are well documented for the value chain steps from metallurgical Si or other semiconductor ores to PV modules. A few reports also describe inverters, systems and the most relevant metric cost per generated energy. They confirm for entire PV systems a learning rate of 20% and an even higher learning rate for cost per energy, induced by increasing overall system efficiency. Even higher learning rates have been recorded for similar technologies: as a long-term trend for Dynamic Random Access Memory (DRAM) chips and flat panel displays learning rates of 40% and 35%, respectively. Comparison to solar PV is quite interesting due to the fact that both technologies are semiconductor based, identical to PV, but DRAMs are getting cheaper by increasing integration density of transistors while displays are getting cheaper by increasing production area. The first cost reduction strategy is not possible for PV, except high concentrating PV (HCPV), whereas generating scaling effects by increasing area might also be a valuable pathway for further cost reductions in PV and have already been applied in last decades. Fundamental differences in cost structures of displays and PV systems should be better analyzed due to a nearly twofold higher learning rate for displays than for PV.

4.3 PV SYSTEM INSTALLED COSTS, 1Q – 2010

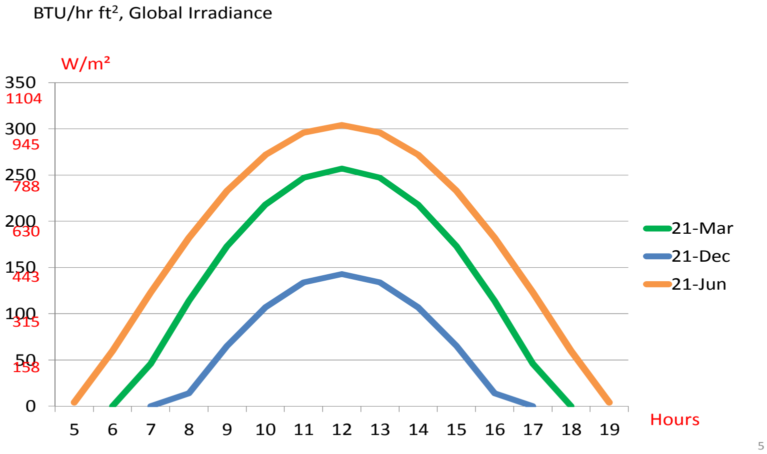
AVERAGE TOTAL PV SYSTEM INSTALLED COSTS, Q1 2010 (KWP)

	Residential rooftop	Commercial rooftop	Ground-mounted
Belgium	4.000 €	3.000 €	2.600 €
Bulgaria	4.022 €	3.217 €	2.916 €
Czech Republic	4.010 €	3.576 €	3.138 €
France	5.000 €	3.300 €	3.000 €
Germany	3.200 €	2.700 €	2.600 €
Greece	4.250 €	3.200 €	3.000 €
Italy	4.500 €	3.000 €	2.800 €
Spain	4.000 €	3.000 €	2.900 €
UK	4.666 €	3.940 €	3.422 €
U.S. (approx.) from Renewable Analytics	6.000 USD	5.000 USD	4.000 USD
China (approx.) from Goldman Sachs			3.000 USD
Exchange rates used here: Euro/BGN 0.51 | Euro/CZK 0.04 | Euro/GBP 1.18			

Table One. Source: iSuppli, for European figures; Renewable Analytics for U.S. figures; and Goldman Sachs for Chinese figures.

5.1 TYPICAL SOLAR RADIATION ON CLEAR DAYS AT LATITUDE 40° N IN ARMENIA

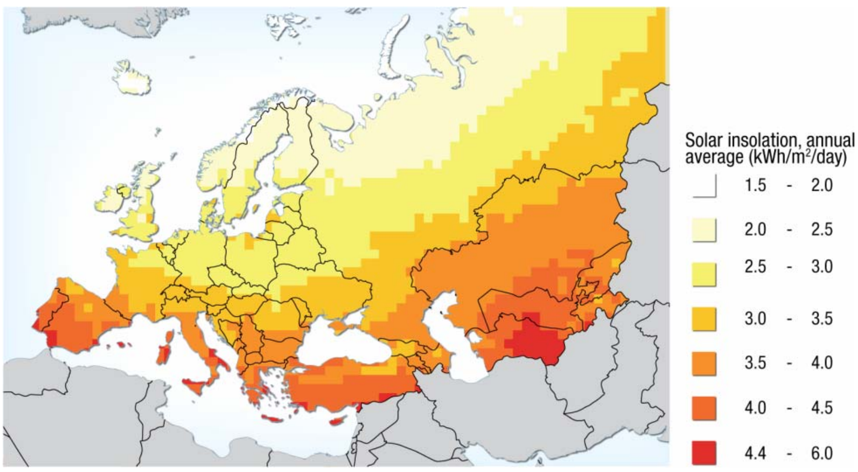
Solar energy is a relatively low-density energy with the intermittent nature. Annually, 3.9×10^{24} J = 1.08×10^{18}kWh of solar energy reaches the surface of the Earth. This is about ten thousand times more than the annual global primary energy demand of the mankind and much more than all available energy reserves on earth.



Typical Solar Radiation on Clear Days at Latitude 40^0 N(the latitude for Armenia ranges from 38^o50'N to 41^o18'N)

The position of the sun in the sky can be uniquely described by two angles—the azimuth and the altitude. The azimuth is the deviation from true south. The altitude is the angle of the sun above the horizon. The radiation depends on the day time as well as month and season as shown in the figure.

5.2 SOLAR INSOLATION IN EUROPE AND NEIGHBORING COUNTRIES



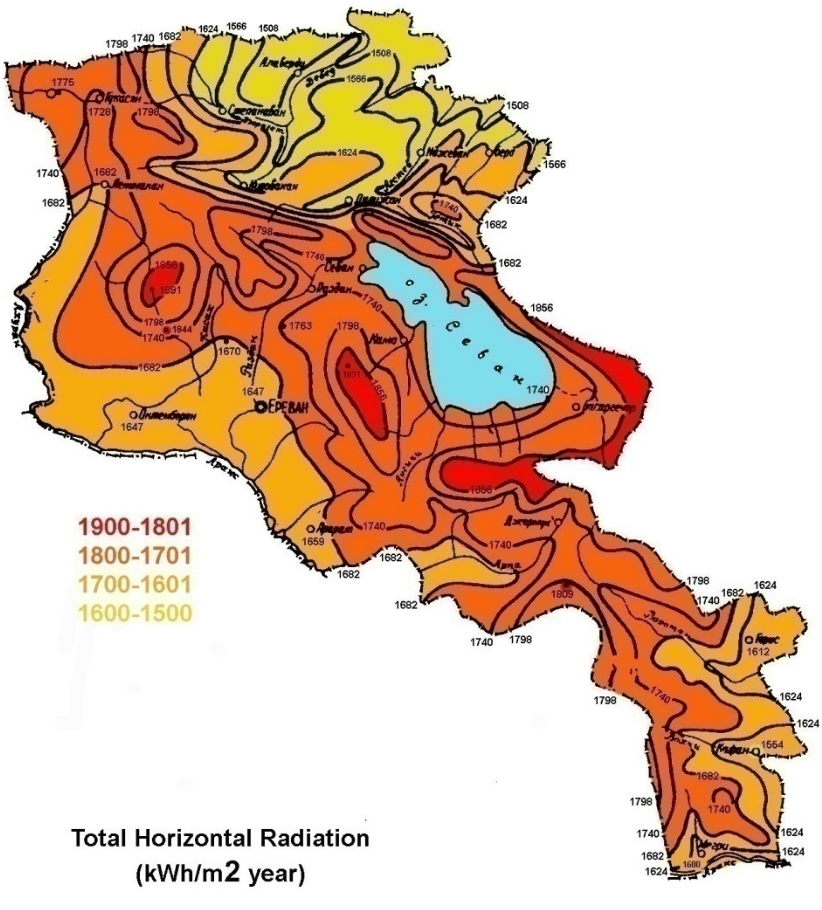
Solar insolation, the quantification of energy per surface area on the ground, can be used as an indicator for the potential for solar energy. This map presents solar insolation in

Europe and neighboring countries, calculated to annual averages from monthly averages 1983 - 1993. While insolation is the fuel that drives the solar engine, there are other factors to consider as well; economics, security, national security. Armenia has good overall solar in the range of 1508 to 1856 kWh/m^{2}year. NASA. 2007.

5.3 SOLAR RESOURCES IN ARMENIA

The Republic of Armenia is situated in eastern part of Asia Minor in the latitude of 38°50' - 41° 18' N and longitude of 43° 27' - 46° 37' E. Armenia is a mountainous country having approximately 30,000km^2 territory with average height of 1,800m and about 75% on the height of 1,000-2,500m above sea level.

The climate is highland continental with hot and dry summers and cold winters.



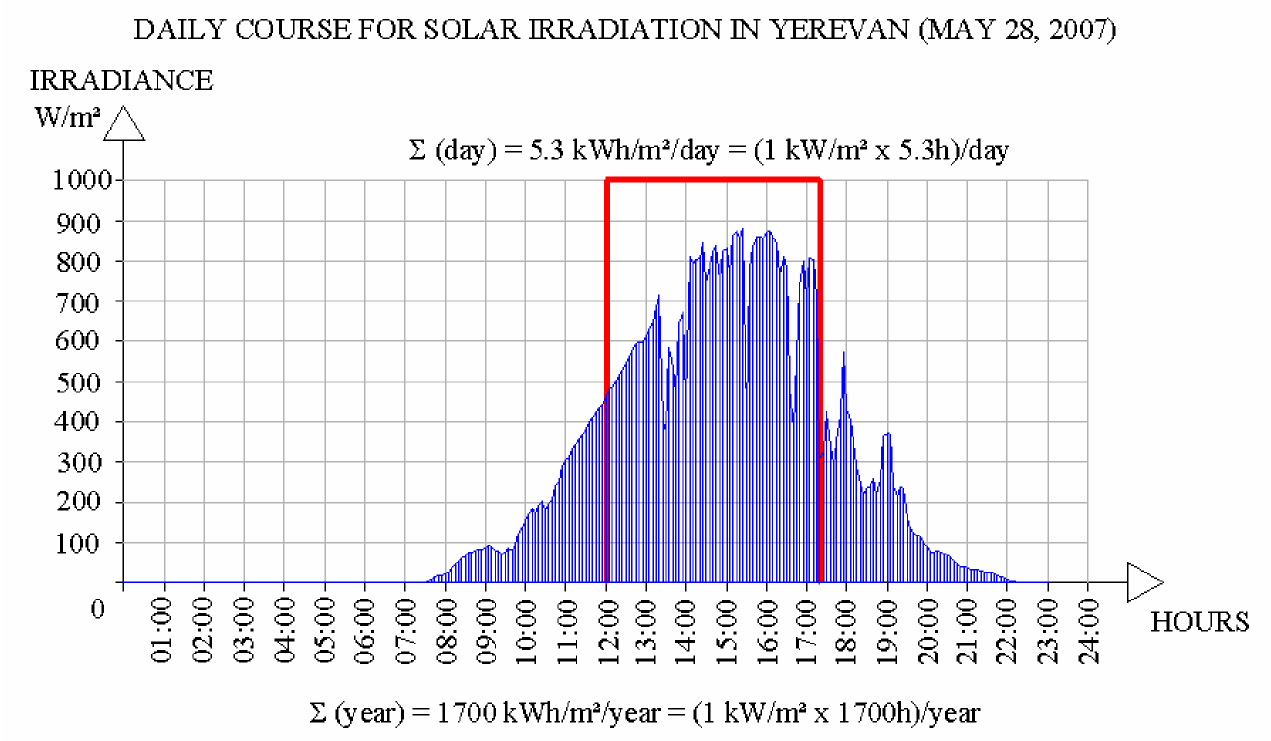
Map of Horizontal Surface Insolation in Armenia

Source: "Support to the Energy Policy of Armenia", TACIS PROJECT, EUROPAID/120653/C/SV/Am, 2007, http://www.renewableenergyarmenia.am/images/Re_sources/3_1_.2.a._solar_potential_fig_1.jpg

Armenia is rich in solar energy resources. The average annual insolation is approximately 1,700 kWh/m^2,(ranging from 1500 kWh/m^2 to 1900 kWh/m^2), as shown on the map above based on 50 weather stations' databases.

As a measure of available sun energy, it is convenient to use peak sun hours. Usually, sunlight intensity (irradiance) is measured in kW/m^2. In case the sunlight intensity is integrated from sunrise to sunset over 1 m^2 of surface, the result is measured in kWh. If daily kWh/m^2 is divided by the peak sun intensity, which is defined as 1 kW/m^2, the resulting units are referred as peak hours.

As a matter of fact, the term peak sun hours is used to indicate the number of hours the sun shines at peak intensity to produce the daily quantity of energy in kWh. Numerically the daily number of peak sun hours is equivalent to kWh/m^2/day.



Typical daily course of solar insolation and equivalent sun hours

The radiation on earth is approximately 1000 W/m^2 or $1kW/m^2$during good weather conditions at noon at sea level. This value is used for the standard test of PV devices at AM 1.5 and temperature 25°C.

From engineering point of view, the key issues are (i) duration of solar energy strikes $1m^2$ of the surface in a given site, and (ii) quantity of DC or AC power generation from $1m^2$ of the PV module, based on which one can determine the area of PV modules needed to provide the desired amount of power and the energy yield of the PV power plant.

PV cell is a semiconductor element that generates direct current (DC) electrical power when illuminated by the light. It is a generator and its “fuel” is free and unlimited sun energy. For practical applications PV cells are interconnected and encapsulated into PV modules. PV modules are often combined in series-parallel to obtain higher power output. When PV modules are connected in series, the voltage adds up. When PV modules are connected in parallel, the current adds up. The power is equal to the product of voltage and current for the PV array.

Produced DC power is usually transformed into AC power by an inverter. PV system consists of PV modules, inverters, batteries, supporting structure for PV modules and other elements. PV systems have two areas of application. One is the off-grid power supply (e.g. telecommunication equipment) and the other is grid-connected electricity generation. The modular nature of PV systems means an extremely wide range of power supply from milliwatts for calculators to megawatts for utility scale grid-connected power plants.

The annual energy production of a PV system depends on local solar data and performance parameters of the system. The amount of insolation depends on geographical location of the site. The inclination of the PV array, on the other hand, depends on the latitude of the site. The yearly maximum insolation usually corresponds to the fixed surfaces tilted at an angle equal to the latitude minus 10°. As an example, 1 kW PV system would generate a 900 to 1000 kWh per year in Germany, and as much as 1800 to 2000 kWh per year in desert locations like Arizona or South Africa.

