高等职业教育“十三五”规划教材 〉〉〉〉 新能源课程群

技能型人才培养特色名校建设规划教材

光伏专业英语

主　编 ◇ 王东霞　张肖肖

副主编 ◇ 崔玉娟　董　霞　张瑞林

中国水利水电出版社

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副主编　崔玉娟　董　霞　张瑞林

参　编　郭　云　陈圣林　李建勇　王玉梅

李　飞　裴勇生　韩烨华　张媛媛

吴朝辉　叶云云　王维海

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内 容 提 要

《光伏专业英语》选用近年来国外太阳能光伏专业教材和专业刊物中的30篇文章，涵盖了太阳辐射、半导体材料、光伏组件制造、光伏发电系统概述、光伏发电系统应用及其他可再生能源等内容。所选文章题材多样，内容新颖，图文并茂，学科前沿知识丰富，融知识性和趣味性于一体。在每篇文章后面附有词汇表和关键句解析，方便学生理解和教师查阅。

《光伏专业英语》既可作为高职高专太阳能光伏技术与应用相关专业的教材，也可作为光伏企业的培训教材，同时可供太阳能光伏相关行业从业人员参考，在一定程度上也可以作为简明的光伏专业词汇手册供读者查阅使用。

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I

序 言

第三次科技革命以来，高新技术产业逐渐成为当今世界经济发展的主旋律和各国国民经济的战略性先导产业，各国相继制定了支持和促进高新技术产业发展的方针政策。我国更是把高新技术产业作为推动经济发展方式转变和产业结构调整的重要力量。

新能源产业是高新技术产业的重要组成部分，能源问题甚至关系到国家的安全和经济命脉。随着科技的日益发展，太阳能这一古老又新颖的能源逐渐成为人们利用的焦点。在我国，光伏产业被列入国家战略性新兴产业发展规划，成为我国为数不多的处于国际领先位置，能够在与欧美企业抗衡中保持优势的产业，其技术水平和产品质量得到越来越多国家的认可。新能源技术发展日新月异，新知识、新标准层出不穷，不断挑战着学校专业教学的科学性。这给当前新能源专业技术人才培养提出极大挑战，新教材的编写和新技术的更新也显得日益迫切。

在这样的大背景下，为解决当前高职新能源应用技术专业教材的匮乏，新能源专业建设协作委员会与中国水利水电出版社联合策划、组织来自企业的专业工程师、部分院校一线教师，协同规划和开发了本系列教材。教材以新能源工程实用技术为脉络，依托来自企业多年积累的工程项目案例，将目前行业发展中最实用、最新的新能源专业技术汇集进专业方案和课程方案，编写入专业教材，传递到教学一线，以期为各高职院校的新能源专业教学提供更多的参考与借鉴。

一、整体规划全面系统，紧贴技术发展和应用要求

新能源应用技术系列教材主要包括光伏技术应用，课程的规划和内容的选择具有体系化、全面化的特征，涉及到光电子材料与器件、电气、电力电子、自动化等多个专业学科领域。教材内容紧扣新能源行业和企业工程实际，以新能源技术人才培养为目标，重在提高专业工程实践能力，尽可能吸收企业新技术、新工艺和案例，按照基础应用到综合的思路进行编写，循序渐进，力求突出高职教材的特点。

二、鼓励工程项目形式教学，知识领域和工程思想同步培养

倡导以工程项目的形式开展教学，按项目、分小组、以团队方式组织实施；倡导各团队

成员之间组织技术交流和沟通，共同解决本组工程方案的技术问题，查询相关技术资料，组织小组撰写项目方案等工程资料。把企业的工程项目引入到课堂教学中，针对工程中实际技能组织教学，让学生在掌握理论体系的同时，能熟悉新能源工程实施中的工作技能，缩短学生未来在企业工作岗位上的适应时间。

三、同步开发教学资源，及时有效更新项目资源

为保证本系列课程在学校的有效实施，丛书编委会还专门投入了大量的人力和物力，为系列课程开发了相应的、专门的教学资源，以有效支撑专业教学实施过程中的备课授课，以及项目资源的更新、疑难问题的解决，详细内容可以访问中国水利水电出版社万水分社的万水书苑网站，以获得更多的资源支持。

