

## COUNTRY NOTES

The Country Notes on Solar Energy have been compiled by the Editors. In addition to national, international, governmental publications/web sites and direct personal communications, the following publications have been consulted:

- *Photovoltaic Power Systems Programme, Annual Reports 2005 and 2006*, International Energy Agency;
- *Trends in Photovoltaic Applications: Survey report of selected IEA countries between 1992 and 2005*, International Energy Agency – Photovoltaic Power Systems Programme, August 2006;
- *Solar Thermal Markets in Europe (Trends and Market Statistics 2005)*, European Solar Thermal Industry Federation, June 2006;
- *PV Status Report 2006*, European Commission, Joint Research Centre, August 2006.

Information provided by WEC Member Committees has been incorporated as available.

### Albania

Most of the country receives a level of insolation of more than 1 500 kWh/m<sup>2</sup>/yr, within a range of

1 185 to 1 690 kWh/m<sup>2</sup>/yr. The western, and especially the southwestern, region of Albania has a particularly significant solar resource.

In 2005, some 32 000 m<sup>2</sup> of solar water heating systems were in service, of which approximately 18 000 m<sup>2</sup> were in the commercial sector and 14 000 m<sup>2</sup> in the residential sector. Output totalled in the region of 45 GWh (25 GWh commercial, 20 GWh residential).

In September 2006 various schemes to encourage the development of the solar thermal market were either being planned or at least considered: incentives in the form of tax credits or soft loans; the encouragement of an SWH manufacturing industry, Government co-financing incentives, legislation for the installation of solar thermal systems in new buildings, etc.

### Algeria

Algeria receives an average insolation of 2 000 h/yr, with the high plateaux and the Sahara receiving 3 900 h/yr. The average solar energy received is 2 400 kWh/m<sup>2</sup>/yr, ranging from 1 700 kWh/m<sup>2</sup>/yr in the north of the country to 2 263 kWh/m<sup>2</sup>/yr in the south.

Whilst the share that solar power contributes to the overall supply of energy is small, it has proved invaluable for the electrification of isolated settlements, especially in the south of the country. Rural PV electrification programmes accord priority to regions that are sparsely populated and situated far from the grid. The

Algerian WEC Member Committee reports that at end-2005 approximately 1.4 MW<sub>p</sub> of photovoltaic capacity had been installed for this purpose. In addition, PV systems provided power for water pumping (0.4 MW<sub>p</sub>), public lighting (0.2 MW<sub>p</sub>), telecommunications (0.5 MW<sub>p</sub>) and other uses (0.2 MW<sub>p</sub>). Total output from PV devices is reported to have been approximately 3 000 MWh in 2005.

### Argentina

Argentina's PAEPRA (Programa de Abastecimiento Eléctrico a la Población Rural de Argentina) was established in 1995 and the PERMER (Proyecto de Energía Renovable en el Mercado Eléctrico Rural) project was subsequently designed to support it.

The main development goal of PERMER is to improve the quality of life of rural inhabitants who have not been reached by the Electric Transformation Programme. It will aim to achieve this objective through:

- provision of an electricity service that meets the basic needs of lighting and social communication, with decentralised supply sources based on technologies mainly using renewable resources;
- promotion of the participation of the private sector in the provision of this supply so as to achieve the sustainability of the project;

- strengthening the institutional capacity of regulation agencies with reference to the implementation and use of renewable energies;
- improvement of information on sources of renewable energies existing in the country.

The project is financed by a US\$ 30 million loan from the International Bank for Reconstruction and Development (IBRD), a US\$ 10 million donation from the Global Environment Facility (GEF), and contributions from the provinces, service concession companies, service users (through tariffs) and the Ministry of Education (for schools), plus a minimum contribution from the National Treasury.

Investigations have found that more than 2 million rural inhabitants and 6 000 public services (schools, health care centres, water services, police, civil registries, etc.) lack an electricity supply. In order for these rural sites to be supplied with electricity, a combination of PV, wind, micro water turbines and/or diesel generators will be utilised.

The Electrification of the Dispersed Electric Market (MED), foreseen in the PERMER project, will supply solar home systems (SHS) for stand-alone installations, but the method of generation for community schemes will be chosen from the range of renewables available and according to the lowest cost at the time. Private companies, established in the relevant Argentine provinces, will implement the project.

The WEC Member Committee for Argentina reports that during 2003-2005 PV facilities were installed under PERMER in households, schools and first-aid stations. At the end of 2005, solar photovoltaic capacity was around 9 000 kW, including 2 000 kW on farms, according to Census data and facilities in the provinces of Buenos Aires, Jujuy, Mendoza, Neuquén, Salta and Santa Fe not included in Project PERMER.

Estimated electrical output from PV facilities in 2005 was 14 000 MWh, assuming an average of 4 daily hours of sunlight and individual consumption of about 100/150  $W_p$  in the residential sector; 600  $W_p$  in schools and 300  $W_p$  in first-aid stations.

### Australia

Solar PV is one of the best established renewable technologies in Australia, with over three decades of technology and market development behind it. The overall market expanded by 15.8% in 2005, bolstered by government grant programmes for rooftop applications and off-grid diesel replacement, with the grid-connected segment growing 29% and off-grid capacity by 14%. Australia's well-established non-domestic off-grid PV market in industrial, agricultural and commercial applications, such as telecommunications, signalling, water pumping, electric fences and cathodic protection, continued to be the largest sector of the PV market, accounting for 41% of capacity additions in 2005 and 55% of cumulative installations. At end-2005, installed PV power was 60 581  $kW_p$ , of which 18 768  $kW_p$

was off-grid domestic, 33 073  $kW_p$  off-grid non-domestic, 6 860  $kW_p$  grid-connected distributed and 1 880  $kW_p$  grid-connected centralised.

The Australian Government provides support for solar energy applications through a number of programmes. Two of particular relevance to photovoltaics are summarised below.

The aim of the Photovoltaic Rebate Program (PVRP) is to encourage the installation of PV systems in residential and community buildings. A reported 1 042 systems were installed in 2005, amounting to 1.55 MW; 65% of installations, accounting for 73% of installed capacity, were on grid-connected buildings and a total of AUD 4.2 million was allocated in rebates. Since the start of the programme in 2000, over 7 600 systems, amounting to 9.5  $MW_p$  have been installed and grants of more than AUD 34 million have been provided. PVRP is funded by the Australian Government, with administration by the State Governments.

The aims of the Remote Renewable Power Generation Program (RRPGP) are to increase the use of renewable energy for power generation in off-grid areas, to reduce diesel use, to assist the Australian renewable energy industry, to assist in meeting the infrastructure needs of indigenous communities and to reduce greenhouse gas emissions.

Each State has established a slightly different programme, to meet the specific needs of local off-grid applications. However, in general, the target groups are indigenous and other small

communities, commercial operations, including pastoral properties, tourist facilities and mining operations, water pumping and isolated households that operate within diesel grids or use direct diesel generation. Core funding for this programme is provided to the States by the Australian Government, on the basis of diesel fuel excise duty collected from public generators not connected to main electricity grids. Grants are available for up to 50% of the capital cost of renewable energy systems replacing the use of diesel. The programme is administered by the State Governments, with additional funding provided by some States, and will extend to 2009/2010, although some States may expend their allocations before then.

A specific allocation of AUD 8 million has been made to the Aboriginal and Torres Strait Islander Commission (ATSIC) for the Bushlight Programme to assist with the development of industry capability and local understanding of renewable energy systems in indigenous communities.

In 2005, 2.08 MW of PV capacity was installed under RRP GP, bringing the cumulative total under the programme to 5.35 MW. Although RRP GP is not PV specific, almost all the small systems installed to date include a PV element. The overall programme has funds of some AUD 205 million allocated to it, of which AUD 141 million had been committed by the end of 2005.

### Austria

The *IEA-PVPS 2005 Annual Report* states that there is no federal support for PV in Austria, as

the feed-in tariff introduced in 2003 quickly reached its cap of 15 MW. However, a number of regions offer subsidies under a variety of schemes. Despite the discontinuity, growth in the PV park has been substantial in recent years, with installed capacity at year-end multiplying four-fold between 2001 and 2005.

Out of an installed total of 24 021 kW<sub>p</sub> at end-2005, 2 895 kW<sub>p</sub> was off-grid, 19 973 kW<sub>p</sub> grid-connected distributed and 1 153 kW<sub>p</sub> grid-connected centralised. Although the initial installations were standalone systems, in recent years the emphasis has been on grid-connected distributed systems, which now represent more than 80% of the overall installed capacity. Electrical output from all PV installations amounted to about 13 000 MWh in 2005.

The Austrian WEC Member Committee reports that total output from active solar heating devices was 3 712 TJ in 2005, with a somewhat larger contribution (4 248 TJ) from passive sources (e.g. use of appropriate building orientation and design). The total glazed area of solar thermal collectors in operation in 2005 was 2 319 000 m<sup>2</sup>, giving an output capacity of about 1 623 MW<sub>t</sub>.