Calculation of the required area of PV modules to produce specified amount of electricity at a given site depends on the efficiency of PV cells and modules measured at standard test conditions of 1000W/m^2 irradiance, 25°C PV module temperature, and AM1.5 air mass value. As of May 2011 the highest reported efficiency of industrial monocrystalline silicon solar cells is 19.6% while it is 43.5% for multi-junction cells at 400 suns concentration.

In Armenia an average irradiation is 1,700kWh/m^2 per year or 4.7 kWh/ m^2 per day. A typical PV module has approximately 15% efficiency in converting the sunlight into electricity. It means that every square meter of the PV module produces, on average, 1,700kWh x 0.15 = 255kWh per year or 4.7 x 0.15 = 0.7 kWh per day. The PV area in square meters needed to cover expected yearly or daily consumption of electrical energy in kWh can be calculated by dividing that amount by 255kWh/m^2 or 0.7kWh/m^2 correspondingly.

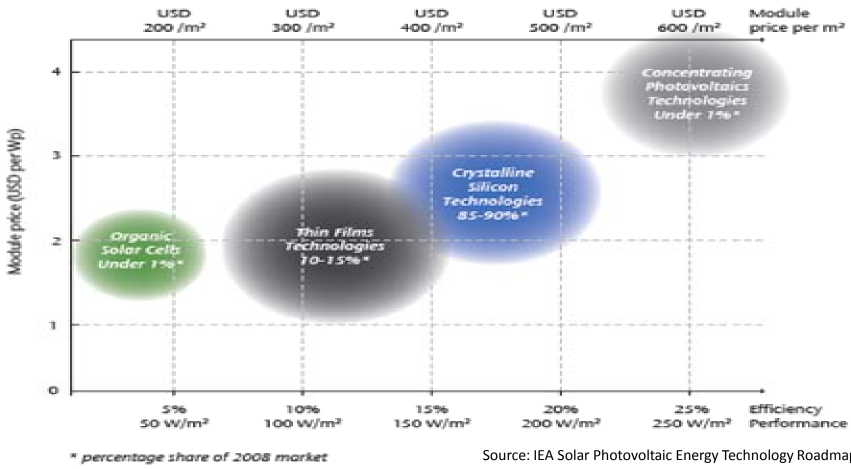
At the same time, calculation of the required land area for installation of PV system or plant also depends on the PV module efficiency. As such, for example, land area required for 10MW PV power plant with 15% efficiency PV modules can be calculated as follows: under standard test conditions 15% efficiency the PV module will generate 150W/m^2 electricity, and thusthe PV module surface area will be 10MW (or 10,000,000W) / 150W/m^2 = 66,667m^2. Accordingly, the yearly energy yield for the solar radiation in Armenia will be 10MW x 1,700h = 17,000MWh.

An obvious advantage of PV power plants is the possibility of dividing them into a number of small decentralized power plants in different regions and being inherently modular in the nature be constructed upon power demand and financing availability.

The most important performance of the PV system is the ratio of AC energy delivered to the grid to the energy production of an ideal, loss-less PV plant with 25°C cell temperature and the same solar insolation. This gives a practical indication of how much of the ideally available PV energy has actually been used. In good grid-connected PV systems with proper orientation, high inverter's efficiency and low wiring losses this ratio is approximately 0.80 – 0.85.

6.1 CURRENT PERFORMANCE AND PRICE OF DIFFERENT PV MODULE TECHNOLOGIES

While its use is small today, PV power has a particularly promising future. Global PV capacity has been increasing at an average annual growth rate of more than 40% since 2000 and it has significant potential for long-term growth over the next decades. Driven by improved efficiency and reduced cost, the IEA technology roadmap envisions that by 2050, PV will provide 11% of global electricity production (4,500 TWh per year), corresponding to 3,000 gigawatts of cumulative installed PV capacity. In addition to contributing to significant greenhouse gas emission reductions, this level of PV will deliver substantial benefits in terms of the security of energy supply and socioeconomic development.



Source: IEA Solar Photovoltaic Energy Technology Roadmap

29

Conversion efficiency, defined as the ratio between the produced electrical power and the amount of incident solar energy per second, is one of the main performance indicators of PV cells and modules. The table provides the current efficiencies of different commercial PV modules. PV systems can be connected to the utility grid or operated in stand-alone applications. They can also be used in building-integrated systems (BIPV) or be ground-mounted, for example, in large-scale, grid-connected electricity production facilities.

The investment costs of PV systems are still relatively high, although they are decreasing rapidly as a result of technology improvements and economies of volume and scale. High investment costs, or total system costs, represent the most important barrier to PV deployment today. Total system costs are composed of the sum of module costs plus the expenses for the “balance-of-system”, including mounting structures, inverters, cabling and power management devices. While the costs of different technology module types vary on a per watt basis (see Figure: Current Performance and price of different PV module technologies), these differences are less significant at the system level, which also takes into account the efficiency and land-use needs of the technology. Total system costs are sensitive to economies of scale and can vary substantially depending on the type of application.

Current efficiencies of different PV technology commercial modules

Wafer-based c-Si		Thin films		
sc-Si	mc-Si	a-Si; a-Si/μc-Si	CdTe	CIS/CIGS
14-20%	13-15%	6-9%	9-11%	10-12%

Typical turn-key prices in 2008 in leading market countries ranged from USD 4,000/kW for utility scale, multi-megawatt applications, to USD 6,000/kW for small-scale applications in the residential sector.

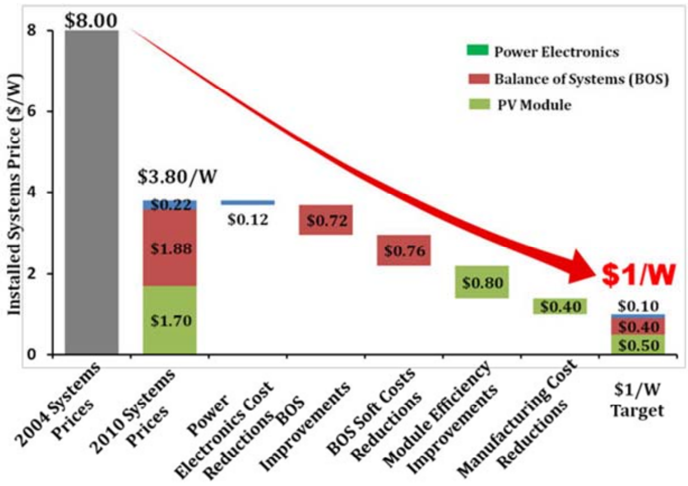
Associated levelized electricity generation costs from PV systems depend heavily on two factors: the amount of yearly sunlight irradiation (and associated capacity factor), and the interest/discount rate. PV systems do not have moving parts, so operating and maintenance (O&M) costs are relatively small, estimated at around 1% of capital investment per year. Assuming an interest rate of10%, the PV electricity generation costs in 2008 for utility-scale applications ranged from USD 240/MWh in locations with very high irradiation and capacity factor (2,000 kWh/kW, i.e. a 23% capacity factor), to USD 480/MWh in sites with moderate-low irradiation (1,000 kWh/kW, corresponding to a capacity factor of 11%). The corresponding generation costs for residential PV systems ranged from USD 360-720 /MWh, depending on the relevant incident solar energy. While these residential system costs are very high, it should be noted that residential PV systems provide electricity at the distribution grid level saving transmission costs and losses. Therefore they compete with electricity grid retail prices, which, in a number of OECD countries, can also be very high.

General technology targets

Targets (rounded figures)	2008	2020	2030	2050
Typical flat-plate module efficiencies	Up to 16%	Up to 23%	Up to 25%	Up to 40%
Typical maximum system energy pay-back time (in years) in 1500 kWh/kWp regime	2 years	1 year	0.75 year	0.5 year
Operational lifetime	25 years	30 years	35 years	40 years

6.2 FINANCIAL TRENDS TO ACHIEVE THE U.S. SUNSHOT GOAL

The technical performance of the PV modules is continuing to improve. According to the IEA, typical commercial flat-plate module efficiencies are expected to increase from 16% in 2010 to 25% in 2030 with the potential of increasing up to 40% in 2050. Several countries have a long history of supporting the advancement of photovoltaics. Steven Chu, Secretary, U.S. Department of Energy, recently announced the SunShot program designed to reduce the cost of PV systems from about \$4/watt to \$1/watt by 2020. The resulting electricity price will be competitive with utility power at \$0.05-0.06/kWh. It is estimated that by 2030, 14% of the U.S.'s power will be generated from solar PV.



Source: U.S. Department of Energy, EERE

Based on the above graph data one can assume that PV will be competitive without subsidies at $.05-$.06/kWh The key cost items for the installed cost of **$1/watt** include:

- $.50/watt for a PV module
- $.40/watt for the balance of systems
- $.10/watt for power electronics

It is expected that DOE will provide $200 million/year to achieve the set goal by 2020, that is

- 157 GW from distributed sources such as commercial & residential building installations
- 232 GW from utility scale power generation

This strategy will prompt to achieve 14% of electricity generation in US by 2030 by solar PV. Currently about 1% of total electricity n the US is generated by solar PV plant

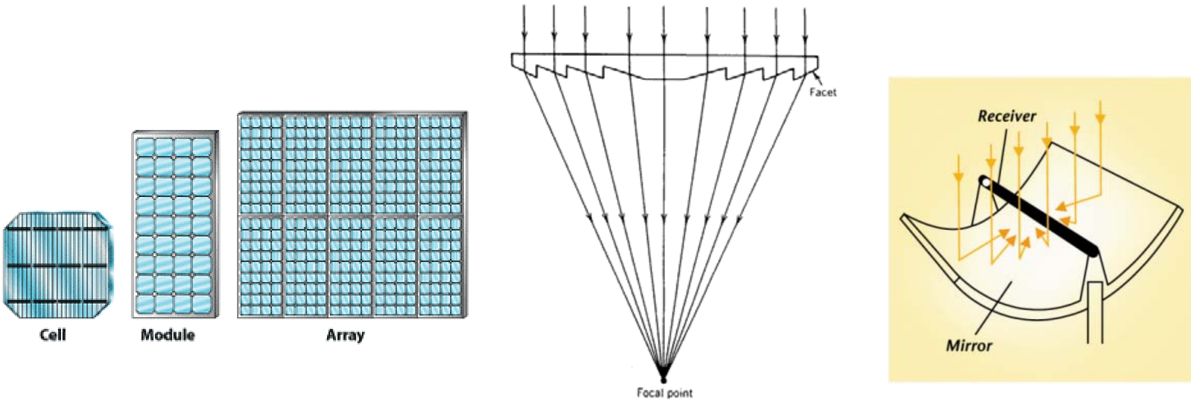
6.3 FLAT PLATE SOLAR PV VERSUS CONCENTRATORS

Flat plate solar PV converts the sun's radiation that falls on its surface, while a concentrator uses redirected sun light to increase its intensity (for instance from one sun to 100 suns or more). This is an opportunity to substitute reflectors for PV material. However, to maintain the sun's concentrated energy on the PV material as it moves across the sky, a tracking system is required. Below is a general description of a flat plate array, a two axis concentrator and a single axis concentrator.

- Flat plate Solar PV are simple
  - Widely available on the market
  - Collect direct and indirect radiation

  - Can be installed on existing structures
  - Don’t collect as much energy

- Concentrators can collect more energy
  - Substituting less expensive concentrating material for more expensive PV material
  - Collect direct radiation
  - Requires acquiring and tracking the sun
  - Can present a wind profile requiring additional structure



Solar energy collection technology options.

6.4 TECHNICAL LIMITATIONS

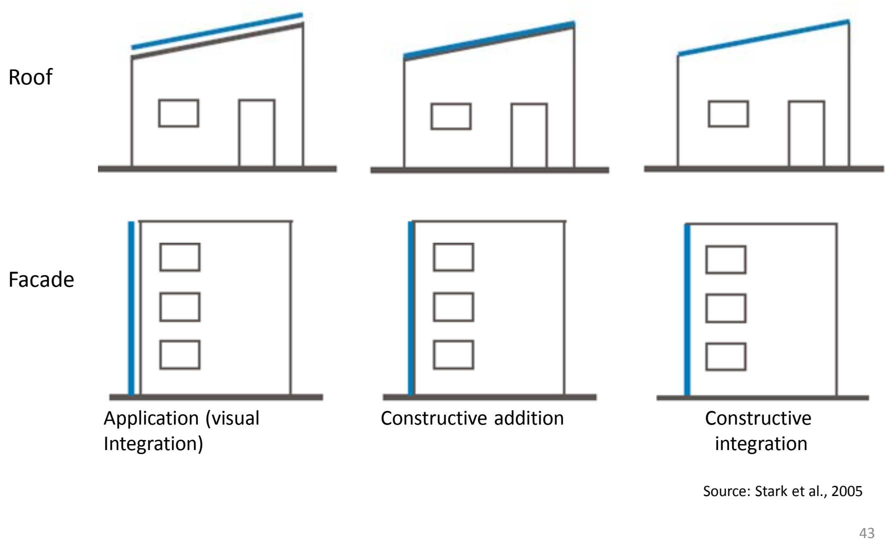
The substitution of classical building materials by active solar components represents an interesting multi-functional use of solar technology in buildings. Active PV solar modules produce not only electricity but also heat which can be used for heating and cooling needs of buildings. With e.g. back-ventilated PV double facades, the heat supplied by the modules can serve as useful thermal energy for pre-heating outside air and can recover heat losses of a room. In PV modules only a small part of the absorbed irradiance, usually about 10–15%, is converted into electricity, with mainly heat being produced. This heat can be used but it reduces the electrical power of the PV generator due to the module’s rise in temperature. Crucial for the temperature levels are, at a given solar irradiance, the convective heat transfer and optimal ventilation at the front and rear of the PV module.

Buildings account today for about 40% of the final energy consumption of the European Union and the reduction of energy consumption in buildings is of high economic relevance. When considering the potential solar contribution to the different energy requirements in buildings (heating, cooling, electricity), it is necessary to analyze the solar irradiance, the efficiency of the solar technology and the available surface in buildings as well as the economically usable potential. Active solar-energy use in buildings today contributes primarily to meeting electricity requirements by PV, and to warm water heating by solar thermal collectors. For a first design of a solar energy system, it is usually sufficient to consider the annual solar energy supply on the receiver surface.