本系列教材的推出是出版社、院校教师和企业联合策划开发的成果。教材主创人员先后数次组织研讨会开展交流、组织修订以保证专业建设和课程建设具有科学的指向性。来自皇明太阳能集团有限公司、力诺集团、晶科能源有限公司、晶科电力有限公司、越海光通信科技有限公司、山东威特人工环境有限公司、山东奥冠新能科技有限公司的众多专业工程师和产品经理于洪水、彭波、黄小章、姜金国等为教材提供了技术审核和工程项目方案的支持，并承担全书的技术资料整理和企业工程项目的审阅工作。山东理工职业技术学院的静国梁、曲道宽，威海职业学院的景悦林，菏泽职业学院的王记生，皇明太阳能职业中专的董兆广等都在教材成稿过程中给予了支持，在此一并表示衷心感谢！

本书规划、编写与出版过程历经三年时间，在技术、文字和应用方面历经多次的修订，但考虑到前沿技术、新增内容较多，加之作者文字水平有限，错漏之处在所难免，敬请广大读者批评指正。

丛书编委会

前　言

光伏发电是利用半导体界面的光生伏特效应而将光能直接转变为电能的一种技术，它是太阳能发电的一种。这种技术的关键元件是太阳能电池。随着现代工业的发展，全球能源危机和大气污染问题日益突出，传统的燃料能源正在一天天减少，对环境造成的危害日益突出，同时全球约有20亿人的生活得不到正常的能源供应。这个时候，全世界都把目光投向了可再生能源，希望可再生能源能够改变人类的能源结构，维持长远的可持续发展，其中光伏发电以其独有的优势成为人们关注的焦点。英语作为世界性语言，是每一位当代大学生必须掌握的交流工具。作为光伏专业的学生，学好光伏专业英语是获取相关信息、掌握学科发展动态的必要前提。我们编写此书，希望帮助光伏专业的学生提高其在该专业的英语水平。

本书共四章，每一章由若干篇课内学习课文和一篇课外阅读材料组成，每一篇课文都是编者精心挑选的，既要向学生介绍学科基础知识，又要介绍行业较新的知识动态，同时也要考虑到学生的英语水平。综合考虑，选取了难度适中的几十篇文章，文章内容涵盖了光伏行业历史及发展、太阳能电池、光伏组件、光伏发电系统等内容。所选文章题材多样，内容新颖，学科前沿知识丰富，融知识性和趣味性于一体。

本书作为光伏专业英语课程，具有以下特色：

1．内容针对性强：本书内容涵盖太阳能光伏发电技术的各类专业知识，内容既全面又简练。

2．内容新颖：本书所选文章出自最新的英文原版教材、专业期刊、论文报告及专业网站，学科前沿知识丰富，语言准确性强。

3．趣味性强：为了提高学生的学习兴趣，编者重视教材内容的趣味性，在介绍专业知识的同时，介绍相关的最新的或常见的光伏产品并配有图片。

本书由王东霞、张肖肖任主编，负责全书的统稿、修改、定稿工作，崔玉娟、董霞、张瑞林任副主编。参考本书编写工作的还有：郭云、陈圣林、王玉梅、李飞、裴勇生、李建勇、韩烨华、吴朝辉、张媛媛、叶云云、王维海等。中国水利水电出版社的有关负责同志对本书的出版给予了大力支持。在本书编写过程中参考了大量国内外光伏专业的文献资料，在此，谨向这些著作者以及为本书出版付出辛勤劳动的同志深表感谢！