With regard to new household solar collecting panels, the most recent ESTIF (European Solar Thermal Industry Federation) tabulation shows Austria in second place in terms of area installed in 2005, far ahead of sun-rich countries such as Spain or Italy.

An interesting idea combining the power of the sun and energy from biomass has been

implemented in Salzburg. The *Stieglgründe* project uses a combination of solar energy and wood pellet combustion to provide heating and hot water to 128 households. The site was so constructed as to allow for maximum use of any rays from the sun. Heating costs for each household are only € 150 per annum.

### Botswana

Despite Botswana's high rate of solar insolation, the country's available resource has been under-utilised in the past, being mainly used for powering telecommunication systems, water pumping, etc.

The National Photovoltaic Rural Electrification Programme, funded by the Government, ran from 1997 until 2001. From November 2001, under the PV Master Plan - a project jointly developed by the Botswanan and Japanese Governments (through the Japanese International Cooperation Agency) - several pilot schemes were instituted.

In early 2006, the Government announced that as part of its 2005-2006 Budget, the National Rural Photovoltaic Electrification Programme would offer subsidised PV packages to at least 88 villages. The package offered to villages satisfying various criteria (distance from grid, level of population etc.) includes PV panels and battery banks, solar water heating systems etc.

In April 2007 the Government called for tenders for a solar thermal power plant prefeasibility study.

### Brazil

The resource potential is available in two publications: *Atlas Solarimétrico do Brasil-Banco de Dados Terrestre*, UFPE, 2000 and *Atlas de Irradiação Solar do Brasil*, LABSOLAR-UFSC & DGE-INPE, 1998. However, the methodologies used in the Atlases are different. The former is a model based on ground station information and the latter uses a model based on satellite data.

The total photovoltaic power installed in Brazil is estimated to be between 12 and 15 MW<sub>p</sub>, 50% of the projects are for telecommunications systems and the other 50% for rural energy systems, but specific capacity data are not collected.

The Brazilian Government established PRODEEM - Programa de Desenvolvimento Energético de Estados e Municípios (Programme for Energy Development of States and Municipalities) in December 1994. The aim of the Programme is to provide energy for the basic social demands of poor communities isolated from conventional systems. PRODEEM uses photovoltaic systems to supply energy to schools, health clinics, water pumping, etc. The total PV power installed under PRODEEM stands at over 5 MW<sub>p</sub>.

### Bulgaria

The Bulgarian WEC Member Committee reports that average annual solar hours are about 2 150 and annual average solar radiation resources

1 517 kWh/m<sup>2</sup>. The total theoretical potential of solar energy is 13 103 ttoe, and the available annual potential is about 390 ttoe.

For the 2004 edition of the present *Survey*, the Member Committee observed that Bulgaria could be divided into three zones according to the solar insolation received, namely:

Zone A - encompasses regions in the south east, part of the southern Black Sea coastal region and the valleys of the rivers Struma, Mesta and Maritza. The amount of sunshine is over 2 200 h/yr and the total solar radiation received on a horizontal surface is greater than 1 600 kWh/m<sup>2</sup>.

Zone B - encompasses regions in the Danube plain, the Dobrudja region, the Trace lowland, west Bulgaria, the Balkan hollow fields and Stara Planina mountain regions. The amount of sunshine ranges from 2 000 to 2 200 h/yr and total solar radiation from 1 500 to 1 600 kWh/m<sup>2</sup>.

Zone C - encompasses the remaining parts of Bulgaria, mainly the mountainous regions, where sunshine is less than 2 000 h/yr and total solar radiation less than 1 500 kWh/m<sup>2</sup>.

Installed PV capacity at end-2005 is reported to have been negligible and no data are available regarding the installed capacity of solar water-heating devices. At present there are no grid-connected systems for utilising solar energy for electricity generation.

## Canada

The Canadian solar photovoltaic (PV) industry continues to grow. Installed capacity of solar PV stands at 16.8 MW, an increase of nearly 7 MW since 2002. Most PV capacity is in off-grid applications such as transport route signalling, navigational aids, isolated residential buildings, telecommunications, and remote sensing and monitoring, generally in remote areas of the country. Solar thermal capacity in 2004 was 385 TJ.

Government programmes to encourage market development of solar technologies include various ongoing projects under the TEAM (Technology Early Action Measures) Program, as well as subsidies offered under the Renewable Energy Deployment Initiative (REDI) program for the purchase of solar water and air heating systems.

Solar hot water and solar air heating systems used directly in industrial applications, and photovoltaic equipment with capacity of 3 kW or larger qualify for tax incentives with accelerated depreciation treatment.

In 2005, a Solar Buildings Research Network of 24 top Canadian researchers in solar energy and buildings from 10 Canadian universities was created to develop the solar-optimised homes and commercial buildings of the future. The initial budget of the Network is CDN\$ 6 million, and approximately 40 research projects are

under way. Major Canadian energy and construction industries are involved in most of the projects. The Network is a cornerstone of Canadian efforts to promote innovative research and development in solar energy utilisation.

The province of Ontario has recently introduced the Standards Offer Program, where small renewable energy projects are able to participate in electricity markets. Under this scheme, solar PV projects will receive CDN\$ 0.42/kWh.

### China

It is estimated that two-thirds of the country receives solar radiation energy in excess of 4.6 kWh/m<sup>2</sup>/day, with the western provinces particularly well endowed. China's annual solar power potential has been estimated to be 1 680 billion toe or 19 536 000 TWh. Capturing 1% of this resource, and utilising it with 15% efficiency, could supply as much electricity as the whole world presently consumes in eighteen months.

In 2004 the World Bank approved a loan and Global Environment Facility (GEF) grant to China for its Renewable Energy Development Project (REDP), in which photovoltaics feature prominently. Assistance will be provided to PV companies to market, sell and maintain 300-400 thousand systems in remote parts of the north-western provinces. The project will eventually involve the installation of around 10 MW<sub>p</sub> of PV,

either on a stand-alone basis or as hybrid systems in conjunction with wind power.

China's 11<sup>th</sup> 5-Year Plan (2006-2010), approved by the Government in October 2004, stresses the need for energy conservation and diversification. In the first phase of the Village Programme, some 250 MW<sub>p</sub> of PV systems are planned for installation, bringing power to 2 million households that have been out of reach of mains electricity. Additionally, the 11<sup>th</sup> Plan will support around 50 MW<sub>p</sub> of roof-top and BIPV systems, as well as a 20 MW<sub>p</sub> demonstration plant in the Gobi desert.

In October 2005, a '100 000 solar roofs' project was approved by the Shanghai municipal government; it is planned for 70 MW<sub>p</sub> of PV capacity to be in place by 2010, with an eventual total of 360 MW<sub>p</sub>, providing an annual output of 432 GWh.

In November 2006, a new law in the city of Shenzhen came into effect, promoting the use of solar energy to heat water and generate electricity. The Shenzhen Construction Bureau anticipates that half of the city's new buildings will have solar water heating and one in five will have a PV power system.

Plans have been announced to utilise PV systems on a large scale for the summer Olympic Games in 2008, exemplifying the concept of the 'Green Olympics'. It is proposed

to install PV panels on the outer walls of the Olympic Stadium and gymnasiums and for the majority of the street lights in the Olympic Village to be solar-powered.

#### **Côte d'Ivoire**

There is a plentiful supply of insolation in Côte d'Ivoire, with the total estimated at between 1 500 and 1 800 kWh/m<sup>2</sup>/yr. The Government, the private sector and some non-governmental charitable organisations have been active in promoting the exploitation and use of solar energy. The applications foreseen include pumping water in villages, hospital refrigeration units in rural areas, the use of solar thermal energy to dry feeds, etc.

#### **Denmark**

There is no unified national PV programme, although a large number of projects have received support from the Renewable Energy Development Programme of the Danish Energy Authority (DEA), and through the Public Service Obligation (PSO) of the Danish transmission system operator. Since 2004, the DEA has collaborated with the electricity sector and other interested parties in pursuing a national PV strategy that encompasses RD&D, but excludes deployment.

As part of the plan to increase the deployment of building-integrated systems, a 4-year nationwide solar cell project, SOL 1000, is being implemented. The programme is intended to demonstrate low-cost and architecturally

acceptable integration of PV technology on the existing housing stock. The objective is to install about 650 kW<sub>p</sub> of BIPV. Alongside this project is running an R&D package (SOL 2000A) funded by the PSO.

At the end of 2005 installed PV power was 2 650 kW<sub>p</sub>, of which 70 kW<sub>p</sub> was off-grid domestic, 225 kW<sub>p</sub> off-grid non-domestic and 2 355 kW<sub>p</sub> grid-connected distributed. Output of electricity from PV amounted to 2 160 MWh in 2005.

