WORLD ENERGY COUNCIL
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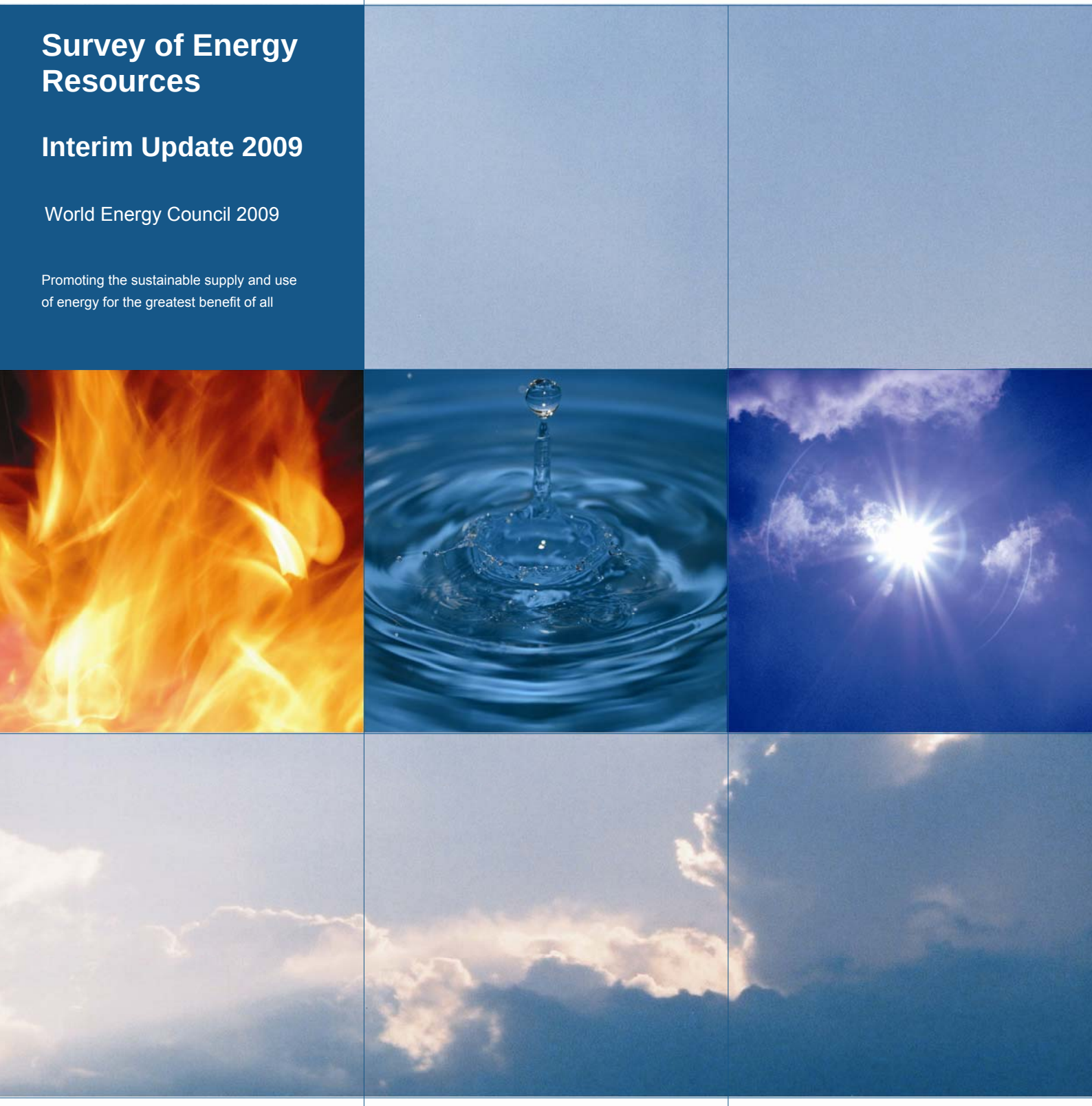
Survey of Energy Resources

Interim Update 2009

World Energy Council 2009

Promoting the sustainable supply and use of energy for the greatest benefit of all



Survey of Energy Resources Interim Update 2009

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Foreword

The 21st edition of the World Energy Council's *Survey of Energy Resources* was published in 2007 and the 22nd edition is scheduled for publication in 2010. With rapid changes taking place in the energy markets and the role of energy rising equally rapidly in public affairs, the WEC Studies Committee decided in 2008 to provide an interim update of the status of the most important energy resources.