编　者

2016年4月

目 录

1

Introduction to Photovoltaic

1.1 Photovoltaic

Solar power resources are abundant, widely available, one of the major renewable energy sources that have the greatest development potential. One important way to convert solar radiation into electricity occurs by the photovoltaic effect which was first observed by Becquerel. It is quite generally defined as the emergence of an electric voltage between two electrodes attached to a solid or liquid system upon shining light onto this system. Practically all photovoltaic devices incorporate a pn-junction in a semiconductor across which the photovoltage is developed. These devices are also known as solar cells. A cross-section through a typical solar cell is shown in **Fig. 1.1**. The semiconductor material has to be able to absorb a large part of the solar spectrum. Dependent on the absorption properties of the material the light is absorbed in a region more or less close to the surface. When light quanta are absorbed, electron hole pairs are generated and if their recombination is prevented they can reach the junction where they are separated by an electric field. Even for weakly absorbing semiconductors like silicon most carriers are generated near the surface. This leads to the typical solar cell structure of **Fig. 1.1**: the pn-junction which separates the emitter and base layer is very close to the surface in order to have a high collection probability for free carriers. The thin emitter layer above the junction has a relatively high resistance which requires a well designed contact grid also shown in the figure. The operating principles have been described in many publications, and will not be addressed further here.

For practical use solar cells are packaged into modules containing either a number of crystalline Si cells connected in series or a layer of thin-film material which is also internally series connected. The module serves two purposes, it protects the solar cells from the ambient and it delivers a higher voltage than a single cell which develops only a voltage of less than 1 V.

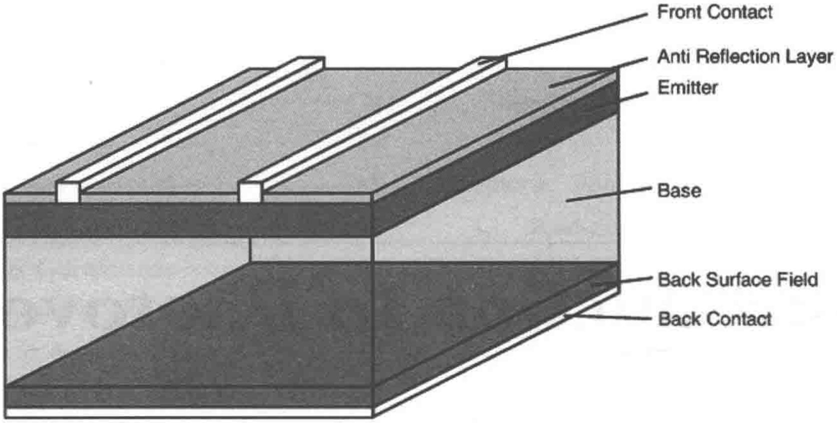

Fig. 1.1 Typical solar cell

Photovoltaic market in 2000 is about 277 MW corresponding to a value of over US$ 1 billion. This is a remarkable market but still far away from constituting a noticeable contribution to the world energy consumption. Market growth from 1990 to 2001 was between 15% and 25%. This market growth would be very satisfying for any conventional product but in the case of PV it is entirely insufficient if we consider the goals. The main motivation for developing solar energy is the desire to get away from depletable fossil fuels with their adverse effect on the environment. At the present growth rate, it will take us far into the second half of this century get a relevant contribution by PV to world energy demand. As will be pointed out below, support programs in several countries are already accelerating market growth. Besides the terrestrial market there is also the space market which has entirely different boundary conditions and also different materials requirements. In order to keep the volume of this paper at a reasonable size, space solar cell materials will not be included.

There are two major market sectors, grid connected and so called stand alone systems. The former delivers power directly to the grid. For this purpose the dc current from the solar modules is converted into ac by an inverter. The latter supplies power to decentralized systems and small scale consumer products. A major market currently being developed is in solar home systems supplying basic electricity demand of rural population in developing countries. The magnitude of this task can be appreciated if one is aware that about 2 billion persons are without access to electricity today. At present, both markets need subsidies, the grid connected installations because PV is much more costly than grid electricity, and solar home systems because the potential users lack the investment capital. On the other hand, there is also a significant industrial stand alone market which is today fully economical.

Because of its high potential the market is hotly contested and new companies are entering constantly. It is significant that several large oil companies have now established firm footholds in photovoltaic. Indeed, a recent study of possible future energy scenarios up to the year 2060 that was published by the Shell company predicts a multi-gigawatt energy production by renewable energies including photovoltaic. On the other hand, the strong competition leads to very low profit margins of most participants of this market.