Active solar technologies are especially appropriate for meeting this energy requirement, as the elements can be integrated into the shell of the building, thus substituting classical building materials and requiring no additional area. Solar modules for PV electricity production can be built like glazing into all common construction systems.

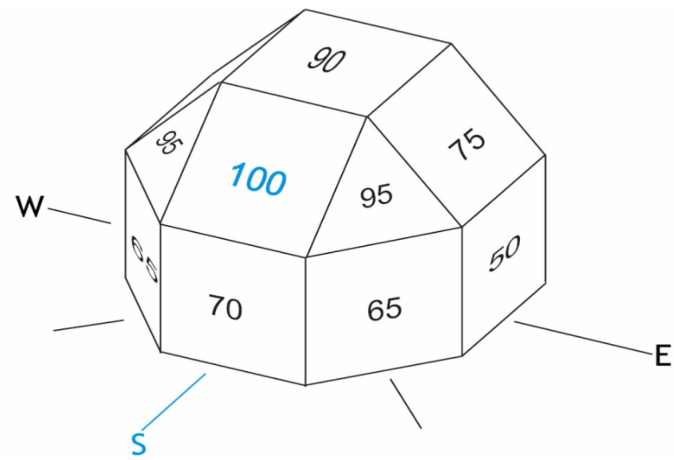
By encapsulating the extremely thin semiconductor cells in a glass–glass or glass–plastic combination, photovoltaic modules are particularly suitable for integration in buildings, since the usual glazing constructions can be used. The components necessary for the system engineering, such as circuit-breakers, fuses and inverters, can be placed anywhere in the building (or even outside), and take up very little space.

Three levels of integration



- Existing buildings typically bear all of the costs of adding Solar PV
  - Orientation may not be optimal
  - PV Array may be blocked or shadowed
  - Equipment and materials are added on
  - Strengthening of building for additional weight
  - Seldom opportunity to take advantage of DC power
- Integrating Solar PV into new buildings will allow improved economics by offsetting roof/façade costs
  - Integrated into roof/façade design
  - Proper load bearing design
  - Offsetting building materials
  - Organizing building equipment to accommodate solar PV

This puts certain technical limitations on roof or façade mounted PV modules along with architectural and construction permits and regulations.



Angle of inclination effect on yearly amount of irradiation in % in Southern Europe or Armenia

Many existing surfaces (roofs, car parks etc.) are suitable for PV modules integration, even if their orientation differs considerably from the optimum. This also means there is no need to carry out expensive civil works to level the site of building integrated PV arrays.

Façade integrated PV modules generate more energy in winter time and the heat can be used for space heating meanwhile roof integrated modules apart from electricity can provide heat for cooling needs by means of e.g. absorption chillers.

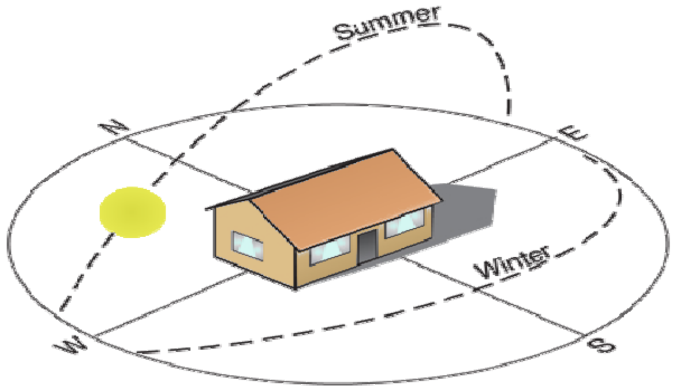
In light of the extensive commercial building construction underway in Yerevan, the use of BIPV could be considered. However, to facilitate incentives would be needed to make the added investment cost-effective.

6.5 APPROPRIATE ORIENTATION OF THE BUILDING TO US THE SUN ENERGY MORE EFFICIENLY

The reflectance and transmittance of optical materials depend on the angle of incidence, therefore the performance of PV modules is affected by their orientation with respect to the sun, due to the angular variation of the glass reflection. Optimal orientation of the building enhances passive solar energy utilization and annual PV system yield.

A value of 0.2% loss for each degree of deviation from the optimum value is a rough approximation. This is true to an even greater extent in the case of azimuthal orientation, where only a 0.08% loss occurs for each degree of deviation from the south.

The fact that the sun is lower in the sky in winter than in summer can help to plan and construct buildings that capture free heat in winter and reject the heat in summer. The orientation of the whole building plays an important part in ensuring such a 'passive' process works. The diagram below shows optimal orientation of the building.



Optimal sun orientation of a building

The ideal house orientation is that when main long axis of the building runs East-West, i.e. the ridge line. It can be re-oriented by as much as 20 degrees without significant negative effect, but the most glass on the building must be facing towards the sun. When planning for the building orientation one should also take into account the location of landscape features around the land plot, i.e. trees and walls, etc. which could impact on the amount of captured sun energy. Ideally you do not want them blocking the sun light as the sun tracks across the sky.

It is very important to orientate the house with respect to the Sun and not to magnetic North (or South) (as it is shown on the diagram above).

Apparent magnetic North can be very different to where Solar North is (up to 20 degrees depending on geographical location), and this can impact on a passive solar design being effective or not.

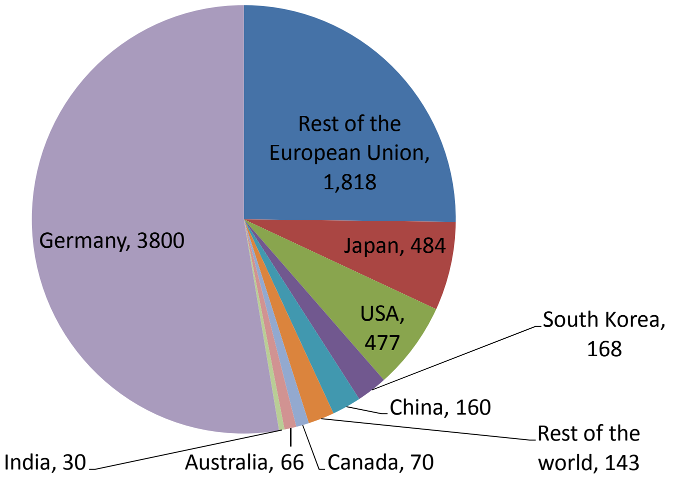
Also of importance is that the rooms most used must be on the side of the house orientated towards the sun, i.e. the kitchen, lounge, etc. The least used rooms should be on the side of the house in shade, i.e. garage, laundry; these will also act as additional thermal mass, if properly insulated.

It is important to design the house in a way that it is comfortable during the whole year and not just for a single season. Sometimes, solar homes are built with large areas of upward, titled, south-facing glass, designed to catch every bit of sun, winter or summer. While tilted glass does maximize heat gain during the winter months, it also maximizes that same heat gain during the summer.

7.1 NEW PV GLOBAL INSTALLED CAP. 2009

In 2008, about 90% of installations were rooftop, residential, commercial and industrial. Flat plate PV integrates well into buildings. The International Energy Agency (IEA), projects that in 2050, residential and commercial rooftop installations will still be about 60% of a much larger market. Integrating PV into roofs and facades can increase the economics of the system by offsetting the cost of other building materials, assuring that an unobstructed roof or façade is available, load bearing elements of the building are properly designed from the beginning and the buildings electrical system is organized to accommodate solar PV. This approach may allow technical and financial synergies leading to attractive returns.

As can be seen in the following graphic, more than 50% of all the PV manufactured in the world is installed in Germany. As a result, there is a great deal of technical and economic PV experience in the country. Many of the following examples are derived from that experience.



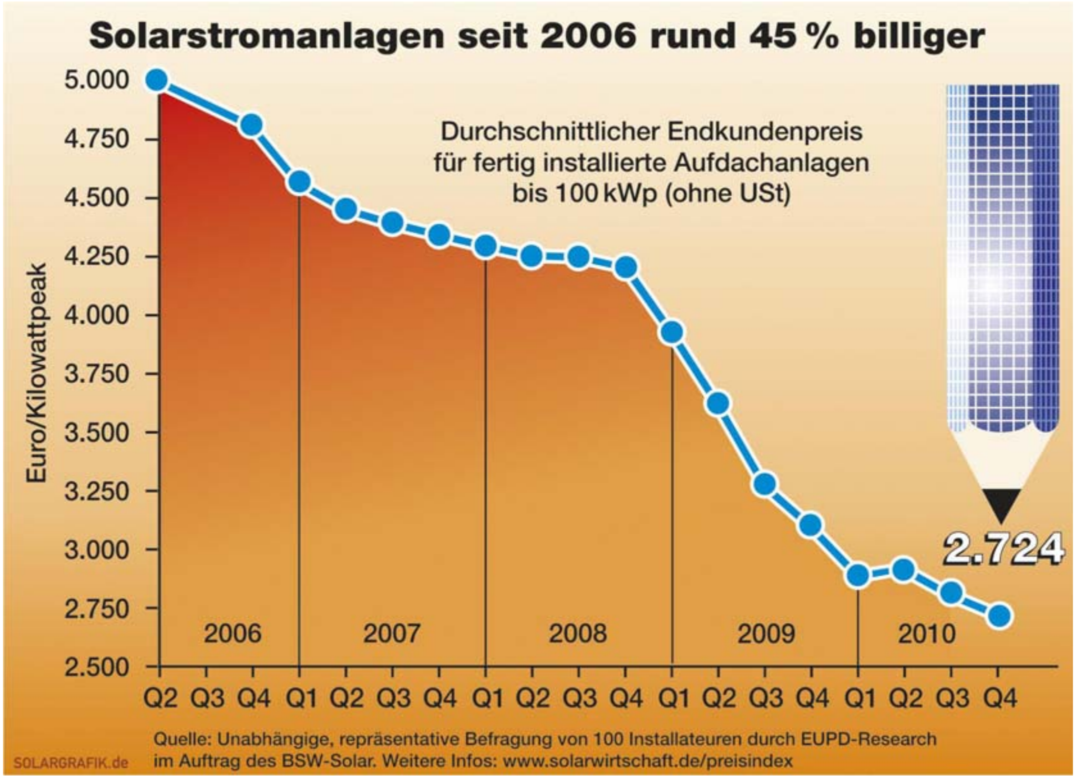
Source: European Photovoltaik Industry Association (EPIA); Press release: "Global Market Outlook for Photovoltaics until 2014", as at: April 2010; all figures are provisional

As you can see from the graphic, there is a high dependence of the PV-industry on single markets/countries (more than 50% of the world wide installations were in Germany). Nevertheless, 8 markets now have more than 100 MW of new installation in 2009.

- In 2009, 17% of PV electricity generation capacity in European Union was added.
- Photovoltaic output represented 2% of the electricity supply (kWh) in Germany in 2009.
- In certain distribution grid areas, PV generation exceeds local demand.
- There were 7.2 GW of new global PV installations in 2009.
- 15 GW of new PV capacity was installed in 2010 (European Photovoltaic Industry Association (EPIA) estimates).

- Over the past 10 years, the PV-industry has grown at an annual rate of about 50%.
- There have been large movements over the last three years caused by changes in Feed-In Tariffs (FIT) in various countries.

7.2 DEVELOPMENT OF PV SYSTEM PRICES IN GERMANY

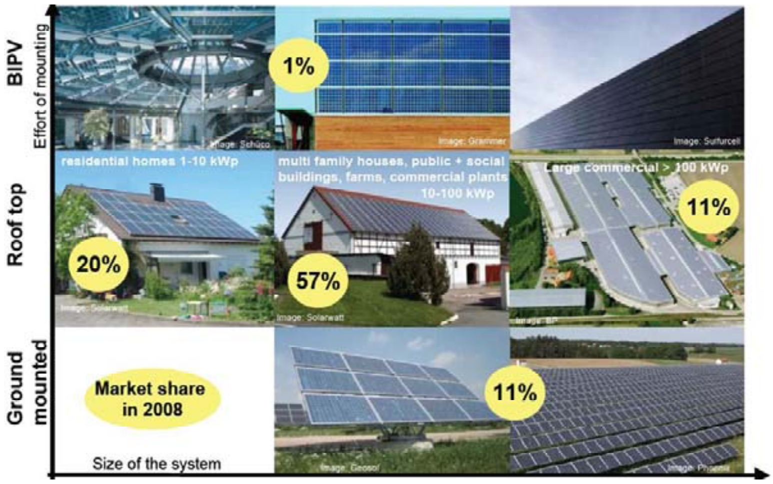


Under German's regulation (renewable energy law, the EEG)public is explicitly charged for an extra fee. The utilities work to make the fee as prominent as possible. Today it amounts to about 15 percent of the bill, which is modest (equivalent to about four beers a month)

In 2005, a poll found that 25 percent thought the level of government support for renewable energy should stay the same, while 62 percent thought it should increase. In 2010, another poll found 73 percent of the public supported continuing or increasing the program. In 2011, EEG tariffs were, for a variety of contingent reasons, spiking. For the first time, 40 percent of Germans said the tariffs had gotten too high. (They're expected to resume falling in coming years as the in response to the Feed-In Tariff Degression.) Then again, in the wake of Fukushima, fully 71 percent of the German public said they'd pay 20 Euros ($29) more per month for clean, non-nuclear power.

This is a good example of how the government set a goal and comes up with a strategy to achieve it - spreading the costs in a fair and transparent fashion,

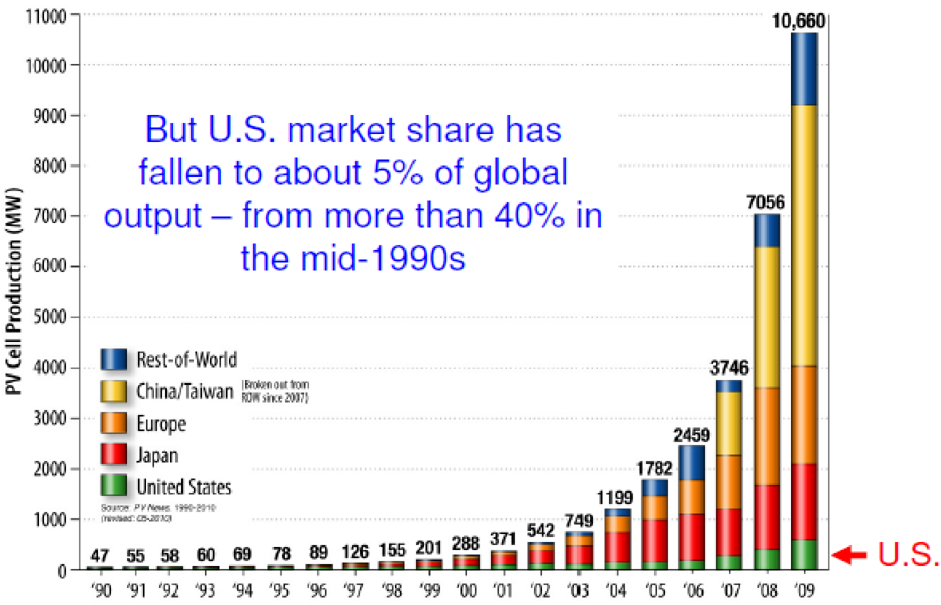
7.3 SEGMENTS OF THE GERMAN PHOTOVOLTAIC MARKET IN 2008



Source: Workshop, Advantages of and possible issues surrounding grid-connected PV power systems, Februarty 16,2010

In 2008, 88% of the PV installations in Germany were rooftop systems, 11% were ground mounted and 1% was building integrated PV systems.