The Danish WEC Member Committee reports that heat output from active solar systems in 2005 was 49 terajoules. The total glazed area of solar thermal collectors in operation in 2005 was 337 000 m<sup>2</sup>, giving an output capacity of about 236 MW<sub>t</sub>.

#### **Egypt (Arab Republic)**

Egypt is located in the world's solar belt and has an excellent solar availability. The Egyptian WEC Member Committee reports that average solar radiation ranges from about 1 950 kWh/m<sup>2</sup>/yr on the Mediterranean coast to more than 2 600 kWh/m<sup>2</sup>/yr in Upper Egypt, while about 90% of the Egyptian territory has an average global radiation greater than 2 200 kWh/m<sup>2</sup>/yr.

Recognising the important role renewable energy can play in meeting future energy needs, the New & Renewable Energy Authority (NREA) has set itself the target of providing at least 3% of the country's electrical energy demand from renewables by the year 2010.

Photovoltaic (PV) solar systems are presently considered economically advantageous only in remote applications of low power demand, where a grid extension appears non-economic, while conventional stand-alone power sources (e.g. diesel generator sets) show excessive operating costs, in addition to polluting the environment.

A number of PV systems totalling about 4.5 MW<sub>p</sub> have been installed in Egypt, primarily by NREA, but also by other national and international entities, including some private companies.

The main applications are water pumping, desalination, rural clinics, telecommunications, rural village electrification, ice-making, billboards and cathodic protection.

The Egyptian Member Committee has also reported that a protocol has been confirmed between the NREA and the Italian Ministry of Environment and Territory (IMET) in the framework of the Renewable Energy for the Mediterranean Countries Program MEDREP, to use PV systems for lighting applications in two villages located in the Siwa Oasis (Matrouh Governorate), consisting of 100 households, 2 medical centres, 1 school, 3 mosques and 80 street lamps. The implementation of these projects is greatly dependent on the availability of funds (mainly international support), owing to the relatively high investment costs.

### **Ethiopia**

Solar energy availability in Ethiopia ranges between 1 700 and 2 200 kWh/m<sup>2</sup>/yr. Solar PV is used for telecommunication applications, for

rural lighting and for rural social services (water pumping, health and education). Three-quarters of the installed PV capacity is used for telecoms. Total installed PV capacity was 2 940 kW<sub>p</sub> at end-2005.

Solar water heating is employed by some urban homes and commercial establishments. At the end of 2005 an estimated 200 units, with 400 m<sup>2</sup> of absorber area, were operational.

### **Finland**

The average annual insolation in Finland is 1 150 kWh/m<sup>2</sup>. The seasonal variation of solar radiation in Finland is large; the main part of solar radiation is obtained between March and September.

The sum of installed photovoltaics is 4.0 MW<sub>p</sub>, of which 95% consists of local PV systems in summer houses, etc., mostly small units in the range of 50-100 W<sub>p</sub>. Recently, two somewhat larger installations have been made in Viitasaari (5 kW<sub>p</sub>) and Saarijärvi (6 kW<sub>p</sub>).

Whilst the PV sector remains fairly modest, the Ministry of Trade and Industry's Action Plan contains a national target of 40 MW<sub>p</sub> installed PV capacity by 2010, with a corresponding 2025 level of 500 MW<sub>p</sub>.

The total glazed area of solar thermal collectors in operation in 2005 was 14 000 m<sup>2</sup>, giving an output capacity of about 10 MW<sub>t</sub>.

### **France**

By end-2005 France (including its overseas departments [DOM]) had a total installed PV

capacity of 33 043 kW<sub>p</sub>, of which 13 844 kW<sub>p</sub> was off-grid domestic, 6 232 kW<sub>p</sub> off-grid non-domestic and 12 967 kW<sub>p</sub> grid-connected distributed. Metropolitan France accounted for almost 49% of total PV capacity and about 42% of PV output. The annual average increase in capacity between 2000 and 2005 was about 24%.

The principal sources of subsidies for PV installations in France are ADEME (Agence de l'environnement et de la maîtrise de l'énergie: the body charged with promoting renewable energy), the regional councils and the European Commission.

An Arrêté dated 7 July 2006 specifies the following new targets for PV installations: an additional 160 MW by 2010 and an additional 500 MW (including the 160) by 2015.

The French feed-in tariff for PV electricity was updated by an Arrêté dated 10 July 2006 (€ 0.30 to 0.55/kWh), for installations with a capacity of below 12 MW.

Solar thermal output in 2005 is reported to have been 1 632 TJ, of which 941 was in metropolitan France. The total glazed area of solar thermal collectors in operation in 2005 was 396 000 m<sup>2</sup>, giving an output capacity of about 277 MW<sub>t</sub>.

The Loi POPE of 13 July 2005 specifies a target of 200 000 solar water-heaters and 50 000 solar roofs per annum in 2010.

All solar equipment benefits from an increase in the tax credit to 50% from 1 January 2006.

### Gabon

The Gabonese WEC Member Committee reports that Gabon's average daily insolation is about 4 kWh/m<sup>2</sup> and that there are approximately 300 days of sunshine per year. Photovoltaic cells are used in the electrification of villages and in telecommunications.

### Germany

Germany has the highest level of installed PV capacity amongst the European members of the IEA-PVPS. At end-2005 its capacity stood at 1 429 MW<sub>p</sub>, 25 times that of the next biggest country (Spain). Out of the installed PV total, 29 MW<sub>p</sub> was off-grid and 1 400 MW<sub>p</sub> grid-connected.

Recent growth has been nothing short of phenomenal: averaging 58% per annum from 1999 to 2003 and then accelerating to 80% or more in 2004 and 2005. Major factors contributing to this rapid rate of expansion were the highly successful 100 000 Rooftops Solar Electricity Programme which ran from 1999 to 2003 and the Renewable Energy Sources Act (EEG) which, from April 2000, guaranteed a feed-in tariff for PV.

The Second Amendment of the Renewable Energy Sources Act (EEG) came into force on 1 January 2004. It is expected to promote even further growth in the German solar industry in the coming years. The basic tariff available for solar power installations built in 2005 is € 0.513/kWh. There are bonuses for small installations and BIPV.

Solar thermal technology is also expected to benefit from a market incentive programme. The total glazed area of solar thermal collectors in operation in 2005 was 6 554 000 m<sup>2</sup>, giving an output capacity of about 4 588 MW<sub>t</sub>.

Plans were announced in March 2007 for the construction of one of the world's largest PV power plants. The facility will comprise some 400 000 m<sup>2</sup> of solar panels, with a generating capacity of 40 MW<sub>p</sub>, and will be erected on a former military airfield near Leipzig.

### Greece

Despite the existence of a very high potential for solar energy applications and the beginning of their deployment in the mid-1970s, major applications have so far been restricted to SWH collectors. There has been a negligible market for large-scale hot water systems in the commercial sector (hotels, hospitals and swimming pools) and an even smaller penetration in industry.

In order to promote solar energy the Hellenic State provides a very favourable taxation environment for solar applications but individual consumers' purchases are mainly limited to SWH collectors, because of the high cost of photovoltaic applications. The total glazed area of solar thermal collectors in operation in 2005 was 3 047 000 m<sup>2</sup>, giving an output capacity of about 2 133 MW<sub>t</sub>.

### Guinea

The WEC Member Committee for Guinea reports that the republic is well-endowed with solar energy. The average annual hours of sunshine range from 2 000 at Conakry to 2 700 at Kankan, whilst the average daily insolation is estimated at 4.8 kWh/m<sup>2</sup>, equivalent to some 1 750 kWh/m<sup>2</sup>/yr. Installed capacity of PV systems is reported to have been 148 kW<sub>p</sub> at end-2005.

### Hong Kong, China

The resource potential estimated by a government study in 2002 suggested that with massive deployment on buildings, solar photovoltaic power could generate up to several thousand GWh per year.

In Hong Kong, government, utilities, schools and commercial buildings combined, have more than 800 kW capacity of grid-connected solar photovoltaic panels, mostly on buildings. The largest installation is 350 kW on the roof of the new headquarters of the Electrical and Mechanical Services Department. There are also a number of installations using solar thermal energy for water heating.

Solar energy is the subject of research at a number of universities in Hong Kong. Studies include new photovoltaic materials and systems; integration of photovoltaic systems with buildings; assessment of system performance in

the Hong Kong environment; utilisation of light and heat as an aspect of building architecture and design; solar-boosted heat pump demonstration and assessment.

### Hungary

The Hungarian solar energy market is in an early stage of development, compared with wind or biomass energy applications. Installed PV capacity was about 100 kW<sub>p</sub> at end-2005, with output during the year totalling some 150 MWh.