In 2000, the market showed an accelerated growth of more than 30%. There are good chances that this growth will continue for at least some years because some countries have adopted aggressive measures to stimulate the grid connected market. Japan's very ambitious 70,000 roof program caused an astonishing increase by 63% of Japanese production in 1999. In Germany, a feed-back law was passed which sets a rebate rate of 0.5/kWh of PV generated electricity. If this rate is combined with the already existing 100,000 roof program, PV becomes (only moderately) economical. It can be expected that other countries will follow these examples. In order to meet the growing demand, many PV companies are in the process of setting up substantial new cell and module production capacities.

From Materials Science and Engineering R, by Adolf Goetzberger, 2003.

New Words and Expressions

1. photovoltaic [fəʊtəʊvɒl'teɪɪk] adj. [电子] 光电伏打的，光电的
2. resource [rɪ'sɔːs] n. 资源，财力；办法；智谋
3. renewable [rɪ'njuːəbəl] adj. 可再生的；可更新的；可继续的 n. 再生性能源
4. radiation [reɪdɪ'eɪʃ(ə)n] n. 辐射；发光；放射物
5. voltage ['vəʊltɪdʒ] n. [电] 电压
6. incorporate [ɪn'kɔːpəreɪt] vt. 包含，吸收；体现；把……合并 vi. 合并；混合；组成公司 adj. 合并的；一体化的；组成公司的
7. semiconductor [ˌsemɪkən'dʌktə] n. [电子][物] 半导体
8. resistance [rɪ'zɪst(ə)ns] n. 阻力；电阻；抵抗；反抗；抵抗力
9. grid [grɪd] n. 网格；格子，栅格；输电网
10. module ['mɒdjuːl] n. [计] 模块；组件；模数
11. crystalline ['krɪst(ə)laɪn] adj. 透明的；水晶般的；水晶制的
12. ambient ['æmbɪənt] adj. 周围的；外界的；环绕的 n. 周围环境
13. depletable adj. 可耗减的
14. boundary ['baʊnd(ə)rɪ] n. 边界；范围；分界线 复数 boundaries
15. current ['kʌr(ə)nt] adj. 现在的；流通的，通用的；最近的；草写的 n. （水，气，电）流；趋势；涌流 n. (Current)人名；(英)柯伦特
16. magnitude ['mægnɪtjuːd] n. 大小；量级；[地震] 震级；重要；光度

17. appreciate [ə'priːʃɪeɪt] vt. 欣赏；感激；领会；鉴别 vi. 增值；涨价
18. stimulate ['stɪmjʊleɪt] vt. 刺激；鼓舞，激励 vi. 起刺激作用；起促进作用
    过去式 stimulated 过去分词 stimulated 现在分词 stimulating
19. ambitious [æm'bɪʃəs] adj. 野心勃勃的；有雄心的；热望的；炫耀的
    比较级 more ambitious 最高级 the most ambitious
20. astonishing [ə'stɒnɪʃɪŋ] adj. 惊人的；令人惊讶的 v. 使……惊讶；使……诧异（astonish 的 ing 形式）

Notes

1. It is quite generally defined as the emergence of an electric voltage between two electrodes attached to a solid or liquid system upon shining light onto this system.

参考译文：这通常被定义为当光照在这个系统上时，在两个附属于固体或液体系统的电极之间产生的电压。

2. This is a remarkable market but still far away from constituting a noticeable contribution to the world energy consumption.

参考译文：这是一个引人瞩目的市场，但是离成为世界能源消费的重要组成部分还很远。

3. There are good chances that this growth will continue for at least some years because some countries have adopted aggressive measures to stimulate the grid connected market.