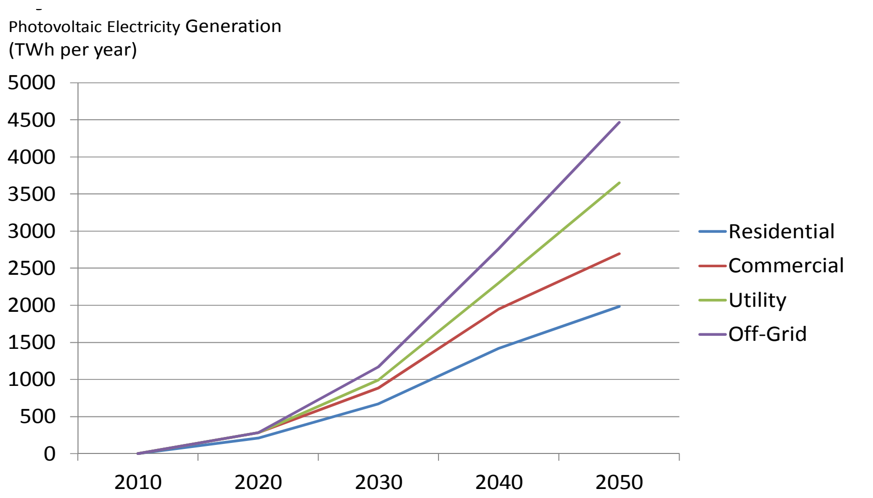
7.4 SOLAR PV IS A BOOMING GLOBAL INDUSTRY



Worldwide production of solar photovoltaics – in Megawatts

The market has been dynamic and evolving. In 1995, 40% of all solar cells were produced in United States. Cell production shifted to Germany in a big way and now the greatest amount of cells are produced in China. In 2009, about 5% of the world's photovoltaic cells were produced in the United States.

7.5 GLOBAL TREND OF SOLAR PV ELECTRICITY GENERATION BY END-USE SECTOR

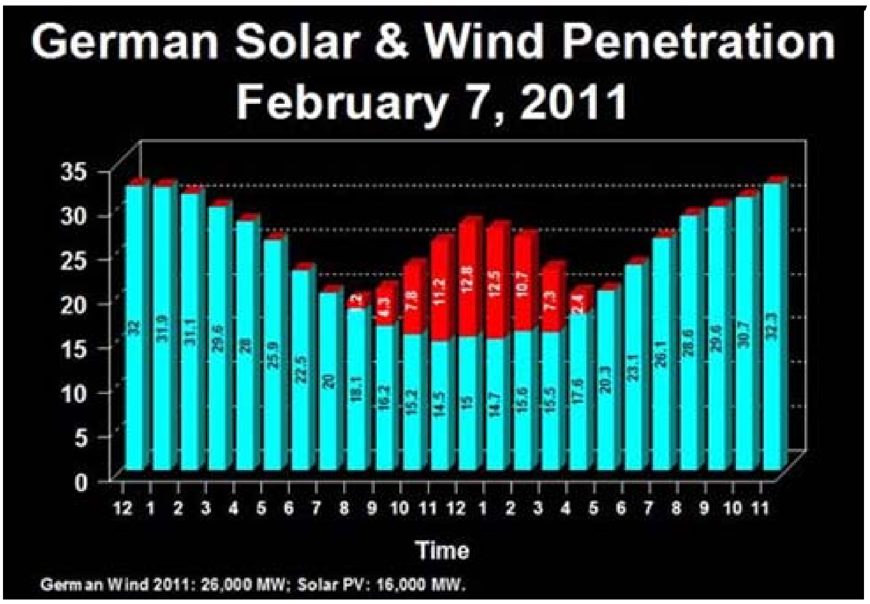


Source: IEA PV Roadmap, IEA analysis based on survey reports of selected countries between 1992 and 2008, IEA PVPS, and IEA 2008 (ETP).
26

The relative share of the four market segments (residential, commercial, utility-scale and off-grid) is expected to change significantly over time. In particular, the cumulative installed capacity of residential PV systems is expected to decrease from almost 60% today to less than 40% by 2050. The figure shows a possible development path for electricity generation of PV systems worldwide by end use sector. The relative shares of PV deployment among the different sectors will vary by country according to each country's particular market framework.

For some locations, there is a synergy between the wind resource and the solar resource. This chart is an example of the sun providing energy during the day, while the wind systems are providing 33% of electricity during non-daylight hours in Germany.

7.6 WIND AND SOLAR SUPPLY THIRD OF GERMANY



Paul Gipe, RE World, 25 March 2011, http://www.renewableenergyworld.com/rea/news/article/2011/03/new-record-for-german-renewable-energy-in-2010

7.7 INTERNATIONAL ENERGY AGENCY'S PV TECHNOLOGY ROADMAP FINDINGS

In 2010, the 28 member countries in the International Energy Agency (IEA) prepared a Roadmap for PV through 2050. Briefly the results were;

- Solar PV power is a commercially available and reliable technology with a significant potential for long-term growth in nearly all world regions. This roadmap estimates that by 2050, PV will provide around 11% of global electricity production and avoid 2.3 gigatonnes (Gt) of CO_2 emissions per year.

- PV will achieve grid parity – i.e. competitiveness with electricity grid retail prices – by 2020 in many regions. As grid parity is achieved, the policy framework should evolve towards fostering self-sustained markets, with the progressive phase-out of economic incentives, but maintaining grid access guarantees and sustained R&D support.

- As PV matures into a mainstream technology, grid integration and management and energy storage become key issues. The PV industry, grid operators and utilities will need to develop new technologies and strategies to integrate large amounts of PV into flexible, efficient and smart grids.

- Governments and industry must increase R&D efforts to reduce costs and ensure PV readiness for rapid deployment, while also supporting longer-term technology innovations.

- There is a need to expand international collaboration in PV research, development, capacity building and financing to accelerate learning and avoid duplicating efforts.

- Emerging major economies are already investing substantially in PV research, development and deployment; however, more needs to be done to foster rural electrification and capacity building. Multilateral and bilateral aid organizations should expand their efforts to express the value of PV energy in low-carbon economic development.

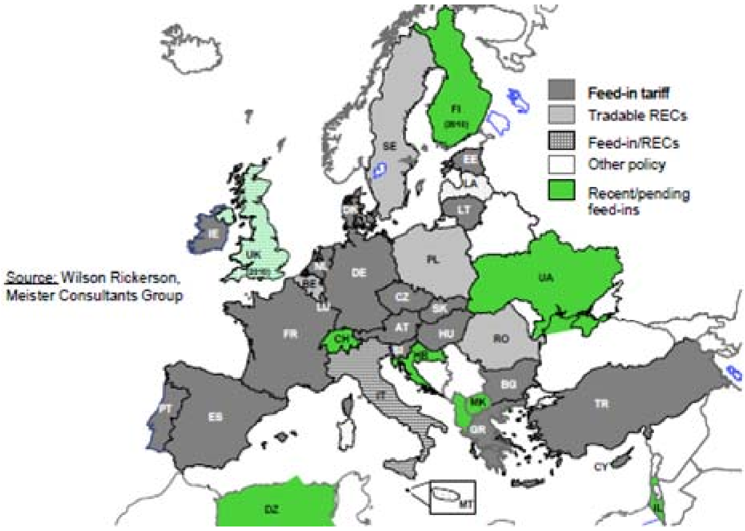
- Achieving this roadmap's vision will require an effective, long-term and balanced policy effort in the next decade to allow for optimal technology progress, cost reduction and ramp-up of industrial manufacturing for mass deployment. Governments will need to provide long-term targets and supporting policies to build confidence for investments in manufacturing capacity and deployment of PV systems.

Accordingly, there is a good opportunity for Armenia to diversify its portfolio of energy sources in overall generation mix. Adding solar, as a domestic source of energy, could reduce dependence on imported energy, stimulate the economy, and increase national energy security.

8. *TARIFF ASSESSMENT*

Feed-In Tariff (FIT) policies are implemented in more than 40 countries around the world and are cited as the primary reason for the success of the German and Spanish renewable energy markets. Experience from Europe is also beginning to demonstrate that properly designed FITs may be more cost-effective than renewable portfolio standards (RPS), which make use of competitive solicitations.

8.1 FIT POLICY: APPLICATION IN EUROPE



50

8.2 FEED-IN TARIFF POLICIES

- Europe credits rapid and stable expansion of diverse RE projects on key FIT policy elements:
  - Long-term policy stability (to attract investors)
  - Long-term contracts (and thus lower c/kWh payments)
  - Target estimated RE project costs across technologies, project sizes, and vintage through differentiation
  - Most end-users able to participate
- FIT policies are for supply procurement and they can be used to complement RES and climate policy goals.
- If designed well, can limit ratepayer costs and also provide investor certainty.
- Long-term targets can drive new RE investment.
- FIT policies implemented in more than 40 countries.

8.3 FUNDAMENTAL FIT POLICY DESIGN OPTIONS

- **Price method:** Estimated cost + targeted return
Avoided cost
- **Payment structure:** Fixed-payment
Premium-payment
    - Constant (over spot market)
    - Sliding
- **Differentiation:** technology, project size, location of project, and sometimes resource quality
- **Bonus payments:** target “smart grid” principles—peak periods; optimal use of transmission system; specific technologies (e.g. advanced grid integration, emerging tech); certain ownership structures (e.g. community owned); deployment in locations with high loads (e.g. urban centers), etc.

More detailed information is provided in the appendix (**Feed-In Tariffs**)

8.4 OTHER FINANCIAL INCENTIVES

A wide variety of incentives are available and proven to be effective to stimulate the deployment of solar electric systems. This includes tax breaks, tax holidays, mandatory generation portfolio requirements and others. In the U.S. each state sets its own state incentive policies that work in combination with tax credits available at the Federal level.

A detailed discussion of the advantages/disadvantages of each system of incentives is beyond the scope of this report. But it can be seen that countries employing FIT over the long term have seen the fastest and most consistent growth in solar electric use and industrial manufacturing development.

In Armenia, the tariff resulting from Net Metering is 30 AMD/kWh (approximately US $0.083/kWh) is not sufficient to support PV based only on electric power cost savings without additional incentives. Projects may be attractive however for other reasons including: power reliability, property value and aesthetics. On the other hand, PV system get economically feasible for some of off-grid locations when the sites are in remote areas and laying out electrical cables is much more expensive and could not provide reliable power supply.

9.1 INTERNATIONAL

World's Third Largest Roof Top Solar PV Power Plant, Philippsburg, Germany

Philippsburg in Baden-Wuerttemberg (Germany) is not only the location for the state-of – the-art and extra-efficient Goodyear Dunlop logistics center for a pan-European distribution of tires. Clean solar power is produced on site. PV developers recently finished construction of the world's third largest roof top solar power plant on the rooftop of the tire stock in Philippsburg with an output of 7.4 MW and approximately 7.3 million kWh/year, covering the annual requirements of approximately 1,800 households. The power plant in Philippsburg is the largest rooftop solar power plant in Germany. General contractor (PV julist) for the construction is juwi Solar GmbH, a subsidiary off the German juwi group from Worrstadt (Rhineland-Palatine).

Usually, only openfield solar power plants can produce large amount of electricity. As an example, a surface of approximately 87,000m^2, 95,500 solar modules (Cadmium telluride (CdTe) thin-film solar cells by First Solar) generate enough power to cover the energy requirements of a small town. In addition, approximately 5,000 tons of carbon dioxide (CO_2) emission is avoided every year. The project was completed in December 2010.

Zero Net Energy US National Renewable Energy Laboratory

When the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) set out to build a new Research Support Facility – basically, a complex of administrative offices – the goal was to move the staff of 825 out of existing conventional office buildings using energy at the rate of 91,000 Btu per square foot per year – expressed as 91 kBtu/ft^2/yr (979 kBtu/m^2/yr). The goal: cut energy use by 65 percent, to 32 kBtu/ft^2/yr (344kBtu/m^2/yr), and make that energy with renewable technologies, right on site. In theory, a new zero-net-energy office building might save the Department of Energy something like $80,000 a year in heating, lighting, air-conditioning and data-center power costs.

Further, the new building was to use off-the-shelf technology and come in for a total budget of $65 million, including design work and furnishings. The design-build contract went to a partnership of RNL Design, an architectural firm with offices in Los Angeles, Denver, Phoenix and Abu Dhabi, and Haselden Construction, of Centennial, Colorado.

When the LEED Platinum project came in on schedule and on budget last fall at 222,000 square feet (20,650 square meters), finished cost worked out to $288 per square foot ($3,096 per square meter). Leadership in Energy & Environmental Design (LEED) is an internationally recognized green building certification system.

Research engineers at NREL have been monitoring the building's performance since the first staffers moved in October 2010. The addition of a remote computer center– it's the data center for several NREL buildings – bumped the total energy budget up to 35 kBtu/ft^2/yr– but Pless reports that midwinter performance is on target for net-zero energy. Before the summer cooling season, the 1.6-megawatt photovoltaic system will be complete and ready to drive the ventilation load. Pless is confident the net-zero goal will be met year-round.

Haselden is now erecting a138,000-square-foot expansion wing with the same net zero features, scheduled for completion in October 2011. It will house another 500 employees.

Building orientation and windows: Office bays are 60 feet wide (18 meters) and oriented to maximize daylight penetration. Window-to-wall ratio to the south is 24 percent and to the north 26 percent. The triple-glazed, argon-filled windows are shaded against summer sun, and are opened (by the occupants) when the building's computer system signals that it would be an efficient cooling tactic. Electrochromic tinted windows on the west wall are controlled by the staff and span 60 feet by 12 feet on three floors. East-facing windows use a cheaper, fully automatic thermochrome technology, darkening as the day grows warmer.