The Studies Committee is most grateful to the Joint SER Editors Judy Trinnaman and Alan Clarke for making the time available to provide this update, which should serve interested parties as a useful document pending the next edition of the full report.

C. P. Jain
Chair WEC Studies Committee

Introduction

This review provides a concise **update of the 2007 *Survey of Energy Resources* (SER)**, based upon information available up to March 2009. It thus provides a snapshot of the world's energy resources at a point approximately mid-way through the triennial SER cycle.

Emphasis is placed upon changes in assessments of fossil-fuel reserves and in the capacity to generate electricity from renewable energy resources. The principal changes in reserves are summarised in tabular form and commented on in brief Country Notes. The Country Notes relating to renewable energy sources endeavour to cover recent developments in actual and planned capacity and utilisation, together with new or revised measures relating to the supply and use of renewable energy.

As renewable energy systems and applications develop and proliferate, it is becoming increasingly difficult to devise accurate quantifications of, for example, generating capacity and electrical output. Photovoltaic devices, especially when used off-grid, constitute a difficult area, as they are employed in a large number of applications, ranging in scale from miniscule amounts to a hundred or more megawatts.

The present review differs from the full *Survey of Energy Resources* in being entirely compiled by the Joint Editors from published material, rather than in part reflecting data and commentary provided by Member Committees of the World Energy Council. No questionnaires have been issued in this connection.

Bioenergy is possibly the hardest energy resource to quantify and furthermore is infrequently and inconsistently reported on a global basis. As the data and supporting commentary in the Country Notes on bioenergy in the full *Survey of Energy Resources* are almost entirely based upon information contributed by WEC Member Committees, the present update does not include a chapter on bioenergy.

Judy Trinnaman and Alan Clarke
Editors

1. Coal

Worldwide coal resources are well-established, and the revisions and amendments that are made from time to time are generally more in the nature of fine tuning than fundamental adjustments. Moreover, in most countries re-assessments of coal resources and reserves on a national basis are carried out only infrequently.

For the purposes of the present interim update of the *Survey of Energy Resources* (SER), the latest available estimates of proved recoverable reserves have been assembled, as far as possible on the same basis as the levels quoted in the 2007 SER. No questionnaires were sent to WEC Member Committees in this connection.

Comparing the end-2007 coal reserves compiled for this review with the end-2005 figures presented in the 2007 SER, the global total has declined by some 21 billion tonnes, or 2.5%. (see Fig. 1). Major changes have occurred in six countries, the largest of which are a reduction of 17.6 billion tonnes in South Africa, a decline of 4.4 billion in the USA and a 2.1 billion increase in India. The Country Notes below provide brief details of the background to the reserve situation in each of the countries concerned.

Table 1.1 provides a country-by-country listing of the world's coal proved reserves, as far as possible on a 'recoverable' basis, whilst Table 1.2 shows the 2007 level of coal production in each of the 70 producing countries. In both compilations, the analysis by rank should be taken as no more than indicative in most instances.

Australia

The 2008 edition of *Australia's Identified Mineral Resources*, published by Geoscience Australia, specifies only moderately changed coal resources and reserves from the levels given in the 2006 edition. Although in-situ 'Economic Demonstrated Resources' of black coal are marginally higher at 56.4 billion tonnes as at end-2007, the recoverable portion is 0.3 lower, at 38.9 billion tonnes. In-situ and recoverable brown coal tonnages both show marginal reductions.

In the case of black coal, the latest assessments of recoverable tonnages in the lower-probability categories 'subeconomic' and 'inferred' resources show rather larger differentials, with the first category a net 2 billion tonnes lower and the second some 4.6 billion tonnes (or 8%) higher than at end-2005. 'Subeconomic' and 'inferred' resources of brown coal are unchanged.