Three-quarters of installed PV systems are autonomous: microwave telecommunication stations, highway emergency phones, traffic data acquisition stations, meteorological survey stations, safety systems, electric fences, water supply systems, monitoring systems in the gas industry, lighting, remote area houses, etc.

About a quarter is grid-connected. These are mainly subsidised pilot or demonstration applications: e.g. at a gasoline filling station, university projects, etc.

There are less than 1 000 applications of solar heat, consisting mainly of small-scale house heating and hot water production. The total glazed area of solar thermal collectors in operation in 2005 was 5 000 m<sup>2</sup>, giving an output capacity of about 4 MW<sub>t</sub>.

### India

The Ministry of New and Renewable Energy (MNRE), formerly the Ministry of Non-Conventional Energy Sources, working in conjunction with the Indian Renewable Energy

Development Agency (IREDA) continues to promote the utilisation of all forms of solar power, as part of the drive to increase the share of renewable energy in the Indian market. This promotion is being achieved through R&D, demonstration projects, government subsidy programmes, programmes based on cost recovery supported by IREDA, and also private sector projects.

India has a good level of solar radiation, receiving the solar energy equivalent of more than 5 000 trillion kWh/yr. Depending on the location, the daily incidence ranges from 4 to 7 kWh/m<sup>2</sup>, with the hours of sunshine ranging from 2 300 to 3 200 per year. Solar thermal and solar photovoltaic technologies are both encompassed by the Solar Energy Programme that is being implemented by the Ministry. The Programme, regarded as one of the largest in the world, plans to utilise India's estimated solar power potential of 20 MW/km<sup>2</sup>, and 35 MW/km<sup>2</sup> solar thermal. The country has also developed a substantial manufacturing capability, becoming a lead producer in the developing world.

Within the overall drive towards renewable energy, the Ministry conducts separate programmes for solar thermal and solar photovoltaic.

- The *Solar Thermal Development Programme* covers solar water heating, solar cooking, solar air heating and solar buildings.

India's overall potential for **solar water heating systems** has been estimated to be 140 million

m<sup>2</sup> of collector area. Up to the present, about 1 million m<sup>2</sup> of collector area has been installed – a low level in comparison with the potential, and as compared with other countries, notably China. A Government scheme for ‘Accelerated development and deployment of Solar Water Heating systems in domestic, industrial and commercial sectors’ has been introduced, with the object of promoting the installation of another million m<sup>2</sup> of collector area during FY 2005-06 and 2006-07. The scheme offers a number of financial and promotional incentives, along with other measures of support. The installation of Evacuated Tube Collectors is being officially encouraged.

Five types of **solar cookers** have been developed:

- *cardboard solar cooker*: low-cost, portable, one or two dishes at a time;
- *box solar cooker*: small, four dishes at a time, intended for small families;
- *dish solar cooker*: fast cooking device for homes and small establishments, for 10-15 people;
- *community solar cooker for indoor cooking*: large, automatically-tracked parabolic reflector, standing outside kitchen through an opening in the north wall, with a secondary reflector further concentrating the rays on to the bottom of

the black-painted cooking pot, for 40-50 people;

- *solar steam cooking system*: large, automatically-tracked parabolic reflectors, coupled in a series and parallel combination, generating steam for use in community kitchens, for thousands of people, usually installed in conjunction with a conventionally fuelled boiler; the world's largest solar cooking system installed at Tirumala in Andhra Pradesh, has the capacity to provide food for 15 000 people per day.

**Solar air heating** technology has been applied to various industrial and agricultural processes (e.g. drying/curing, regeneration of dehumidifying agents, timber seasoning, leather tanning) and also for space heating; many types of solar dryers have been developed for use in different situations. The Government provides financial support for solar air heating/drying systems, and also for solar concentrating systems such as the 160 m<sup>2</sup> parabolic-dish concentrator recently installed for use in milk pasteurisation at a dairy in Maharashtra.

**Solar buildings** have been promoted by the MNRE in an effort to increase energy efficiency; the state government in Himachal Pradesh has actively promoted the incorporation of passive solar design into building design.

- The *Solar Photovoltaic Programme (SPV)* promoted by the Ministry for the past two decades, has been aimed particularly at rural and remote areas. Following the success of the country-wide SPV demonstration and utilisation programme during the period of the Ninth Plan, it is planned, with certain modifications, to continue it during the Tenth Plan (2002-2007).

Of the approximately 80 000 villages not currently connected to the grid, about 18 000 are too remote ever to be considered. The Ministry has the objective that by 2010 they will all have access to power from renewable energy sources, with the Tenth Plan electrifying 5 000 of them. During 2005-2006 the Ministry supported the supply of solar lanterns to certain unelectrified villages.

Among the numerous stand-alone applications of PV found in India are the following:

- emergency/back-up lighting for roads and other areas;
- control systems for switching street lights on/off;
- back-up systems for traffic signals;
- illuminated road studs;
- warning lights at road hazards;

- BIPV systems for load-shaving at peak hours;
- power packs to replace small gasoline/kerosine-powered generators.

In a country where agriculture is a major component of the economy, the SPV Water Pumping Programme will continue to subsidise the large-scale use of PV-powered (1 800 W<sub>p</sub>) pumping systems for farmers.

The Ministry is also implementing a programme for water-pumping windmills, small aerogenerators and wind-PV hybrid systems to enable the huge Indian wind resource to be harnessed in conjunction with the solar power available. These applications will be fully researched and demonstrated prior to deployment in remote areas.

The MNRE is developing a chain of Akshay Urja Shops (previously called Aditya Solar Shops). These are showroom-cum-sales and service centres, initially established to sell solar energy products; their scope has now been widened to cover all renewable energy systems and devices. So far, 104 shops have been opened in 28 States or Union Territories, and the Ministry plans for at least one to exist in each district throughout the country.

### Indonesia

The archipelago of Indonesia comprises over 17 000 islands (according to the latest count using

satellite mapping) of which approximately 6 000 are inhabited. Difficulties in extending the national grid across the islands to the widely dispersed population meant that in 1995 only about 58% of the country's 62 000 villages were electrified. Historically, areas that could not be supplied with conventional electricity from the national grid have relied upon hydro-electricity and stand-alone diesel generators to power mini-grids, or used kerosine for lighting.

Indonesia's situation close to the equator and its daily average insolation level – estimated at 5 kWh/m<sup>2</sup> - make it highly suitable for the installation of solar energy devices, especially for the huge rural population and in remote areas.

Both solar thermal and solar PV applications have been installed throughout the country, estimated in 2004 to total about 5 MW. Most of the solar thermal installations are used for domestic water heating, agriculture or crop drying and cooking. Solar PV systems are used at community centres for lighting, pumping and at health centres for the refrigeration of medicines.

Under the National Plan for PV, the indigenous manufacture of photovoltaic modules will be developed, the utilisation of PV systems in both rural and urban areas will be increased and the mechanism for grid-connected PV will be established.

Although the use of renewable energy is, at present, fairly limited, the Government plans to

increase its share. The National Energy Policy states that by 2025 renewable energy will provide 17% of the energy mix (of which biomass, nuclear, hydro, solar, wind and coal bed methane will supply 5%).

### Iran (Islamic Republic)

According to the Iranian WEC Member Committee, the average annual solar energy potential is about 6 570 MJ/m<sup>2</sup> or 1 825 kWh/m<sup>2</sup>. Most areas in Iran record more than 300 days of sunshine, or over 2 800 hours, in a year.

Installed PV capacity at end-2005 is reported as 300 kW, with 2005 output amounting to 230 MWh. The capacity of solar heating systems is estimated to have been around 5 000 kW at the end of 2005.

#### Programmes for promoting the utilisation of solar energy fall into three categories:

- ▶ building up capacity, such as running university-level training courses, supporting and establishing research centres, encouraging manufacturers to produce the required equipment and systems;
- ▶ carrying out pilot projects by the Government, with the aim of clearing the ground for the private sector to come forward;
- ▶ conducting potential assessment studies.

**Solar projects include:**

- ▶ a 17 MW solar thermal power plant, which would be installed by 2009;
- ▶ 50 MW (or more than 1 million m<sup>2</sup>) of solar water heaters by 2009;
- ▶ installation of several different types of PV systems;
- ▶ a pilot plant for a parabolic-trough solar thermal power plant, with a capacity of 250 kW;
- ▶ installation of PV systems in 40 isolated village households.

**Israel**

With an average annual insolation of approximately 2 000 kWh/m<sup>2</sup> and few natural energy resources, Israel has pioneered the use of solar energy. However, whilst the 1980 law requiring the installation of solar water heaters has had a dramatic effect, PV activity remains largely in the realm of academic research.

The 1980 Solar Law is an amalgam of different legislative measures, all designed to lay down national standards and regulations. The Planning and Building Law requires the installation of solar water heaters for all new buildings (including residential buildings, hotels and institutions, but not industrial buildings, workshops, hospitals or high-rise buildings in excess of 27 m), dictating the size of the installation required for a particular type of

building; the Land Law governs solar installations in existing multi-apartment buildings and the Supervision of Commodities and Services Law provides governmental supervision of the quality of installations and their guarantees.