参考译文：这个增长将持续至少数年，这是很好的机遇，因为一些国家已经采取了积极的措施以促进电网连接市场。

1.2 Development of Photovoltaic in China

According to the China Meteorological Administration, China has abundant solar energy resources. The total potential for solar radiant energy of 1.7×10^{12} tce (tons of standard coal equivalent) per year for the entire country. More than two-third of the country has over 2000 h of sunshine each year, which provides an equivalent annual solar radiation of over $5.02\sim10^{6}$kJ/m^{2}. China's solar energy resource distribution is shown in **Table 1.1**. This illustrates the amount of solar radiation available. Compared with other countries in similar latitude, the solar radiant energy in China is superior to those in Europe and Japan, and similar to those in the United States. As can be seen in **Table 1.1**, provinces located in different latitudes and longitudes have different levels of solar irradiations. The country can be divided into five different regions from I to V. The distribution of China's solar energy resources in different areas varies significantly. In general, the solar resources in the western region (such as Ningxia, Gansu, Xinjiang, Qinghai, and Tibet) are higher than that in the eastern region (such as Guangdong, Shaanxi, Anhui, Heilongjiang, Zhejiang, Fujian, Hunan, and Hubei), and the resources in the northern region (such as Hebei, Shanxi, Inner Mongolia, Shandong, He nan, Jilin, Liaoning, and Shaanxi) are higher than in the southern region (such as Sichuan, Guizhou, Chongqing, Guangxi, and Jiangxi). This does not, however, correlate with the demand for energy. China's electricity loads are concentrated in the eastern and the southern regions, unfortunately, the solar resource-rich regions in the Qinghai-Tibet Plateau, North China and Northwest China are far from the regions which consume the greatest electrical power load.

Table 1.1 Solar energy resources in different regions of China

Type	Annual sunshine hours (h/a)	Total annual solar radiation (MJ/m^2 a)	Total annual solar energy per m^2 expressed in units of energy produced by kg of standard coal (kg)	Provinces
I	3200-3300	6680-8400	225-285	Northern Ningxia, Northern Gansu, Southeastern Xinjiang, Western Qinghai, and Western Tibet
II	3000-3200	5852-6680	200-225	Northwestern Hebei, Northern Shanxi, Southern Inner Mongolia, Southern Ningxia, Central Gansu, Eastern Qinghai, Southeastern Tibet, and Southern Xinjiang
III	2200-3000	5016-5852	170-200	Southeastern Shandong, Southeastern Henan, Northwestern Hebei, Southern Shanxi, Northern Xinjiang, Jilin, Liaoning, Yunnan, Northern Shaanxi, Southeastern Gansu, Southern Guangdong, Southern Fujian, Northern Jiangsu, Northern Anhui, Tianjin, Beijing, and Southwestern Taiwan
IV	1400-2000	4190-5016	140-170	Hunan, Hubei, Guangxi, Jiangxi, Zhejiang, Northern Fujian, Northern Guangdong, Southern Shaanxi, Southern Anhui, Heilongjiang, and Northeastern Taiwan
V	1000-1400	3344-4190	115-140	Sichuan, Guizhou, and Chongqing

Since the 1990s, China's PV power is developing rapidly and the installed capacity is increasing constantly. **Fig. 1.2** shows the annual installed capacity and the cumulative installed capacity from 1976 to 2009. Based on current trends, the cumulative PV power installations will reach 1.8 GWp by 2020 and 1000 GWp by 2050 nationwide in China.

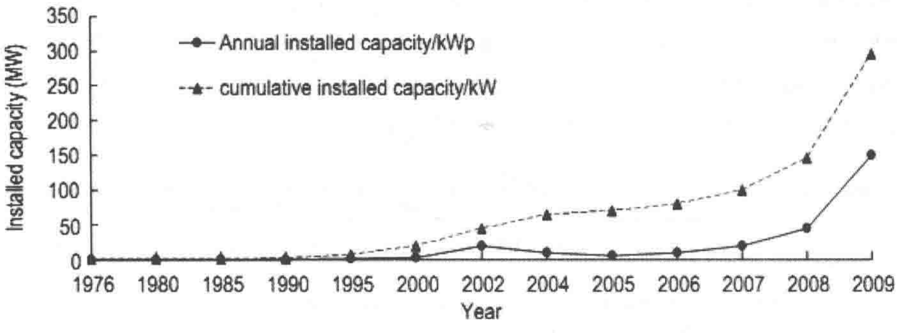

Fig. 1.2 Installed capacity of the solar PV power in China (1976-2009)

To encourage the development of renewable energy such as solar PV power, China has promulgated a series of laws, regulations and financial incentive policies, and has invested significant funds in PV power generation projects. The result of this investment is that China has a number of the world's leading PV companies as well as the successful establishment of research and development centers.