Day lighting is aided by Light Louver window treatments. They look like venetian blinds but each slat is an optical light duct arranged to throw sunlight onto the ceiling, deep in the office bay.

Landscaping features gabion walls, using 1,000 cubic yards of rock out of the foundation excavation, contained in baskets made of recycled steel. Storm water flows off the roof to water the xeriscape plantings. Smart, climate-sensitive computers control additional irrigation, cutting water use about 30 percent. A wing-shaped tower is an air intake for the concrete labyrinth thermal-storage system.

Radiant floor heat is provided with 42 miles (68km) of PEX hydronic tubing. The lobby floor is made largely of recycled granite chips - a byproduct of commercial granite manufacturing- in a ceramic matrix.

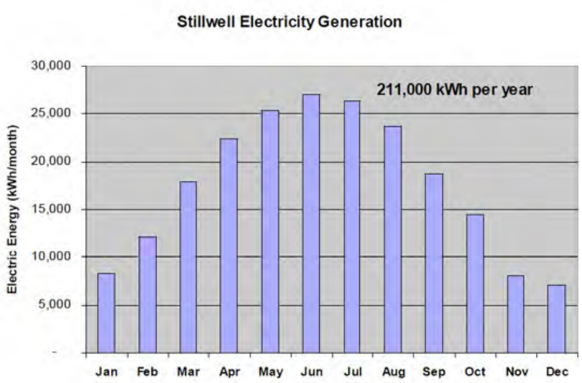
A transpired solar heating system transfers about 75 percent of the sun's energy to air flowing through its perforations and on to the ventilation system, at up to10,000 cubic feet per minute (283 cubic meters per minute).

The Research Support Facility's exterior wall is made from precast concrete panels for thermal mass, and they're insulated with 2 inches (5 cm) of rigid polyisocyanurate foam, to about R13.

A photovoltaic system on the roofs and parking garage totals 1.6 megawatts. This includes 450 kM on the roof of Research Support Facility 1, featuring 240 modules operated under a power purchase agreement from SunEdison. The remainder of the system consists of SunPower modules purchased with American Recovery and Reinvestment Act funds.

Area Lighting and Power – Stillwell Avenue Station, Coney Island, Brooklyn, New York City

The output of the BIPV system at Stillwell Avenue Terminal is enough to provide all the electricity to 33 typical single family houses in the Northeast U.S., 211,000kWh per year. The custom BIPV units, approximately five feet square, contain semitransparent amorphous silicon plates in the center, approximately 5% transparent, with a band of clear glass around the edge. The modules are triple laminated for durability.



The system was designed to provide approximately 10% transparency, including the glazed roof, opaque structure, etc. in order to avoid needing artificial light during the day.

The reconstruction was completed in May 2005 using 2,800 thin film panels; each panel is 5 ft x 20 ft and covering approximately 80,000 ft^2 of solar panels. The 210 kWp (peak power) system provides enough natural light through the roof to reduce the need for daytime lighting. The modules were designed to the Miami-Dade County Hurricane protocols.

Vertical Surface Integration – Co-operative Insurance Building, Manchester, England

In December 2004 a £5.5 million worth project started to install new siding on the CIS Tower's concrete service tower. In 2006 the service tower was clad in 7,000 blue solar panels. The solar paneling is the UK's largest solar array and Europe's largest vertical solar array. According to CIS, the panels generate 180,000 units of electricity each year - enough energy to make 9,000,000 cups of tea. Probably more than CIS staff manage to drink each year. The solar panels will create 181,000 units of renewable electricity each year – equivalent to the energy needed to power 55 homes for a year. In October 2005 Prime Minister Tony Blair switched on the solar panels that had been added on the south side.

When completed, the CIS was the third tallest building in Europe. It is often quoted as being the tallest, but Milan's Pirelli Building and Madrid's Torre De Madrid are taller and were completed earlier.

It is considered by many to be the best of Manchester 1960s buildings. It is the UK's tallest office building outside of London

It was the UK's tallest building outside of London for 43 years. In 2006 it lost this accolade to Birmingham's Holloway Circus Tower, which itself lost the title to the Beetham Tower Manchester later that year.

Dragon-Shaped Solar Stadium in Taiwan is 100% Powered by the Sun

Taiwan completed construction of its solar-powered stadium in 2009 for the World Games. It generates 100% of its electricity from photovoltaic technology. Designed by Toyo Ito, the dragon-shaped 50,000 seat arena is clad in 8,844 solar panels that illuminate the track and field with 3,300 lights.

Building a new stadium is always a massive undertaking that requires millions of dollars, substantial physical labor, and a vast amount of electricity to keep it operating. The stadium design mitigates this energy drain with a 14,155 square meter solar roof that is able to provide enough energy to power the stadium’s 3,300 lights and two jumbo vision screens. To illustrate the power of the system, during a test, the officials found that it took just six minutes to power up the stadium's entire lighting system.

The stadium also integrates additional green features such as permeable paving and the extensive use of reusable, domestically made materials. Built upon a clear area of approximately 19 hectares, nearly 7 hectares has been reserved for development of integrated public green spaces, bike paths, sports parks, and an ecological pond. Additionally, all of the plants occupying the area before construction were transplanted.

Non-sports fans in the community have a lot to cheer for as well. Not only does the solar system provide electricity during the games, but the surplus energy will also be sold during the non-game period. On days where the stadium is not being used, the Taiwanese government plans to feed the extra energy into the local grid, where it will meet almost 80% of the neighboring area's energy requirements. Overall, the stadium will generate 1.14 million KWh per year, preventing the release of 660 tons of carbon dioxide into atmosphere annually.

BIPV: Improve Building Performance with Attractive Design

The figure: BIPV: New Ways to Improve Building Performance with Attractive Design shows one new way to improve building performance with attractive design.

While standard PV solutions are often used in residential or solar-farm applications, BIPV provides the architect with completely new possibilities to incorporate solar technology into buildings. PV systems and architecture can now be combined into one harmonious mixture of design, ecology and economy.

Building integrated photovoltaic modules offer new ways to enhance buildings. The wide variety of elegant forms, colors and optical structures of cells, glass and profiles enables creativity and a modern approach to architectural design. It allows engineers to deliver an energy-efficient, innovative and prestigious project and to set new architectural standards for the future by combining elegance with functionality. PV modules can be incorporated into the building vertically, horizontally or at an angle.

The modules can be tailor-made in accordance with dimensions and customer wishes. A selection of cells and positioning can be adapted according to project design specifics: Transparency, Light control, Module design, Shading, Dimension.

Metal Roofs Building Integrated Photovoltaic Systems

Some "thin film" photovoltaic (PV) laminate roofing systems are embedded with wiring and PV cells that absorb the sun's rays, directly generating energy for your home. Advantages of PV Laminate solar roofing include durability, flexibility and protection similar to traditional asphalt shingles, with a visually appealing design that blends seamlessly into current construction, home design and existing standard roofing. PV Laminate solar power panels replace current roofing material but are very lightweight and offer a low cost of installation. Overall, PV shingles offers outstanding dependability and sturdiness, lasting up to 30 years with little maintenance.

A standing metal seam roof can provide the platform for, thin film photovoltaic modules and laminates that help homeowners and developers supplement their energy needs for residential and commercial facilities with renewable solar energy.

Photovoltaic laminates can be bonded to the metal roof. Wiring connections are then run down to an inverter. The photovoltaic system sends direct electrical current to an inverter where it is converted to alternating electrical current to satisfy the structure's utility loads.

If the photovoltaic supplies more electricity than the structure requires, solar electricity will turn the utility meter backwards and reduce or eliminate the utility bill.

Solar Decathlon National Mall, Washington, D.C.

20 college teams, ranging from MIT to Germany's Technische Universitat Darmstadt, built their prototype houses and transported them to the National Mall in Washington for the October 2009 competition. Together, they created a solar village, which was open to the public. Using the newest products and technologies on the market, the students pushed

the boundaries of residential solar viability, all in the context of a collaborative design process.

Each house must be able to provide enough energy to power proper lighting, run appliances and even to charge an electric car. To generate the power, the teams are allowed to use photovoltaic systems, solar thermal systems, and solar hot water systems. The teams are encouraged to use their own initiatives as long as the energy source comes from the sun. Because the energy available through the PV system was limited, teams had to install energy efficient appliances and create an efficient lighting design. The houses also need proper insulation in order to maintain a stable temperature and reduce the need for heating and cooling.

While technology is an important part of the competition, good solid design is what helps the most. In a house where every kilowatt counts, proper orientation and day lighting access becomes invaluable.

Solar PV Trends for Buildings

The major trends in PV integrated building design can be described as follows:

- PV installations are growing in good and bad global economies
- Most aided by subsidies; Renewable Portfolio Standards, Feed-In Tariffs
- Distributed PV power generation can improve grid reliability
- About 90% of installations are roof top
- Roofs and facades are financially attractive
- Flat plate PV integrates well into buildings
- Integrating PV into new construction may allow technical & financial synergies

Economics of New Construction

Economic implications of PV integrated building design are:

- Can replace external building materials and reduce the costs of a building
- Can be seamlessly integrated into the building envelope to give a sleek, modern look to a building
- Smaller market, many technologies are still under development and are not price-competitive
- Infrastructure, standards not in place, expertise needs to be built up
- Building Integrated PV (BIPV) generates electricity while improving the performance of your building
- Integrating Solar PV into new buildings will allow improved economics by offsetting roof/façade costs
    - Integrated into roof/façade design

- Proper load bearing design
- Offsetting building materials
- Organizing building equipment to accommodate solar PV

At the same time, the economics of existing building retrofit provides that:

- Durable and time tested PV – rated capacity are for up to 25 or 30 years
- Industry standards are well-known to experienced installers
- Efficiency of PV panels - increasing with decreasing price
- Can easily be installed on top of a roof on a building that does not require any structural overhaul
- Big, rectangular, may be visually unappealing
- Does not ‘add-value’ to a home’s functionality besides electricity production
- Placement options are limited
- Existing buildings typically bear all of the costs of adding Solar PV
    - Orientation may not be optimal
    - PV Array may be blocked or shadowed
    - Equipment and materials are added on
    - Strengthening of building for additional weight
    - Seldom opportunity to take advantage of DC power

Economic Constraints in Armenia

Some of economic constraints that are currently limiting building applications of PV in Armenia are:

- Existing buildings typically bear all of the costs of adding Solar PV
- Access to cost competitive components
- Costs of installation
- Investment risks
- Subsidized conventional energy sources
- Lack of state support
- Difficulties in project funding
- Method of applying VAT

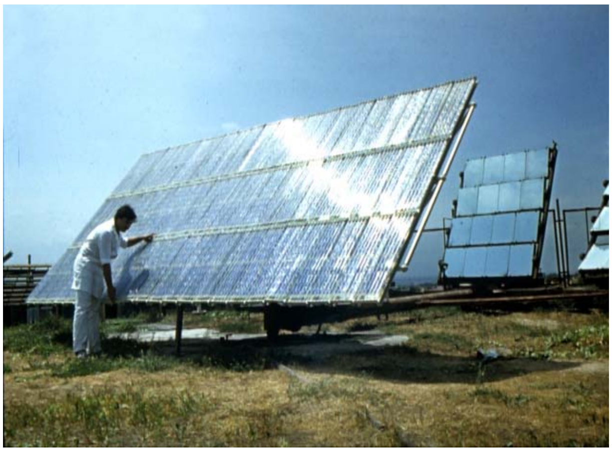
- Non-attractive regulation

9.2 LOCAL EXPERIENCE, ARMENIA

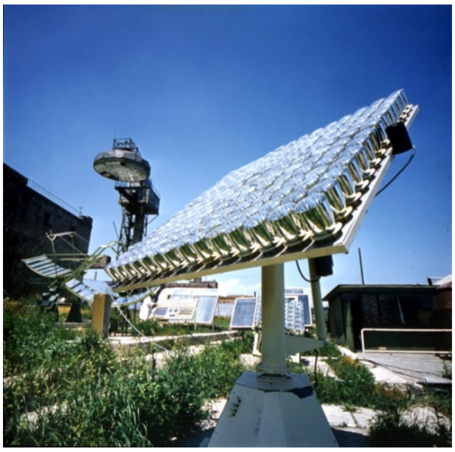
From the mid-1960s to 1990 numerous R&D projects were carried out in Yerevan Solar Institute (Armenian Department of All-Union Power Source Research Institute) which was the solar energy experimental and testing base for soviet and foreign specialists. A number of installations for thermal, thermoelectric, photovoltaic, and photo-electro-chemical conversion of solar energy, solar material science, accelerated material aging, concentrators, tracking systems, etc. have been developed, manufactured, tested and studied.

In 1970 – 1990 a number of optical, tracking systems and concentrating PV were introduced and tested, using plane and concave mirrors, troughs, lenses, linear and concentric Fresnel lenses, compound parabolic concentrators (CPC), and holographic concentrators.

In 1975 – 1985 in Yerevan Solar Institute a production line had been operated for tubular type PV module assembly with silicon solar cells encapsulated inside a transparent glass tube.



Two axes sun tracking tubular PV modules' station, 1976



Two axes sun tracking 0,2kW PV station with compound parabolic concentrators, 1985

Started early 1990s flat solar modules based on imported PV cells have been manufactured by private "Contact-A" company and by Center of Small Energy Systems of the State Engineering University of Armenia. A number of stand-alone PV systems have been installed in Armenia.

8KW PV station at the school in Gyumri, 1990

5kW PV station on the roof of American University of Armenia, 2004

Following the devastating earthquake in Armenia in 1988 the Lord Byron School was built in Gyumri. The school was opened by then UK's Prime Minister Margaret Thatcher on 10 June 1990 on her first trip to the Soviet Union and has been equipped with off-grid 8kW PV station with batteries and DC/AC inverter to power the computer class and lighting. In the last years the PV system was not operating mostly due to the batteries' maintenance problems. It can be reconstructed to the grid connected version (without batteries).

5kW PV station for solar driven air-conditioning system has been installed on the roof of the American University of Armenia in 2004. PV arrays charge batteries and DC/AC inverters provide electricity in off-grid mode to the 3-phase devices of the air-conditioning system.

Grid connected 10kW PV roof of AAWC, 2007

Inverters for 3-phase grid at the AAWC

The PV roof has 220m^2 total area including 124m^2 of photosensitive area. The PV array is connected through three grid-tied FRONIUS IG 30 inverters and reversible electric meter to the 3-phase national grid.