Almost all Israel's residential buildings have solar thermal systems, the vast majority of which are utilised for water heating. It has been reported that the use of solar collectors saves the country in the region of 600 000 toe/yr.

Although the Israel Electric Corporation is required to purchase electricity from private producers, there are no incentives for PV systems. The extensive national grid precludes the same penetration by PV as has been enjoyed by solar water systems. There is no PV module manufacturing capability within the country and currently most activity is concentrated on maintaining the technical excellence that has been achieved through academic research. However, during 2002 PV-operated cameras for vehicle number-plate recognition were installed for use on Israel's first toll road. Additionally, there are instances of PV being used for lighting, irrigation, pumping and refrigeration and in parking-ticket machines. A demonstration PV project was initiated in 2005 in the Bedouin village of Drijat, in the Negev desert. In its first phase, the project provided stand-alone PV systems to 20 households, 6 street lamps, a school and a mosque.

At end-2005 there was 1 044 kW<sub>p</sub> of installed PV power, of which 809 kW<sub>p</sub> was off-grid domestic,

210 kW<sub>p</sub> off-grid non-domestic, 11 kW<sub>p</sub> grid-connected distributed and 14 kW<sub>p</sub> grid-connected centralised.

In November 2002 the Government passed a resolution stating that by 2007 at least 2% of total electric energy must be generated from renewable energy, rising to 5% by 2016.

### Italy

Since the early 1980s, the main thrust of solar energy in Italy has been photovoltaic, the development of which has ranged from research on materials and devices and experimentation for grid and non-grid applications to the dissemination of such technology through various incentive programmes.

Currently, PV electricity is supported via dedicated premium feed-in tariffs with a fixed premium in the range of € 44.5-49.0/MWh according to the plant size for the green value, and via a tariff linked to the market price for the power. Plants up to 20 kW can choose to have the power paid via net-metering or via tariff.

Current applications include small islands electrification, telecom systems, environmental data collection and transmission, isolated spot lighting at bus stops, etc..

According to the IEA-PVPS, 14% of end-2005 PV capacity was off-grid domestic, 19% off-grid non-domestic, 49% grid-connected distributed and 18% grid-connected centralised.

The total glazed area of solar thermal collectors in operation in 2005 was 516 000 m<sup>2</sup>, giving an output capacity of about 361 MW<sub>t</sub>.

In November 2003 ENEL (the largest Italian utility) and ENEA (the Italian Agency for New Technology, Energy and Environment) announced their collaboration on the 'Archimede' project. ENEL's existing Priolo Gargallo gas combined-cycle power plant located in Sicily will be expanded with the addition of a solar plant to be constructed alongside. The innovative technology, albeit inspired by the 3rd century BC mathematician, will use parabolic mirrors to concentrate and accumulate the power from the sun during daylight hours. With the use of a new fluid based on low-cost fused salts and capable of allowing high temperatures to be reached, the process will use the thermal energy collected to produce vapour and thus electricity during a 24-hour cycle. It is estimated that there will be a saving of some 12 000 toe per annum and a reduction in the region of 36 000 t/yr of CO<sub>2</sub> emissions. The testing period has proved to be successful and at the end of March 2007 it was announced that an accord had been signed between ENEL and ENEA for installation to begin. It is expected that the plant will be operational in 2009.

### Japan

As one of the 19 member countries of the Implementing Agreement on Photovoltaic Power Systems (IEA-PVPS) Japan had the highest installed PV capacity (636.8 MW<sub>p</sub>) at end-2002, when it was more than double that of the next

highest country, Germany. In three years, however, Germany managed to overtake Japan, and by end-2005 was 7MW<sub>p</sub> higher than Japan.

Of Japan's 1 421.9 MW<sub>p</sub> total capacity, 1.1 MW<sub>p</sub> was for the off-grid domestic market, 85.9 MW<sub>p</sub> for off-grid non-domestic, 1 332.0 MW<sub>p</sub> for grid-connected distributed and 2.9 MW<sub>p</sub> for grid-connected centralised.

The 1997 New Energy Law led to The Total Primary Energy Supply Outlook in 1998 which specified that the target for installed PV was to be 5 000 MW by FY2010. In 2001 this target was reduced to 4 820 MW. The Ministry of Economy, Trade and Industry (METI) is charged with promoting the measures necessary to achieve this target. The 'Renewable Portfolio Standard' Law introduced during 2002 requires energy suppliers to use a certain percentage of renewable energy.

In addition to the main demonstration programmes ('PV Field Test for Industrial Use' and 'Demonstrative Development of Centralised Grid-Connected PV Systems') both started in FY2002, METI also began in FY2002, three implementation programmes ('Residential PV System Dissemination Programme', 'Introduction and Promotion of New Energy at the Regional Level' and 'Financial Support for Entrepreneurs Introducing New Energy').

The Residential PV System Dissemination Programme granted subsidies to private purchasers of PV installations, providing that they recorded and reported the operational data

of their system. At the end of FY2004, the cumulative capacity of the 217 000 residential PV systems installed under this programme amounted to 795 MW<sub>p</sub>. Nearly 40 000 applications were accepted in 2005, for a total capacity of 155.7 MW<sub>p</sub>. By October 2005 the budget for FY2005 had become exhausted, resulting in the scheme's termination.

It was anticipated in 2006 that some 70 000 residential PV systems would be installed during the year and that the total of incremental PV capacity in all applications could reach around 350 MW<sub>p</sub>. In Japan, most PV installations are on residential property. About 80% of residential systems have been installed on existing houses and 20% on new properties. One commentator has remarked on the fact that, although fully roof-integrated PV systems are readily available, the number of such installations is quite small, and suggests that purchasers prefer to display their green credentials by opting for panels rather than the less noticeable tiles.

The majority of PV installations are likely to continue to take place in the residential sector, at a rate of between 100 000 and 200 000 (400-800 MW<sub>p</sub>) per annum. The number of larger installations on public buildings and industrial property is expected to increase, whilst further applications may be developed in transport and agriculture.

Off-grid non-domestic PV systems are being deployed for use in telecommunications, traffic signs, telemetering, ventilation and lighting.

The production and deployment of solar hot water systems began more than 50 years ago and the market developed during the ensuing three decades. The oil crises of the 1970s fostered further growth but in the late 1990s stagnation set in, not least because of the Government's termination of low-interest loans. In a survey published in April 2003, ESTIF (European Solar Thermal Industry Federation) estimated that 7.360 million m<sup>2</sup> of glazed collectors were in operation in Japan at the end of 2001, of which 7.219 million m<sup>2</sup> were flat-plate collectors and 0.141 million m<sup>2</sup> were vacuum collectors.

### **Jordan**

Jordan lies in the so-called earth-sun belt area and has a high solar potential, with annual average insolation in the region of 1 800 kWh/m<sup>2</sup>/yr.

The Jordanian WEC Member Committee reports that a number of studies and surveys on the utilisation of solar energy have been made for various locations, through the so-called Phoebus Project. Their outcome was encouraging and indicated that the utilisation of solar energy for remote applications is feasible.

The use of solar energy for thermal applications, including electricity generation, is technically possible, owing to the high solar energy intensity (which exceeds 2 000 kWh/m<sup>2</sup>/yr at some locations) and other favourable factors. From an economic point of view, however, solar power plants are not yet viable and would need

additional support to be competitive with conventionally generated power.

Currently the main use of solar energy is for domestic water heating, with approximately 30% of houses having such installations; to supply this market, more than 25 manufacturers are producing locally-designed solar water heater systems.

In addition, photovoltaic systems are used in remote areas throughout the country. PV installations cover a variety of applications, such as water pumping, telecommunications, schools and others, with a reported total capacity of 184 kW<sub>p</sub>.

### **Kenya**

Kenya receives a plentiful supply of solar radiation, averaging between 4 and 6 kWh/m<sup>2</sup>/day, but only a small proportion of this resource has so far been harnessed.

On its official website, the Ministry of Energy states that an estimated 220 000 PV units are in current use, for lighting, water pumping, refrigeration and telecommunications. The Government is presently carrying out a programme of installing PV systems in schools and other institutional buildings in a number of remote areas, as part of its drive to increase the proportion of renewable sources within Kenya's overall energy supply.

Solar thermal devices are used for heating and drying, with around 7 000 units in operation at present.

### Korea (Republic)

The years 2004 and 2005 witnessed rapid growth in Korea's use of photovoltaics, reflecting the implementation of The 2<sup>nd</sup> Basic Plan for New & Renewable Energy Technology Development & Dissemination, established in 2003. This Plan sets a target of a 3% share of total energy consumption for new and renewable energy in 2006, rising to 5% by 2012. The Ministry of Commerce, Industry and Energy (MOCIE) has selected PV as one of the three key technologies to be developed and promoted. It is planned to bring Korea's PV capacity up to 1 300 MW<sub>p</sub> by 2012, through installations on 100 000 residential roof-tops and 70 000 commercial and industrial buildings.