Table 1.2 Electricity sales in China from 2004 to 2010

Year	Sales (10^{13} kW h)	Annual growth rate (%)
2004	17,384	
2005	19,554	12.5
2006	22,825	16.7
2007	26,430	15.8
2008	28,418	7.5
2009	30,586	7.6
2010	35,289	13.3

Another factor that will increase the market for the solar PV power industry is China's demand for electricity, which continues to grow rapidly. The consumption of electricity in China from 2004 to 2010 is shown in **Table 1.2**. According to the statistics, the electricity sales value in China in 2010 is twice as much as that in 2004, and the average annual growth rate from 2004 to 2010 was more than 12%. This increasing demand for electricity, in addition to the shortage of fossil fuels and the negative impact of environmental pollution caused by the burning of fossil fuels, and the demand for renewable energy will increase which will create opportunities for the solar PV power industry.

In recent years, China has actively supported the development of PV power, and has constructed a series of PV power generation projects, mainly in China's western and northern provinces. **Table 1.3** lists the main large-scale PV power generation projects in China from 2004 to 2010. The installed capacities of these projects are in the range of 5–200 MW. However, most of these projects are located in developing regions (such as Qinghai, Gansu and Ningxia) where the grid structure is relatively weak and the distance to the load centers is significant. This poses a challenge to use the generated solar power fully and efficiently.

Table 1.3 The main large-scale PV power generation projects in China (2004-2010)

Year	Sales (10^{13} kW h)	Annual growth rate (%)
2004	17,384	
2005	19,554	12.5
2006	22,825	16.7
2007	26,430	15.8
2008	28,418	7.5
2009	30,586	7.6
2010	35,289	13.3

The solar PV power supply chain consists of silicon materials, wafers, cells, components, and applications industries that utilize the power created by the solar PV power. The solar PV power industry has a close link with the raw material producers, power generating plants, and power supply companies. China's solar PV power industry chain and its influencing factors are shown in **Fig. 1.3**.