At the moment it is still the only grid-connected PV station in Armenia.

10. FINANCIAL, LEGAL AND REGULATORY ISSUES

10.1 PROJECT DEVELOPMENT

Project development in Armenia has been supported by international donor agencies. Some of cost shared research and pilot demonstration projects included:

1. USAID, Evaluation of Wind and Solar Energy Resources, 2001-2002
2. World Bank, Evaluation of biogas, wind and solar energy resources, 2005
3. TACIS (EU), Solar Potential Evaluation, 2006-2007
4. World Bank, Assessment of solar PV industry development in Armenia, 2008-2009
5. Armenian-American Wellness Center (AAWC), 10kW grid connected building integrated PV station, 2007.

Experience has shown in Armenia and other countries that development can be slowed by:

- Lack of government policy
- Lack of information dissemination and consumer awareness about energy
- High cost of solar compared with conventional energy
- Difficulty overcoming established energy systems
- Inadequate financing options for projects
- Failure to account for all costs and benefits of energy choices
- Inadequate workforce skills and training
- Poor perception by public of renewable energy system aesthetics
- Lack of stakeholder/community participation in energy choices and projects.

10.2 LEGAL FRAMEWORK

The government's role in promoting and supporting PV systems strongly influences the implementation extent of these systems. Even without financial support, the government can encourage solar energy by simplifying the requirements for grid-connection and proper tax treatment. These factors are important in determining the economic viability of a PV system and the timing of cash returns to the owner. A key regulatory issue for grid-connected applications is whether PV power plant qualifies for Net Metering as discussed below.

The legal aspects of renewable energy projects in Armenia are regulated by resolutions of the Public Services Regulatory Commission (PSCR) that issues tariffs, terms of power purchase agreement and licensing for construction and operation. The project developer in Armenia must also comply with the tax legislation, the key components of which are similar to those applicable for wind energy.

The Feed-In Tariff is not defined for photovoltaic projects. The Public Regulatory Services Commission (PSRC) is in charge of licensing, issuing Power Purchase Agreements and setting up tariffs. In the case that such projects emerge, the PSRC will set a corresponding tariff. As for the solar energy applications today, net-metering concept (i.e. parallel operation of the solar installation of up to 150 kW capacity that uses most of the electricity for own needs) can be connected to the grid and send the excess to the grid and get it back free of charge with balancing it to zero at the end of one year period. This is equivalent to setting a Feed-In Tariff equal to the retail power price that is currently 30 ADM/kWh during the day.

Value Added Tax (VAT) - A value added tax of 20% is paid on all transactions. The tax is paid by the seller of the goods or services. According to the law all imported equipment for PV plant (PV modules, inverters, controllers, etc.) are subject of this tax. For net metering applications when the PV power plant owner cannot use or does not sell the generated electricity it is lost money and reduces his financial return on his initial investment. Prepayment of VAT is a serious problem for a developer.

Import Duty - Presently the 10% customs charge does not apply for PV modules but it applies for other system components (electronics, materials).

State Duties - One of requirements to get a construction license is paying state duties.

Valuing for Customs - Customs clearance is another problem when customs officers value the imported equipment price (to apply customs duties and VAT). The invoiced price for the imported goods is not necessarily an evidence for customs to calculate customs duties and VAT. The value of imported goods could be estimated voluntarily based on “best practice” of crossing similar goods and their prices recorded or fixed in the past.

10.3 REGULATORY FRAMEWORK

The major regulatory Issues for renewable energy applications are associated with (i) tariff regulation; (ii) licensing procedures; (iii) land acquisition/leasing; (iv) environmental impact assessments; (v) power purchase agreements; and (vi) grid connection permit.

Net Metering is currently the only tariff structure for PV. As an incentive the RoA could establish a higher Feed-In Tariff for net metered power sent to the grid. For a net metered FIT to be effective it would need to have a clear long-term commitment to power price (15-20 years) and be adjusted for currency exchange rates and indexed for inflation. This power price must be fixed for the term of the agreement but each periodic offering could be adjusted to reflect changes in market conditions.

Licensing - PSRC issues construction license upon submission of a project business plan (or full scale feasibility study), and submission of an environmental impact assessment. The operation license is not needed for the net metering applications. There are certain duties to be paid for the licensing procedure. According to the PSRC regulations for construction and operation activities in the power sector the licenses are issued upon submission of the following documents:

- Company papers (copies of the charter and state registration certificate; information on shareholders and partners, information on loans, debt, and other transactions; financial reports);

- Project related business plan (according to the set format);
- Approval of engineering design (along with environmental and technical expertise), equipment offers and secured financing;
- Verification of land use title rights;
- Bank guarantees with minimum 500,000 AMD;
- Payment confirmation of state duties.

The environmental impact assessment is mandatory for any construction project and is complicated regardless of the size of the project.

The Ministry of Nature Protection is in charge of the process. The procedure for environmental impact assessments and getting corresponding resolution includes the following stages: (i) notification of intended activity, (ii) submission of project documentation, and (iii) issuing resolution. There is a lack of experience and knowledge within the environmental impact assessment agency on PV energy projects. The environmental impact assessment is conducted by “Ecological Expertise”, a state, noncommercial organization under the structure of Ministry of Nature Protection.

The environmental impact assessment starts from the moment of submission of the business plan, relevant information, data and associated documents. The application requires specific format for submitted papers. In most cases the overall process requires at least three months (under current law the maximum timeframe is 180 days after all required papers are submitted).

PV systems are inherently beneficial to the environment, reduce power transmission losses, provide carbon displacement and add value to buildings when they are installed.

Grid Connection Permit - All renewable energy generators and combined heat and power (CHP) generators with capacity up to 150kW can be connected to the grid based on the net metering procedure according to the PSRC regulation. Thus, in the case of net metering no power purchase agreement is needed.

Standardization - Certain equipment and devices, regardless of their origin and certification (for quality and international standards), will be subject to strict customs regulation that requires obtaining corresponding certification or standard from National Standard Institute. The goods having the highest international standards will be mandated. PV systems are currently required to pass testing at the National Institute of Standards (NIS). Due to the absence of proper testing laboratories and instrumentation, as well as lack of qualified personnel, NIS may not be in a position to conduct testing and issue a certificate that will be required to complete customs clearance. In such cases the importer will be faced with the risk of delays in customs clearance and thus payment of penalties for overstaying the goods at customs. An option could be to have NIS accept certification by accredited laboratories in other countries.

10.4 APPROVALS AND GRID CONNECTION

Technical and organizational provisions on connection of solar PV power plants to the electric grid are under consideration at the moment and will be presented in the Standard of the RoA Ministry of Economy in “Renewable Energy. Solar Energy Connection of Photovoltaic Power Plants (with up to 5 MW capacity) to the Common Grid of Electrical

Power System. General provisions." It will define legal and commercial relationship between the parties, as well as technical conditions of connection.

General interconnection technical requirements and specifications are applicable to distributed generation from solar photovoltaic and other solar electric systems interconnected for parallel operation with the Electric Networks of Armenia (ENA) distribution system. The protection and safety devices and other requirements specified in the following sections are intended to provide protection for the ENA system and its workers, other ENA Customers, and the general public. They are not imposed to provide protection for the Customer's generation equipment or personnel. This is the sole responsibility of the Customer.

With respect to the above protection objectives, it is necessary to disconnect a parallel generator when trouble occurs, to :

(a) insure that if a fault on the ENA system persists, the fault current supplied by the Customer's generator is interrupted;

(b) prevent the possibility of re-closing into an out-of-sync isolated system composed of the utility distribution system, or a section of it, and the Customer's generator;

(c) prevent re-closing into the Customer's generation system that may be out of synchronization or stalled; and

(d) prevent unintentional islanding.

The protection requirements are minimal for smaller installations, but increase as the size of the Customer's generation increases. Small installations usually ensure that the generator is small compared with the magnitude of any load with which it might be isolated. Thus, for any fault on the utility system, utility protective devices will operate and normally isolate the generation with a large amount of load, causing voltage collapse and automatic shutdown of the generator.

For larger installations the probability of isolated operation is higher since the available generation may be sufficient to carry the entire load, or part thereof, of the local ENA circuit. In instances referred to as "Islanding", where the ENA system arrangement is such that it is possible that during a grid fault interruption, that the distributed generators may have sufficient output to continue to operate comparatively large amounts of load without grid system connection. In these cases, additional protection and generator shutdown schemes are required.

The Customer is solely responsible for the protection of his equipment from automatic re-closing by the utility ENA. Normally this applies to automatic re-closing of overhead distribution circuits. When the ENA source breaker trips, the Customer must ensure that his generator is disconnected from the utility circuit prior to automatic re-closure by the utility (the automatic re-closing on ENA distribution feeders is normally delayed by at least 2 seconds). Automatic re-closing out-of-sync with the Customer's generator may cause severe damage to Customer equipment and could also pose a serious hazard to Customer or Utility personnel.

The draft standard, "Renewable Energy - Solar Energy Connection of Photovoltaic Power Plants (with up to 5 MW capacity) to the Common Grid of Electrical Power System General Provisions" – addresses the following topics:

- Service Disconnect Switch

- Transfer trip system if a generator size and physical location on a feeder is such that it could support an isolated (islanded) section of the grid.
- Electric meter(s) to record the output of the generator(s).
- Allowing grid systems and substation modifications.
- Responsibilities for the design, installation, operation and maintenance of all equipment on the Customer's side of the Point of Interconnection.

11. CONCLUSIONS

Armenia has a good solar resource, many years of R&D experience in solar thermal and PV applications, but is in the early stage of its broad commercial utilization. The findings of the report are aimed to assist solar energy development in Armenia. Expanding its energy portfolio to include solar, improving the legal and regulatory environment and creating solar energy development strategy can increase national, energy and economic security, while creating jobs. Most of the countries aggressively pursuing solar installations have less insolation than Armenia.

Worldwide energy growth will continue at a strong pace. To grow, countries will need to expand their energy supply. Utilizing domestic resources, such as solar, will facilitate growth and diversify energy sources while creating a domestic industry. The economics of solar electric photovoltaics is continuing to improve. The price of PV modules has been decreasing for over 30 years. PV installations are continuing to grow in good and bad global economies. Production has been increasing by about 45% for the past 10 years. The technical performance of the modules is continuing to improve. It is estimated that by 2030, 14% of the U.S.'s power will be generated from solar PV.

Buildings are not only large consumers of energy, but in 2008 about 90% of solar electric installations were on residential, commercial and industrial rooftops. Distributed PV power generation can improve grid reliability. Having small and large generators dispersed around a geographic region can lead to a stronger power system network, making it less susceptible to natural, economic and human risks.

12. RECOMMENDATIONS

1. Delegate the approval of PV electric plants up to 150kW to the Distribution Company to simplify the grid connection procedure.

2. Eliminate the requirement for an Environmental Impact Assessment (environmental expertise) for all building integrated PV stations and ground mounted PV power plants up to 150kW.

3. National Institute of Standards should adopt the international certificates for PV plant equipment.

4. Create a National Solar Energy Development Strategy. The strategy should define the goals to be reached in coming 20 – 30 years in terms of MW of PV power plants installed, milestones and steps.

5. Establish a sufficiently attractive Feed-In Tariff for limited demonstrations and pilot projects.

6. Establish a limit of 1 MW per year for grid connected PV power plants which could be installed in 2011 – 2013 under special Feed-In Tariff. To define the limit and Feed-In Tariff policy for 2014-2020.

13. REFERENCES

1. Handbook of photovoltaic science and engineering. Edited by A. Luque and S.Hegedus, 2003, J. Wiley & Sons Ltd., England.

2. Understanding Renewable Energy Systems. V.Quaschning. Earthscan, 2005.

3. Support to the Energy Policy of Armenia. TACIS PROJECT, EUROPAID/120653/C/SV/Am, 2007.

4. V. Afyan, “Implementation of solar water heating and PV systems in Armenia,” the Third International Renewable Energy and Clean Energy Conference, Conference Proceedings, Yerevan, June 27-29, 2007.

5. Alternative energy demystified. S.Gibilisco. McGrawHill, 2007.

6. Renewable Energy FocusNews, 20 April, 2011.

7. http://www.contact-a.am

8. http://www.aua/ERC/solar

9. Procedures for the Parallel Operation of Micro Power Plants of Independent Generators Using Renewable Energy with RoA National Grid. PSRC Resolution No.194-N dated November 30, 2005.

10. Ursula Eicker. Solar Technologies for Buildings, J. Wiley & Sons, 2003

11. Wind Energy Development in Armenia: Legal, Regulatory, Tax and Customs Regulations. PA Government Services Inc., Contract number EPP-1-08-03-00008-00, April 2010.

12. Draft Standard, “Renewable Energy. Solar Energy Connection of Photovoltaic Power Plants (with up to 5 MW capacity) to the Common Grid of Electrical Power System. General provisions”, RoA Ministry of Economy, 2011

13. NASA Surface meteorology and Solar Energy: Global Data, release 5.1 - Insolation on horizontal surface (1983-1993). http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s01 (Accessed July 14th 2007)

14. Annual Energy Outlook 2011, Early Release Overview, U.S. Energy Information Administration, U.S. Department of Energy, April 26, 2011, Report Number: DOE/EIA-0383 (2011)

15. Jacobson, M. Z., and Delucchi, M. A. (2010). Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials.

16. Evaluation of Different Feed-In Tariff Design Options – Best practice paper for the International Feed-In Cooperation, 2nd edition, update by October 2008, Fraunhofer Institute Systems and Innovation Research, Anne Klein, Benjamin Pfluger, Anne Held, Mario Ragwitz, Gustav Resch and Thomas Faber

17. Delucchi, M. A., and Jacobson, M. Z. (2010). Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies.

18. Feed-In Tariff Policy: Design, Implementation, and RPS Policy Interactions, Karlynn Cory, Toby Couture, and Claire Kreycik, National Renewable Energy Laboratory, Technical Report NREL/TP-6A2-45549, March 2009

19. The Energy Report: 100% Renewable Energy by 2050, WWF – World Wide Fund For Nature (Formerly World Wildlife Fund), Gland, Switzerland. January 2011 WWF International, Ecofys, & Office for Metropolitan Architecture. (2011).