In two years installed PV capacity rose by 150%, to reach 15 021 kW<sub>p</sub> by the end of 2005. Under the direction of MOCIE, an intensive programme of research, development and demonstration is being undertaken, with the object of improving the technological and commercial aspects of photovoltaic products and promoting their diffusion, both in Korea and abroad.

A project was announced in May 2007 for a 19.6 MW<sub>p</sub> PV power plant, to be built in Sinan, 400 km south-west of Seoul. The scheme, consisting of more than 100 000 sun-tracking solar modules, is expected to generate up to 27 GWh. On completion, scheduled for late 2008, it will become one of the world's largest PV power stations.

### Latvia

Latvia's total solar radiation varies between 900 and 1 100 kWh/m<sup>2</sup>/yr; although the amount of sunshine the country receives is only about 1 200 h/yr, solar power is being utilised to good effect.

PV systems have been installed in lighthouses and lightships and in some small demonstration projects, as at Riga Technical College.

Solar collectors have been installed at a number of schools and other locations. The Danish-financed solar thermal project at Aizkraukle Secondary School Nr. 2, completed in 2002 with 155 m<sup>2</sup> of collectors, was at the time the largest such project in the Baltic States. The total glazed area of solar thermal collectors in operation in 2005 was 2 650 m<sup>2</sup>, giving an output capacity of about 2 MW<sub>t</sub>.

### Lithuania

The total annual potential of solar energy in Lithuania is assessed at 1 000 kWh/m<sup>2</sup> and the technical potential at about 1.5 TWh per annum. So far, solar energy has been used for heating, hot water production and the drying of agricultural products.

The project, Development of the Lithuanian solar program 2000-2005 and its implementation into the World Solar Program, coordinated by the Institute of Lithuanian Scientific Society and funded by UNESCO, envisaged the construction

of 0.05 MW of photovoltaic power equipment and 1 000 m<sup>2</sup> of solar collectors.

The Lithuanian WEC Member Committee reports that the total area of solar collectors installed is currently about 1 000 m<sup>2</sup>, with total heat production in 2005 some 500 MWh.

### Mexico

The Mexican WEC Member Committee reports that by end-2005 a cumulative total of 18 650 kW PV capacity had been installed, and that total generation from PV systems in 2005 was just over 34 000 MWh. It also reports that recent studies for a forthcoming 4-year rural electrification programme, co-financed by the GEF, the World Bank and the Mexican Government, have shown that PV would be the least expensive alternative in more than 51% of almost 9 500 targeted communities in four southern states. A pilot neighbourhood of 100 houses with PV roof-tops of 1 kW each is planned for implementation in northwest Mexico in the near future.

In 2005, the Mexican PV market was about 0.5 MW<sub>p</sub>, of which rural electrification accounted for 307 kW<sub>p</sub> (including 242 water pumping systems with 200 kW<sub>p</sub>), grid-connected systems for 30 kW<sub>p</sub>, and professional applications (telecommunications, offshore oil platforms, etc.) for 175 kW<sub>p</sub>.

The *Balance nacional de energía 2004* states that at end-2004 there were 642 644 m<sup>2</sup> of flat-plate solar collectors installed, mainly used for

heating water for swimming pools and general hygiene. Solar heat production in 2005 was an estimated 3 075 TJ.

### Namibia

Namibia has a substantial solar energy potential, owing to its high level of solar radiation. Currently efforts are being made by the Government and its partners to increase the use of solar energy. People can buy their equipment through the government-sponsored soft-interest loan scheme, the Solar Revolving Fund and Bank Windhoek.

Current and planned projects include:

- the removal of barriers to the Namibian renewable energy programme (UNDP/GEF/Ministry of Mines and Energy);
- establishment of a renewable energy and energy efficiency institute;
- building capacity for renewable energy and energy efficiency.

Solar home systems, solar water heaters and PV water pumps are the most widely-used applications of solar energy, but there are also a number of telecommunication systems.

The Namibian WEC Member Committee reports that at end-2005 some 700 kW of PV capacity had been installed, providing an output of 306.6 MWh during the year.

## Netherlands

There is at present no national programme for organising the deployment of photovoltaic systems, but various aids to individuals and companies are in place. The feed-in tariff has, however, been set at a low level and requires the PV owner to buy a special meter, to become a member of EnerQ, the managers of the MEP (Milieukwaliteit van de Elektriciteitsproductie) regulation under which the tariff is offered, and to acquire green-certificates. A net-metering scheme for small-scale domestic PV systems was launched in 2005.

At end-2005 a total of 50 776 kW<sub>p</sub> PV had been installed, of which 4 919 kW<sub>p</sub> was off-grid, 43 377 kW<sub>p</sub> grid-connected distributed and 2 480 kW<sub>p</sub> grid-connected centralised.

By the end of 2005, the City of the Sun Project, partly financed by the European Union, had installed 3.7 MW<sub>p</sub> (out of a targeted level of 5 MW<sub>p</sub>) in the new HAL neighbourhoods in the vicinity of Heerhugowaard, Alkmaar and Langedijk.

Development of the Dutch solar thermal market began in the mid-1970s and, owing to support from the Government in the form of a Long-Term Agreement for the Implementation of Solar Hot Water Systems (SHWS) and also subsidy schemes, it showed considerable success, especially in the house-building sector. By 2001 nearly 15% of all new residential dwellings were supplied with a Domestic Hot Water (DHW) system.

Installation of solar thermal systems in existing buildings had almost stopped after 2003 when the financial incentives ended but the new-build market was revitalised owing to tighter energy efficiency regulations. In 2005, 15-20% of all new buildings incorporated a solar thermal system and the total glazed area of solar thermal collectors in operation was 304 000 m<sup>2</sup>, giving an output capacity of about 213 MW<sub>t</sub>.

## Norway

The majority of Norway's commercial solar market consists of off-grid PV systems. By the end of 2002 a total of about 100 000 private systems had been installed, mostly in recreational cabins and leisure craft, and the market was showing signs of approaching saturation. In the public sector, the Norwegian Coastal Administration had installed approximately 1 840 installations with a total of about 3 600 modules, supplying lighthouses and coastal lanterns along Norway's coastline.

There are no public schemes to promote PV applications, and no national demonstration or field-test programmes were in operation in 2005. Nevertheless, several buildings with integrated PV have been constructed in recent years, the most notable being the new Oslo Opera House.

Total installed PV capacity was 7 252 kW<sub>p</sub> at end-2005, of which the off-grid domestic market accounted for 6 800 kW<sub>p</sub> (94%), off-grid non-domestic 377 kW<sub>p</sub> and grid-connected distributed 75 kW<sub>p</sub>.

### Pakistan

The *Pakistan Energy Yearbook 2006*, published by the Hydrocarbon Development Institute of Pakistan, reports that in 2005-2006 the Alternative Energy Development Board (AEDB) successfully deployed solar energy technologies in nine villages under its '100 Solar Homes Programme'. In each of the villages a hundred or more houses were provided with a basic electrical installation, comprising an 88 W solar panel, four LED lights, a 12 V DC fan and a TV socket. Each of the 991 households in the scheme was also provided with a solar cooker and a solar disinfecting unit.

In another initiative, the AEDB has devised a Solar Water and Desalination project to provide clean potable water in the remote areas of Tharparkar in Sindh. Five villages in Tharparkar will each be provided with a PV brackish-water pump, and a solar thermal desalination unit will be installed in each house.

The Board has also developed a project for the demonstration of solar thermal power generation technologies, including Parabolic Trough (35 kW) and Stirling Dish (10 kW). With the assistance of the provincial governments of Sindh and Balochistan, demonstration sites have been identified.

Private-sector companies in Pakistan, with the facilitation of the AEDB, have developed a number of products for areas that have been electrified with solar energy, including LED

lights, solar lanterns, pedal generators, hand generators and solar mobile-phone chargers.

### Paraguay

The Paraguayan WEC Member Committee reports that work on the utilisation of solar energy in rural communities is being carried out in conjunction with the Latin American Energy Organization (OLADE). Other projects in this area are under way, with the support of other international organisations.

### Peru

The Peruvian WEC Member Committee reports that the installed capacity of photovoltaic cells at the end of 2005 was 3 713.5 kW<sub>p</sub> and that electricity generation from PV totalled 3 109.9 MWh in 2005. Direct output of heat from solar devices amounted to 62.6 TJ.

Solar Photovoltaic Panels are mainly used for village electrification, water pumping and telecommunication systems. The Ministry of Energy and Mines and some NGOs provide these types of system.