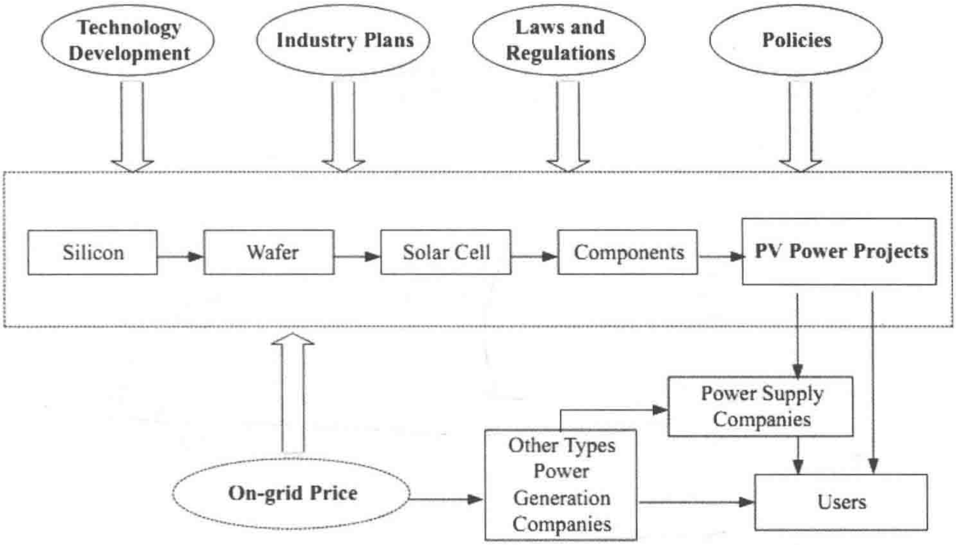

Fig. 1.3 Diagram of the solar PV power generation industry

In China, the main factors that affect the PV power industry are the technology, the industry plan, the laws, the price and the incentive policies. Technology is a key factor that affects the competitiveness of the PV power industry, especially the cost of solar PV power generation. The government plays a key role by regulating the renewable power market, especially since the current industrial environment is not mature. The Chinese government has formulated a series of industry plans for the PV power development. These industry plans serve as a strategic and directional guide to the development of PV power industry. In order to encourage the solar photovoltaic power, China also released supporting laws, policies and regulations. These laws, policies and regulations have an important impact and ensure a framework to sustain the stable, healthy and orderly operation of the PV power industry. Related policies, such as electricity price policies, tariff subsidy policies and project incentive policies, provide various advantages and favorable conditions that greatly improve the competitiveness of the industry. Therefore, this paper will review and examine the factors affecting the growth of the solar photovoltaic power industry in China based on the following five aspects: (1) the technology development, (2) the industry development plans, (3) the laws and regulations, (4) the electricity price policies, (5) the project incentive policies.

Since the successful development of the first crystalline silicon PV cell in 1958, China's PV power has evolved, going from small to large in scale, from single arrays to multiple arrays in type, from low to high in conversion efficiency. Milestone events in the development of China's solar energy technology, and in the growth, research and development of the solar PV power technology are shown in **Fig. 1.4**.

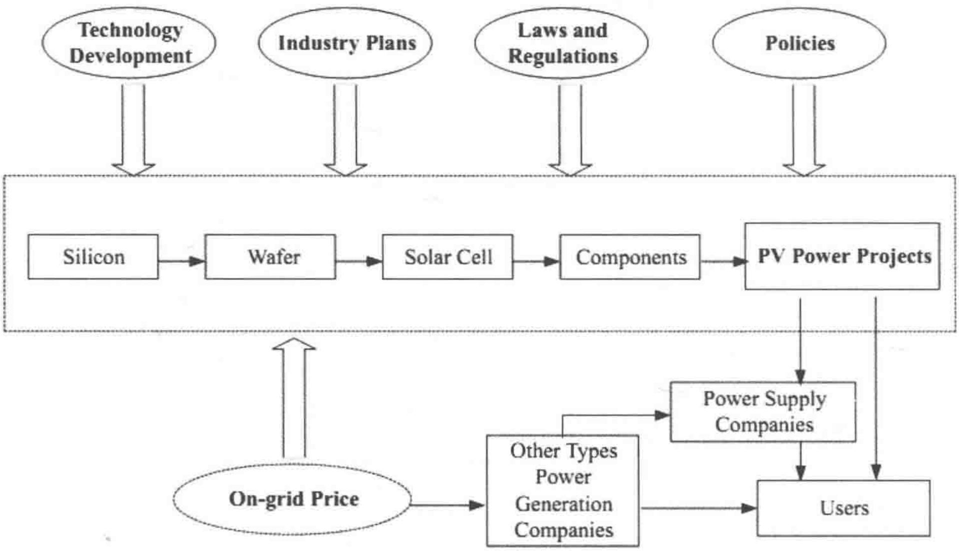

Fig. 1.4 Milestones in the development of the solar PV power technology development in China

In China, the technology development of solar PV power can be divided into three stages, germination stage, seedling stage and growth stage.

In the germination stage (from 1958 to 1970s), the development and manufacture of the solar cells was the key goal. In 1968, an institute in Tianjin developed and manufactured the first solar cell in China using satellite technologies. In the 1970s, a few solar cell factories were set up in the cities of Shanghai, Ningbo and Kaifeng.

In the seedling stage (from 1980s to 1990s), the State Scientific and Technological Commission set up China Optics and Electronics Technology Centre, which started the study of monocrystalline silicon solar cells, polysilicon silicon solar cells and the application of PV systems. In 1986, China's first 0.56 kW wind and solar hybrid system was established in Inner Mongolia. In 1989, China's first 10 kW PV power station began operation in Tibet. In the 1990s, the Institute of Electrical Engineering at the Chinese Academy of Sciences developed and constructed an independent PV station. A few production bases were formed in the Pearl River Delta areas and China began to export various PV products.