20. Research and Development Investments in PV – a Limiting Factor for a Fast PV Diffusion? Ch. Breyer, Ch. Birkner, F. Kersten, A. Gerlach, J.Ch. Goldschmidt, G. Stryi-Hipp, D.F. Montoro, M. Riede, Solar Energy 2010

21. International Energy Outlook 2010, final report, U.S. Energy Information Administration DOE-EIA-0484(2010), July 2010

22. Solar Generation 6: Solar Photovoltaic Electricity Empowering the World 2011, European Photovoltaic Industry Association & Greenpeace International

23. Solar Electric Power, The U.S. Photovoltaic Industry Roadmap, January 2003

24. Is it Time for a “Sun Shot”? $1/Watt Workshop, Steven Chu, Secretary, U.S. Department of Energy, Washington, D.C., 10 August 2010

25. Technology Roadmap, Solar Photovoltaic Energy, International Energy Agency, 2010

26. Renewable Energy, Annual Energy Review, U.S. Energy Information Administration, U.S. Department of Energy, 2009

27. Advancing a Sustainable Solar Energy Future, SEMI PV Group Policy Principles and Recommended Best Practices for Solar Feed-In Tariffs, December 2009

28. IV CONTO ENERGIA Decreto, Italy – 5 maggio 2011

29. Annual Energy Review 2009, U.S. Energy Information Administration August 2010 DOE/EIA-0384 (2009)

30. The Cost-Efficient Zero-Net Office Building, by Seth Masia, Solar Today, May 2011

31. Zeroing In on Net-Zero Energy, by Joann Gonchar McGraw Hill Construction Continuing Education December 2010

32. U.S. Solar Market Insight: 2010 Year in Review, Executive Summary, Solar Energy Industries Assocition, SEIA/GMT Research

33. Building Integrated Photovoltaics; European Commission, Directorate-General for Energy and Transport, by Didier Lenoir

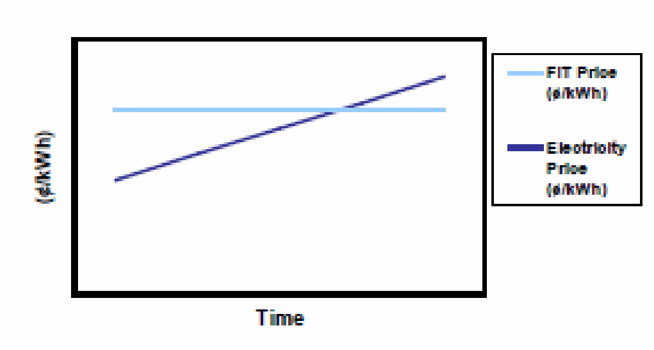
34. Giant Solar Canopy Makes a Splash at Summer Olympics, Solar Design Associates 2006

35. Stillwell Avenue Terminal Train Shed, Kiss + Cathcart, Architects 2007

36. The Evolution of Building Integrated Photovoltaics (BIPV) in teh German and French Technological Innovation Systems for Solar Cells by Fabien Crassard/Johannes Rode, Master of Science Thesis in Management adn Economics of Innovation 2007

37. Renewable Energy Feed-In Tariffs: Lessons Learned from the U.S. and Abroad, by Karlynn Cory, Strategic Energy Analysis Center – Financing Team Lead, National Renewable Energy Laboratory, U.S. Department of Energy Technical Assistance Project Webinar, October 28th, 2009

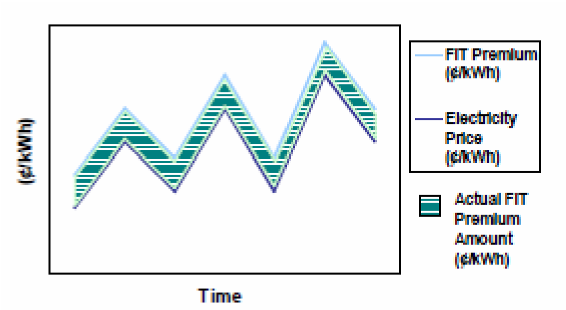
Fixed Price Feed-In Tariff Model



Properly designed fixed FIT mechanism can offe the following advantages:

- The total FIT payment to the project remains independent from the market price
- It is a predetermined payment for a guaranteed period of time.
- The fixed-price FIT policies offer market-independent payments
- They create stable conditions for investors.
- This risk reduction can lead to lower project-financing costs

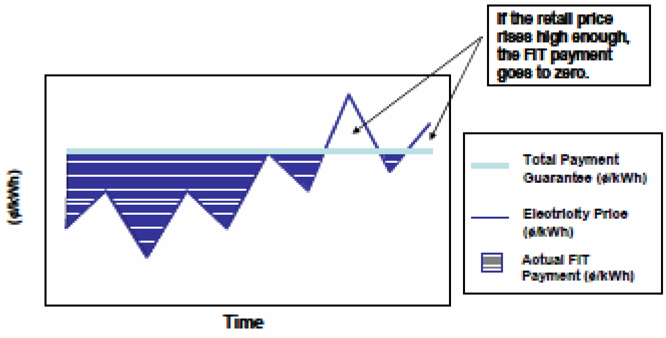
Non-Variable Premium Price Feed-In Tariff Model



The advantages of this type of a model can be:

- FIT payments can be offered as a premium on top of the spot-market electricity price.
- The project owner receives payment for the total electricity generated, as well as a FIT payment.
- The premium FIT payments can be either non-variable, or variable
- Although a non-variable premium is a simpler design, it risks resulting in windfall profits for developers if spot-market prices for electricity increase significantly.
- If electricity prices fall, the investor's return would be at risk

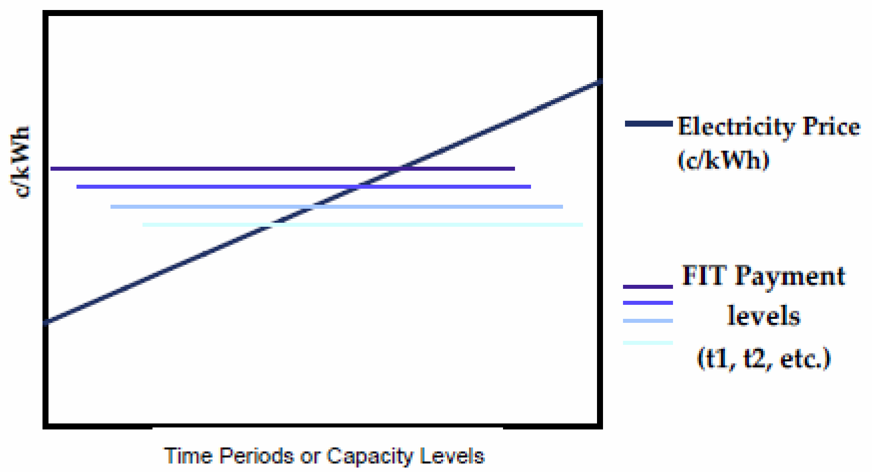
Netherlands Variable Premium-Price FIT (Spot-Market Gap Model)



This is anotther variation of FIT model that offers:

- The variable-premium FIT payment structure based on project costs is the "spot-market gap" model
- The government guarantees projects will receive a predetermined, minimum total payment.
- Instead of paying projects the total amount through a FIT payment, the project receives its payment through two separate revenue streams.
- It's a hybrid approach between the fixed-price and the premium-price models.

Tariff Degression



Tariff degression works as the follows:

- Feed-In Tariffs are fixed once a system has been installed and registered
- Duration of payment is fixed
- Tariffs vary depending on when the system is installed and registered
- Tariffs can also vary by;
  - Technology
  - System size
  - New build
  - Retrofit
  - Stand alone system

Feed-In Tariff Policy: Flexible Design

	Germany	Spain	The Netherlands
Payment level basis	RE project cost (declines over time)	'08: premium + spot '09: RE project cost	RE project cost (declines over time)
Payment level structure (for a contract)	Fixed payment level, 20 years, no inflation adj.	'09: Fixed or premium w/cap and floor (PV: fixed only), 15-25 years, w/inflation adj.	Spot market gap
Differentiation	Tech., project size, resource quality, and vintage	Tech., and project size	Tech., project size, and resource quality
Caps a/project size b/program	a/ biomass: 20 MW a/ (none for wind or solar) b/none	a/ '08 PV: 50 MW a/ '09 PV: 10 MW b/ '08 PV: 5 year target (National Energy Plan) b/ '09 solar: 400 MW b/ '10 wind: 20,155 MW	a/ PV: 3.5 kW b/ 4-year budgets: - Wind: ~2,000 MW - Offshore: ~400 MW - Biomass: ~250MW - Biogas: ~15 MW - PV: ~70-90MW
Payment level adjustments	Analyzed every 4 years with annual increments	Analyzed annually, re-set (and retroactive)	Subject to government review at any time

Sources: EEG 2008, RD 661/2007, RD 1578/2008, and van Erck 2008

Current Solar Feed-In Tariff Rates by Region

Region	Country/State/City	Rate (€/kWh)	Size	Length (years)	Notes
Asia	Republic of Korea	0.3405 0.3250 0.3095 0.2940 0.2476	< 30 kW < 200 kW < 1 MW < 3 MW > 3 MW	20	• 500 MW program cap • 15 year rates also available
	Jiangsu, China	0.3619 0.2103	Roof Mounted Ground Mounted	TBD	• 400 MW program target
	Taiwan (proposed)	0.1672 0.1920 0.1860	< 10 kW < 500 kW > 500 kW	TBD	
Australia	Australian Capital Territory	0.3105 0.2484	< 10 kW < 30 kW	20	
	New South Wales	0.3722	< 10 kW	7	• Can be claimed in tandem with rebate
North America	Ontario	0.5106 0.4540 0.4043 0.3432 0.2821	< 10 kW Any System Type > 10 < 250 kW Rooftop > 250 < 500 kW Rooftop > 500 kW Rooftop < 10 MW Ground Mounted	20	• Adders for aboriginal and community ownership
	Gainesville, Florida	0.2133 0.1866	Roof Mounted or Pavement Mounted, or Ground Mounted < 25 kW Ground Mounted > 25 kW	20	• 4 MW annual cap
	San Antonio, Texas	0.1800	50 kW Minimum 500 kW Maximum	20	• 10 MW program cap • 2 year program length
	Vermont	0.2000	< 2.2 MW	25	• 50 MW program cap

continued

Source: SEMI, November 2009

Region	Country/State/City	Rate (€/kWh)	Size	Length (years)	Notes
European Union	Austria	0.4598 0.3998 0.2998	< 5 kW < 10 kW > 10 kW	12	
	Bulgaria	0.4208 0.3860	< 5 kW > 5 kW	25	
	Cyprus	0.36 0.34	< 20 kW < 150 kW	20	
	Czech Republic	0.4963 0.4925	< 30 kW > 30 kW	20	
	France	0.328 0.437 0.6018	Mainland Installations Overseas and Corsica BIPV	20	
	Germany	0.4301 0.4091 0.3958 0.33 0.3194	< 30 kW Rooftop <100 Rooftop < 1 MW > 1 MW Ground Mounted	20	
	Greece	0.45 0.4 0.5 0.45	< 100 kW Interconnected > 100 kW Interconnected < 100 kW Uninterconnected Islands > 100 kW Unitnerconnected Islands	20	
	Italy	0.48 0.431 0.392 0.451 0.412 0.372 0.431 0.392 0.353	1 kW–3 kW Full BIPV 1 kW–3 kW Partial BIPV 1 kW–3 kW Non-BIPV 3 kW–20 kW Full BIPV 3 kW–20 kW Partial BIPV 3 kW–20 kW Non BIPV > 20 kW Full BIPV > 20 kW Partial BIPV > 20 kW Non-BIPV	20	
	Luxembourg	0.42 0.37	< 30 kW 31–1000 kW	15	
	The Netherlands	383 353	0.6 kW–15 kW 15 kW–100 kW	15	
	Portugal	0.42 0.32	< 5 kW > 5 kW	15	
	Slovak Republic	0.2774		12	
	Slovenia	0.4154 0.38 0.315 0.4778 0.437 0.3626 0.3904 0.3597 0.2899	< 50 kW < 1 MW < 5 MW < 50 kW BIPV < 1 MW BIPV < 5 MW BIPV < 50 kW Ground Mounted < 1 MW Ground Mounted < 5 MW Ground Mounted	15	
	Spain	0.32–0.34 0.32	Rooftop Systems Ground Mounted	25	
	United Kingdom (proposed)	0.3457895 0.40713925 0.3457895 0.312326 0.290017 0.290017	< 4 kW (new construction) < 4 kW (retrofit) < 10 kW < 100 kW < 5 MW Stand Alone System	20	

continued

Source: SEML November 2009

Region	Country/State/City	Rate (€/kWh)	Size	Length (years)	Notes
Non-European Union	Croatia	0.46 0.41 0.26	< 10 kW < 30 kW > 30 kW	12	
	Israel	0.36 0.29	< 30 kW 50 kW–5 MW	20	• 50 MW program cap
	Switzerland	0.49 0.43 0.41 0.39 0.43 0.35 0.33 0.32 0.59 0.48 0.44 0.41	< 10 kW Roof Mounted < 30 kW Roof Mounted < 100 kW Roof Mounted > 100 kW Roof Mounted < 10 kW Ground Mounted < 30 kW Ground Mounted < 100 kW Ground Mounted > 100 kW Ground Mounted < 10 kW BIPV < 30 kW BIPV < 100 kW BIPV > 100 kW BIPV	25	• Program capped at 0.006% of electricity sales, with solar capped at 5% of that
	Turkey	0.28 0.22	First 10 Years Second 10 Years	20	
	Ukraine	0.23695357 0.247724187	< 100 kW > 100 kW	Through 2030	• Floor price set in Euros • 1.8 multiplier in peak hours

Source: SEMI, November 2009

Helene-Weigel-Platz, Berlin, Germany

- Completed as part of a reconstruction project
- PV elements integrated on the 70 meter high south façade
- 480 modules made of laminated safety glass
- 426 m^2 of polycrystalline silicon cells
- 50 kWp
- 25,000 kWh/year
- 72 tons of CO^2/year
- 3.6 million €
- Completed 2000

For the renovation of the Doppelwohnhochhäuser at the Helene-Weigel-Platz, the WBG Marzahn wanted to signal and demonstrate solutions for a future-oriented management of high-rise building stocks.

They have succeeded in integrating a photovoltaic system clearly visible on the south facade rising 70 m high. It consists of 480 modules made of laminated safety glass each containing 72 solar cells. The 426 m² plant produces about 25,000 kWh of electricity per year. Parts of electrical requirements for HVAC, elevators, ventilation, lighting, etc. are provided. The solar system is connected to the grid and can feed the electricity consumed in the building not provided by the network.