In the period 1996-2002 the Ministry of Energy and Mines installed 1 523 PV panels of 50 W<sub>p</sub> each. According to the National Rural Electrification Plan, in the period 2005-2014, the installation of 4 524 PV panels is planned.

Solar thermal systems are used mainly for water heating, solar drying and cooking.

## Portugal

Utilisation of Portugal's solar energy resource has, up to the present, been relatively low. The Government has now set goals for the development of renewable energy, including a target of 150 MW<sub>p</sub> for installed capacity of PV by 2010. Penetration of the market will be facilitated by a favourable feed-in tariff, as well as financial and fiscal incentives. At end-2005, the installed PV capacity was only about 3 000 kW<sub>p</sub> (of which 73 kW<sub>p</sub> was grid-connected).

Portugal's first building-integrated PV system (12 kW<sub>p</sub>) was developed by the National Institute for Engineering and Industry Technology (INETI), and installed on the south façade of the Renewable Energy Department's Solar Building XXI. Another PV project completed in 2005 was a 25 kW<sub>p</sub> system installed by the German Energy Agency (DENA) at the Lisbon German School.

Located in Alentejo, 200 km southeast of Lisbon, the 11 MW, 52 000 PV module, Serpa power plant was inaugurated at the end of March 2007. The world's largest centralised PV power plant, with an eventual capacity of 62 MW<sub>p</sub>, is planned for construction in the same area. At end-October 2006, the first phase of the project (42 MW<sub>p</sub>: 32 MW<sub>p</sub> fixed panels + 10 MW<sub>p</sub> solar trackers) was stated to have a scheduled completion date of September 2008, with the second phase (20 MW<sub>p</sub>) planned for construction during 2008-2010. Together the two plants account for 49% of the Government's maximum quota for PV power in 2010.

The total glazed area of solar thermal collectors in operation in 2005 was 161 000 m<sup>2</sup>, giving an output capacity of about 113 MW<sub>t</sub>.

## Romania

The Romanian WEC Member Committee reports that the solar energy potential, as given by the average amount of energy from solar radiation on a horizontal surface, is about 1 300 kWh/m<sup>2</sup>/yr.

The geographical distribution of the solar energy potential indicates that more than half of Romania's area benefits from an annual energy flow of between 1 000 and 1 300 kWh/m<sup>2</sup>/yr. The solar-thermal potential is 144 000 TJ/yr, whilst the solar-electric potential is 6 TWh/yr.

The planned project and research programmes will promote investment projects in order to ensure optimum conditions for the development of medium and long-term applications.

The demonstration projects for heat generation based on solar sources are developed by means of high-performance solar-thermal systems (e.g. as a heat carrier and for hot-water production in individual households), which can operate in parallel with conventional heating systems.

For the development of demonstration programmes, especially for rural electrification, relatively low power (ranging from 200 W to 5 000 W) solar applications will be developed.

On the basis of feasibility studies, projects designed for PV grid-connected systems will be put into operation.

Current applications comprise:

- demonstration grid-connected PV systems;
- building-integrated grid-connected systems;
- rural electrification;
- small off-grid public & private installations;
- hybrid PV/wind systems;
- PV for telecommunications.

### Russian Federation

With its vast size, Russia necessarily receives a very substantial amount of solar radiation, but the geographical diversity of the country means that the resource is not uniformly available. The average solar radiation in the southern regions is about 1 400 kWh/m<sup>2</sup>/yr whilst the remote northern areas receive about 810 kWh/m<sup>2</sup>/yr.

The regions with the best potential comprise the North Caucasus, regions bordering the Black Sea and the Caspian, and the southern parts of Siberia and the Far East. Areas below or near latitude 50°N have particularly favourable solar radiation. The resource is extremely seasonal: at 55°N it ranges from 1.69 kWh/m<sup>2</sup>/day in January to 11.41 kWh/m<sup>2</sup>/day in July.

Although it has been estimated that the gross potential, the technical potential and the economic potential for solar energy are 2.3 trillion tce, 2 300 million tce and 12.5 million tce, respectively, Russia's enormous indigenous fossil fuel reserves have meant that historically, little attention has been paid to the renewable energies. However, with about 10 million people having no access to an electricity grid and most rural settlements having no centralised heat supply, the possibilities for off-grid solar energy or hybrid applications are huge.

The building of a single Solar Power Plant 'Kislovodskaya SPP' (1.5 MW), with assumed output 2.04 million kWh, has been delayed.

### Spain

The Instituto para la Diversificación y Ahorro de la Energía (IDAE), an organisation within the Ministerio de Industria, Turismo y Comercio, produced a Plan for the Promotion of Renewable Energy in Spain covering the period 2000-2010, which was approved by the Spanish Government on 30 December 1999. In 2005, IDAE produced a revision, in the shape of the Plan de Energías Renovables en España (PER) 2005-2010. This plan retains a commitment for renewables to cover at least 12% of total energy consumption in 2010, and for renewables to provide 29.4% of electricity demand in the same year. However, some of the specific objectives for individual sources have been modified. The current targets for the development of solar energy applications are summarised below.

- low-temperature solar-thermal energy:** the potential area of solar panels is estimated at 26.5 million m<sup>2</sup>; the objective for installations during 2005-2010 is 4.2 million m<sup>2</sup>. With the inclusion of the 0.7 million m<sup>2</sup> in place in 2004, a total of nearly 5 million m<sup>2</sup> of solar panels could be operational by the end of 2010. The total glazed area of solar thermal collectors in operation in 2005 was 527 000 m<sup>2</sup>, giving an output capacity of about 369 MW<sub>t</sub>.
- solar thermo-electric energy:** Spain has built up a particular expertise with regard to high-temperature systems, having conducted much research at the Plataforma Solar de Almería in the south-east of the country. The target for 2010 has been raised from 200 MW to 500 MW, with the proviso that the 200 MW limit on the granting of subsidies would have to be removed. It is now envisaged that by 2010 annual generation of electricity by Spanish solar thermo-electric power plants will be in the order of 1 300 GWh.
- solar-photovoltaic:** the potential resource is estimated at 2 300 MW<sub>p</sub>. The following targets have been set for installation during the period 2005-2010: 15 MW<sub>p</sub> in isolated installations; 205 MW<sub>p</sub>

in fixed arrays of less than 100 kW<sub>p</sub>; 112 MW<sub>p</sub> in tracking arrays of less than 100 kW<sub>p</sub>, and 31 MW<sub>p</sub> in installations of greater than 100 kW<sub>p</sub>. The total increment of 363 MW<sub>p</sub>, when added to the 37 MW<sub>p</sub> of PV capacity existing in 2004, points to a total peak capacity of some 400 MW in 2010. At end-2005, 27.5% of PV capacity was off-grid and 72.5% grid-connected.

At the beginning of 2003 a 1.2 MW<sub>p</sub> solar PV plant covering 70 000 m<sup>2</sup> was opened near the town of Tudela in the Navarre region. The location of the site receives 1 600 kWh/m<sup>2</sup>/yr solar radiation; while the central section of the 12 602 PV panels is connected to the grid, the remaining 'distributed' area will be used for research on a variety of PV technologies and types of panel.

### Sweden

With its electricity generation currently dependent on nuclear and hydro, Sweden's market for solar energy is negligible. As in Norway and Finland, the main application of PV is in the domestic off-grid sector, where installations are sited in remote cabins, campers, caravans and boats.

According to the IEA (PVPS), installed PV capacity in Sweden at end-2005 amounted to 4 237 kW<sub>p</sub>, with an annual output of less than 3 GWh during 2005. Of the total capacity, 3 350 kW<sub>p</sub> (79%) was off-grid domestic, 633 kW<sub>p</sub> off-

grid non-domestic and 254 kW<sub>p</sub> grid-connected distributed.

From 15 May 2005 to the end of 2007, an investment subsidy of 70% has been made available for the installation of PV systems on public buildings. A cap of 100 million Swedish kronor (approximately € 11 million) applies, corresponding to 2-3 MW of additional PV capacity. This subsidy scheme is reported to have jump-started the Swedish PV market. By the beginning of 2006, one-third of the budget had been applied for, with much interest being shown by the major population centres of Stockholm, Gothenburg and Malmö. As a result of the subsidy, installed PV capacity will jump by 70% by around the end of 2007, and grid-connected building-integrated capacity will increase tenfold.

The market for solar thermal systems has not been strong and by end-2001 it was estimated that a total of 192 157 m<sup>2</sup> had been installed, of which 156 522 m<sup>2</sup> were flat plate collectors, 1 704 m<sup>2</sup> were vacuum collectors and 33 931 m<sup>2</sup> were unglazed collectors. The total glazed area of solar thermal collectors in operation in 2005 was 208 000 m<sup>2</sup>, giving an output capacity of about 146 MW<sub>t</sub>.

### Switzerland

Following the Government's national programme Energy 2000, launched in 1990, Swiss-Energy (also spanning 10 years) is a further programme for the promotion of renewable energy and more efficient use of energy. However, budget

reductions introduced in 2003 have cut federal support for pilot/demonstration schemes.

Switzerland has a dedicated national PV programme which covers not only all aspects of RD&D, but also the promotion of the technology and its market deployment. The implantation of PV systems continues to be driven by the 'Solar electricity from the utility' campaign and other green-power publicity. Growth in 2005 was particularly strong, with a 4.3 MW<sub>p</sub> increase in the installed capacity of grid-connected systems. Two large systems were completed by Swiss electric utilities: one of 850 kW<sub>p</sub> in Berne and the other of 1 MW<sub>p</sub> in Geneva.

The Swiss WEC Member Committee reports end-2005 capacity as 26 300 kW<sub>p</sub>. IEA-PVPS data indicate that capacity is split 10.8% off-grid domestic, 1.2% off-grid non-domestic, 78.5% grid-connected distributed and 9.5% grid-connected centralised.

The Member Committee, quoting advice from the Federal Office of Energy, shows PV output as rising from the 2005 level of 19.3 GWh to 40 GWh by 2010 and 225 GWh by 2030 – providing a cost-covering feed-in tariff scheme is adopted.

The total glazed area of solar thermal collectors in operation in 2005 was 392 000 m<sup>2</sup>, giving an output capacity of about 274 MW<sub>t</sub>.

### Tanzania

The Tanzanian WEC Member Committee, quoting the Ministry of Energy and Minerals,

reports that in recent years solar photovoltaics (PV) have been used for telecommunication, lighting, refrigeration, water pumping and powering other electronic equipment in individual residences, schools, health centres/rural dispensaries and missionary centres. The estimated current installed PV capacity in Tanzania is about 1.2 MW<sub>p</sub>, with an annual growth rate of about 20%.

Solar cooking, pasteurising and advanced solar crop-drying technologies are still in their infancy. More research and development is required to address the social and technical barriers that have been identified.

Pilot projects have been established in a number of areas in order to sensitise the communities, and will subsequently be carried out in other parts of the country.

### Thailand

Thailand has appreciable solar energy resources in almost all regions, especially in the north and northeast. The average daily solar intensity is 18.2 MJ/m<sup>2</sup>. End-2005 installed photovoltaic capacity was 23 700 kW<sub>p</sub>.

During the period to 2011, stand-alone PV systems totalling 8.57 MW are scheduled to be installed in remote areas where no transmission line access is planned.

One of the most important research programmes is the project for a PV development

laboratory and testing centre, to be completed in 2008.

Current applications of solar energy in Thailand include: solar home systems; battery charging stations; telecommunications; PV for health clinics; ocean navigator systems; greenhouse solar drying; hot water systems; PV for schools and water pumping.

### Turkey

Based on meteorological measurements made during 1966-1982, Turkey's average annual number of hours of sunshine is put at 2 640 and its average annual insolation at 1 311 kWh/m<sup>2</sup>. More recent research has, however, indicated that these levels could be considerably understated.

The republic's utilisation of its significant solar radiation resource is largely in the form of solar thermal collectors. The market was initiated during the 1970s in response to the growth of the tourism industry and the need for plentiful hot water. The country's energy supply difficulties and the political and economic uncertainties of the 1980s provided further impetus to market development. Although deployment has been extensive - it is estimated that well over 8 million m<sup>2</sup> of flat plate collectors have been installed - the sector has not demonstrated a high degree of advanced technology. Turkish customers have historically preferred simple, inexpensive installations, albeit that this approach has sometimes led to problems of utilisation and maintenance.

It is expected that the solar thermal market will continue to grow, largely through the installation of more roof-top collectors, but also possibly through larger-scale projects, such as winter-season greenhouse heating in the agricultural areas of southern Turkey.

Use of solar PV devices in Turkey has been very largely confined to official installations in remote areas: e.g. telecommunications, forest-fire observation towers and roadside emergency facilities.

### Ukraine

The average annual level of insolation is 1 070 kWh/m<sup>2</sup> in the northern regions of Ukraine and 1 400 kWh/m<sup>2</sup> in the southern regions.

The Ukrainian WEC Member Committee states that the potential use of solar energy for energy and heat supply in thousands tons of reference fuel (equal to thousands of tonnes of coal equivalent) is seen as rising as follows: 2005 – 14.6; 2010 – 50.5; 2015 – 145.1; 2020 – 328.0; 2025 – 590.96; 2030 – 927.6.

To achieve the level in 2030, it is planned to bring solar energy capacities up to 2 175 MW, including solar electrical energy up to 1 250 MW with production of 2 010 GWh/yr (0.7 million tons of reference fuel per year), and solar heat energy up to 925 MW (0.2 million tons of reference fuel per year).

Ukraine's main research programmes comprise:

- a programme of state support for the development of non-conventional and renewable energy sources and small hydro and thermal energy up to 2010. (Order of Government (Cabinet of Ministers) of Ukraine, No 1505 of 31 December 1997);
- a development programme for solar energy in Ukraine (being undertaken by the Ministry of Industry Policy).

Examples of solar energy installations include:

a 5 kW PV system for the Institute of Renewable Energy of the National Academy of Sciences; a 10 kW solar heat supply system for the NAS Botanical Garden; a 10 kW system on Zmyyny Island in the Black Sea; and a 1 kW installation in the Kyiv Polytechnic Institute.

### United Kingdom

In part for the obvious climatic reasons, the United Kingdom has not installed solar energy devices to anything like the same extent as its more southerly (and therefore generally sunnier) European colleagues. By the end of 2005, the UK's total PV capacity was 10 877 kW<sub>p</sub>, equivalent to 0.18 watts per capita, compared with Spain's 1.32 W/capita and Italy's 0.64. Even more striking is the contrast with nearer neighbours such as the Netherlands and Germany. In their cases climatic differences are clearly not so marked, but the disparity in PV

deployment is even wider, with Dutch PV averaging 3.12 W/capita and Germany way out ahead with 17.32.

In the UK there has been a Major Photovoltaic Demonstration Programme (MPDP) offering grants for small, medium and large-scale installations, which has encouraged a significant number of new projects. Installed PV capacity grew by about 33% in 2005, with the MPDP providing support for 80% of the new capacity. At the year-end, 91.5% of the UK total of 10.9 MW<sub>p</sub> was grid-connected distributed capacity.

The Demonstration Programme ended in March 2006, with the last installations funded by the scheme being completed by March 2007. Future financial support for PV installations will be furnished by the Low Carbon Buildings Programme, part of the Government's new Microgeneration Strategy.

Solar collectors for heating water are used in the UK to a limited extent. In 2005, according to DTI estimates, they contributed 172.4 GWh for heating swimming pools, and 77.1 GWh towards domestic hot water supply. The total glazed area of solar thermal collectors in operation in 2005 was 197 000 m<sup>2</sup>, giving an output capacity of about 138 MW<sub>t</sub>.

### United States of America

Raw solar resources are far in excess of all projected energy demand in the mid-term. Solar insolation levels in the US vary from less than 400 W/m<sup>2</sup> to over 700 W/m<sup>2</sup>, depending on

latitude, climate (primarily average cloud cover), terrain, and application (that is, using a fixed-angle collector compared to a collector that tracks the sun). However, the USA has approximately 9 million square kilometres of land area.

The United States Energy Association (the WEC Member Committee for the USA) reports that, according to the EIA, central station photovoltaic capacity was 11 000 kW at the end of 2005 and that, on the basis of the stock of equipment in place, there was an estimated 485 000 kW of dispersed PV capacity in operation. Output of electricity from the centralised PV capacity was 15 593 MWh, implying an average capacity factor of approximately 0.16.

Solar thermo-electric capacity at end-2005 is reported as 400.4 MW, producing 534 701 MWh during the year, at a capacity factor of 0.15.

Direct solar heating panels produced a total of 51 652 TJ in 2005.

The aim of the Department of Energy's Solar Energy Technologies Program (Solar Program) is, through public-private partnerships, to 'bring reliable and affordable solar energy technologies to the marketplace'. The Solar Program currently carries out research and development in the fields of PV and CSP systems for electricity generation, and into solar heating systems for producing hot water (or hot air) for domestic, commercial or industrial purposes. The Program is also investigating a form of solar lighting that uses small solar concentrators and fibre optics

in combination to provide daylight illumination inside buildings.

### **Uruguay**

Uruguay has a well-developed electricity grid, with about 95% of the population having a connection. The principal applications of solar energy are for water heating and photovoltaics, the latter mainly for lighting.

The Uruguayan WEC Member Committee reports that by the end of 2007, within the framework of the Energy Efficiency Project, UTE (the national electricity company) will complete the installation of 1 000 photovoltaic panels (55 W each) in low-income homes in isolated rural areas.