As solar systems were still rare in 1999, they were produced in custom manufacturing. Without funding, the system would recover their costs only in about 90 years. By the onset of mass production, the costs have fallen already. Therefore, at the time of its construction, the plant was a model in the right direction. Another factor that favors the way to the economy is that the solar panels instead of the conventional facade elements are used. Cost of the normal facade cladding can be so.

A ventilated façade using Eternit panels was selected in the course of the renovation. On the South façade, PV modules replace the Eternit panels.

The reconstruction is not only a sign of innovation and environmental protection, it is aesthetically appealing: with the now blue facade of the South, the House looks just beautiful.

Data building Helene WeigelPlace

Location:	Helene-Weigel-Platz 6 / 7, Berlin-Marzahn
Client:	Housing MarzahnmbH Mehrower Avenue 52 12687 Berlin Department: customer center group maintenance and maintenance Mrs.Weißenfels FON 49-30-93-888-942 Fax 49-30-93-888-709
Completion:	1999
Promotion:	PV system: investment subsidy of Vattenfall and the InvestitionsBank Berlin
Photovoltaics:	Area: 426 m²
Performance:	48 kWpeak
Power production:	about 25,000 kWh/year
CO_2-Reduction effect:	Approx. 72 tons/year
Literature:	Literature: Meuter, Hartmut (1999): high-rise refurbishment in Berlin-Marzahn, in: Federal construction sheet heft 4 / 99, S. 44-47
Cost	3.6 million €, completed 2000

Thyssenkrupp Stahl, Duisburg-Beeckerwerth, Germany

As part of the reorganization of its hot slitting facility in Duisburg-Beeckerwerth, the builder, ThyssenKrupp Stahl, installed over an area of 1,400 square meters on the outer facade nanocrystalline solar modules, manufactured by ThyssenKrupp Bausysteme, with a rating of 51 kilowatt peak. Despite the fact that the angle to the sun of 90 degree is not optimal, the system’s photovoltaic modules achieve by a constant efficiency of 8%, an annual yield of about 32,000 kWh/year. Responsible for the planning and installation of the system was the ContecnaSystembauHoesch GmbH in Oberhausen.

The entire solar facade was realized by color-coordinated, undulating greens, so that the building would be useful integrated in the surrounding landscape. This was the proof that industrial buildings do not always have to express the sadness and the coolness of a manufacturing plant.

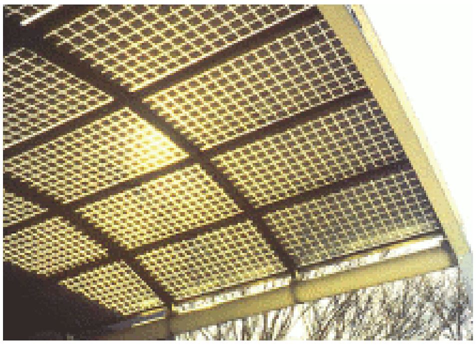
As rhausen.

The

Technical Data

solar modules	1004 solar modules ‚Thyssen Krupp Solartec design'
facade-fields	6 with different number of modules (40-200)
height of the fields	up to 24 m
solar surface	approx 1000 square meter
total rating	51.06 kWp
efficiency	8 %
solar technology	nanocrystalline three-layer coating technology of UNISOLAR® on a flexible solar film
inverter	19 inverter with different rating
solar cable	approx 10 km relocated with Multi-Contact-connectors
expected annual yield of the facade system	32,130 kWh/a, despite the unfavorable angle to the sun with 90 degree
Cost	830,000 €, completed May 2002

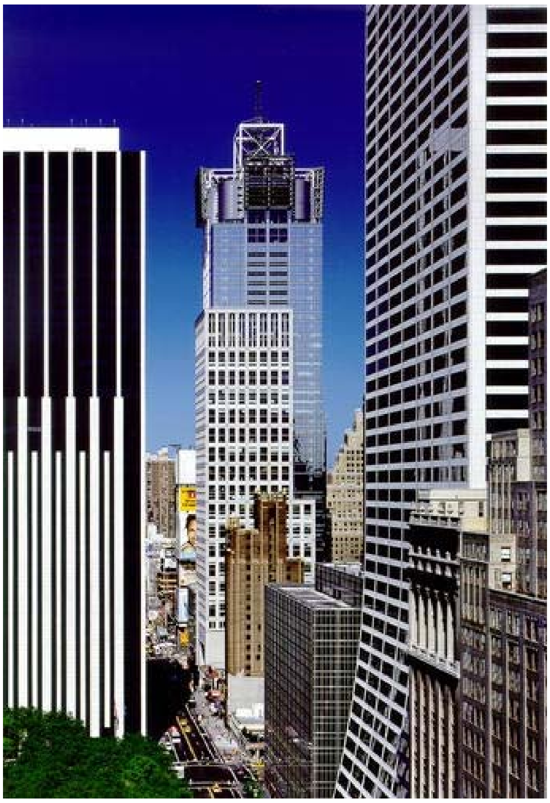
1996 Summer Olympics' Solar PV Powered Natatorium, Atlanta, Georgia



- Solar system provides 30% of the building's power
- 340 kWp
- 2,856 PV modules installed on the main roof of the swimming facility

- 32,720 square feet of solar panels
- PV modules integrated into a custom designed arched support structure to form the skin of the canopy over the entrance
- Each PV module featured its own integrated DC to AC micro inverter to deliver 60 Hz AC power directly to the building
- 274 solar thermal collectors
- Completed 1996

Number 4 Times Square Building, New York City



Thin-film photovoltaic (PV) panels

- Integral part of the tower's curtain wall
- Replaced glass spandrels from 37th to 43rd floors
- Custom PV modules fit the building's rigorous aesthetic, structural and electrical criteria
- On the south and east faces of the tower
- Equivalent of power for five to seven houses
- 48 floor skyscraper at Broadway & 42nd
- Completed December 1998

Henley Way, Rotherham, South Yorkshire Housing Association, England

- 23 homes with roof integrated solar systems
- Solar PV and solar thermal roof tiles
- Net-metering
- 3 kWp, 2500 kWh/year
- Saving 1.5 tons of CO_2/year
- 60% of hot water requirements of the 3 bedroom home

Completed November 2007

Building Integrated Photovoltaics: Loyola Marymount University

As a result of the innovative partnership between Loyola Marymount University (LMU), the Los Angeles Department of Water and Power (LADWP), the Southern California Gas Company, and solar electric company PowerLight, the 723-kilowatt hours peak solar rooftop system was installed on two of the university's largest buildings – University Hall and the Von der Ahe Library. The solar roof system is expected to generate 868,000 kWh annually, providing 26% of total energy used at the university. Additional benefits include thermal insulation and protection of the roof from weather and UV radiation, resulting in decreased heating and cooling energy costs and extended roof life. The evaluation panel for the Green Power Purchasing Award for Onsite Generation includes EPA and DOE experts, together with other experts from other federal agencies.

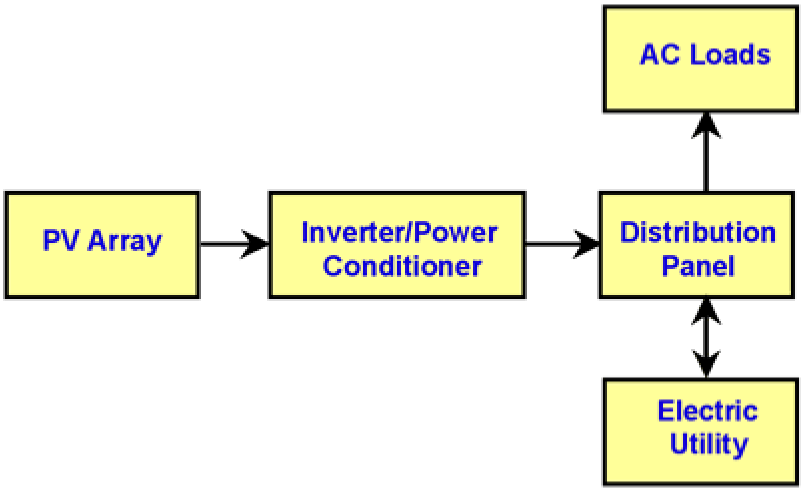
LMU is a pioneer in environmental responsibility through the uses of recycled water for its landscape, development of the first university-wide recycling program, and use of low-water consuming toilets and washers. In 2003, the U.S. Environmental Protection Agency (EPA) and the Department of Energy (DOE) awarded a Green Power Purchasing Award for Onsite Generation to LMU. The prestigious award recognizes organizations that are significantly advancing the development of renewable energy sources and energy efficiency. LMU has the largest solar electric rooftop system of any university in the world, and the largest system in Southern California.

- Provides 26% of total energy used at the university
- 723 kWp solar PV roof system
- 868,000 kWh annually
- Additional thermal insulation and protection from UV & weather
- Partnership between Loyola Marymount University, the Los Angeles Department of Water & Power, the Southern California Gas Company and PowerLight

Utility-Interactive Photovoltaic System

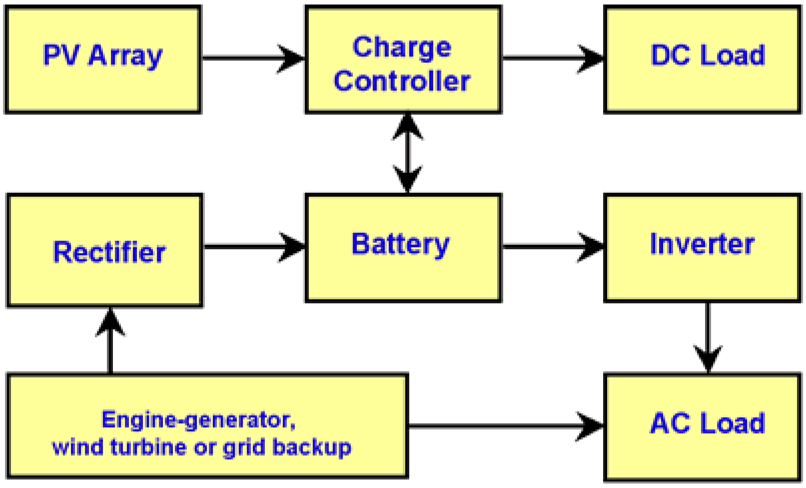
Photovoltaic power systems are generally classified according to their functional and operational requiremnets, their component configerations, and how the equipment is connected to other power sources and electrical loads. The two principal classifications are grid-connected or utility-interactive systems and stand-alone systems. Photovotlaic systems can be designed to provide DC and/or AC power service, can operate interconnected with or independent of the udtility grid, and can be connected with other energy sources and energy storage systems.

Grid-connected or utility interactive PV systems are designed to operate in parallel with and interconnected with the electric utility grid. The primary component in grid-connected PV systems is the inverter, or power conditioning unit (PCU). The PCU converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utilty grid and automatically stops supplying power to the grid when the utiltiy gird is not energized. A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC produced by the PV system to either supply on-site electrical loads, or to back-feed the grid when the PV system output is greater than the on-site load demand. At night and during other periods when the electrical loads are greater than the PV system output, the balance of power required by the loads is received from the electric utility. This safety feature is required in all grid-connected PV systems, and ensures that the PV system will not continue to operate and feed back into the utility grid when the grid is down for service or repair.



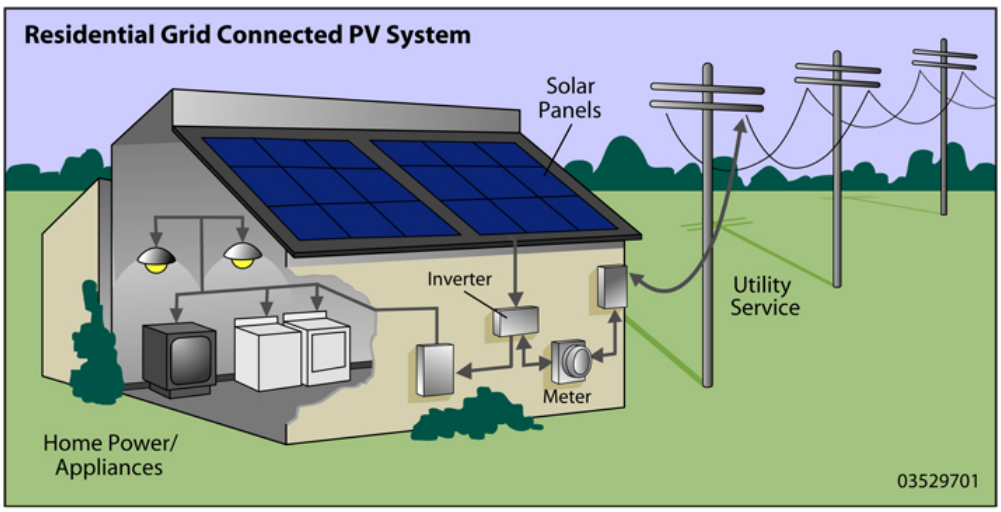
- PV Array produces DC Power
- Power Conditioning Unit (PCU) Converts DC Power to AC Consistent with the Voltage and Power Quality of the Grid
- Supplies power not required by the AC Loads to the Grid
- Draws power from the Grid when not generated on site
- Automatically stops supplying power to the Grid When the Utility Grid is not Energized
- Must meet interconnection standards

Photovoltaic Hybrid Systems with Battery Storage for Critical Loads



- PV Array produces DC power
- Can Operate Independent of the Grid
- Sized to Supply Specific DC and/or AC Loads
- Operate Beyond Sunlight Hours
- Greater System Complexity
- Larger Loads
- Must meet interconnection standards

Photovoltaics Provides Clean, Renewable Electricity to Your Home



- Solar panels
- DC to AC Inverter
- AC loads
- Electric Meter
- Electric utility grid network
- Scalable to meet energy needs
- Provides energy during the day when electricity prices are highest
- Utility connection provides energy during non-sunlight times

Roof Area Needed in Square Feet (shown in **Bold Type**)							
PV Module Efficiency (%)	PV Capacity Rating (Watts)						
	100	250	500	1,000	2,000	4,000	10,000
4	**30**	**75**	**150**	**300**	**600**	**1,200**	**3,000**
8	**15**	**38**	**75**	**150**	**300**	**600**	**1,500**
12	**10**	**25**	**50**	**100**	**200**	**400**	**1,000**
16	**8**	**20**	**40**	**80**	**160**	**320**	**800**
For example, to generate 2,000 watts from a 12%-efficient system, you need 200 square feet of roof area.							

1 square meter = 10.76 square feet