Chile

The Comisión Nacional de Energía states that Chile's coal reserves are 155 million tonnes. Although there is no indication of the date of this assessment, it has been adopted for the purpose of the present interim update in preference to the figure of 1 181 million quoted in previous *Surveys*, which dates back to 1978. A number of Chile's coal mines have ceased operating in recent years.

Colombia

The end-2007 level of proved reserves has been projected from an assessment for end-2003

Figure 1
Coal: principal changes in proved recoverable reserves
Source: compiled by WEC, based on national sources

	SER '07	SER '09	change	
	million tonnes			per cent
	(end-2005)	(end-2007)		
India	56 498	58 600	2 102	3.7
Colombia	6 959	6 814	- 145	-2.1
Australia	76 600	76 200	- 400	-0.5
Chile	1 181	155	-1 026	-86.9
United States of America	242 721	238 308	-4 413	-1.8
South Africa	48 000	30 408	-17 592	-36.7
Other countries	415 529	415 516	- 13	N
TOTAL WORLD	847 488	826 001	-21 487	-2.5

'measured reserves' produced by the Colombian geological service Ingeominas in 2004 and quoted in *Mercado Nacional e Internacional de Carbón Colombiano*, published by the Unidad de Planeación Minero Energética (UPME) of the Ministerio de Minas y Energía.

The published figure of 7 063.6 million tonnes has been reduced by the cumulative tonnage of coal produced in Colombia during the years 2004-2007, on the assumption that there were no significant additions to measured reserves during this period. The split of reserves by rank has also been estimated, assuming that the only significant sub-bituminous deposits are in the Alto San Jorge area, where the measured reserves were 381 million tonnes at end-2003 and annual output is approximately 350 000 tonnes.

India

Coal reserves have been updated from the 2007-08 edition of the Indian Ministry of Coal's Annual Report. This quotes total proved geological resources of hard coal as 99 060 million tonnes (as at 1 April 2007), an increase of 3 194 million tonnes or 3.3% over the level for 1 January 2006 quoted in the 2005-06 Annual Report. The estimated proved recoverable reserves given in the present interim review are based on the level of 52 240 million tonnes reported by the WEC Member Committee for the 2007 *Survey*, increased in line with geological resources. Proved recoverable reserves of lignite have been updated in a similar fashion.

The net change in India's total proved recoverable reserves of all ranks of coal is some 2.1 billion tonnes, representing a 3.7% increase during the 15-month period.

South Africa

Assessments of South Africa's coal resources remain in a state of flux. While a number of surveys (e.g. de Jager, 1983; Bredell, 1987; and later studies by the Minerals Bureau) have attempted to quantify the reserves present in each of South Africa's many coalfields, there is not yet total consensus in respect of the tonnages that are currently economically and technologically recoverable.

For the purpose of the present interim update of the *Survey of Energy Resources*, a figure of 30 408 million tonnes has been adopted, based on advice from an expert South African source. This level is based upon the de Jager report, with the individual coalfield reserves adjusted by subtracting cumulative coal production over the period 1982-2007, and then a view being taken of the mineability of coal in major prospective producing areas, in particular the Waterberg coalfield, but also the Springbok Flats, Limpopo and parts of the Free State coalfields. The net outcome is a total for South Africa's proved recoverable coal reserves

that is more than one-third lower than the level reported for the 2007 *Survey*, but that is arguably more realistic in the present circumstances.

United States of America

The prime source of U.S. coal reserves is the *Annual Coal Report* issued by the Energy Information Administration of the Department of Energy. The 2007 edition of this document provides detailed information on the size and location of coal resources and reserves, analysed by state and by mining method, but not by rank. By courtesy of the EIA, supplementary information has been provided which enables separate reserves for anthracite/bituminous coal, sub-bituminous coal and lignite to be included in the present interim review.

Total recoverable reserves amount to 238.3 billion tonnes, some 4.4 billion, or 1.8%, lower than the level reported by the U.S. WEC Member Committee for the 2007 *Survey*, which was also derived from EIA data. It should be borne in mind that the EIA's recoverable coal reserves are measured and indicated (proved and probable), in a commingled database, and that separate proved and probable categories are not available.

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Table 1.1
Coal: proved recoverable reserves at end-2007

Sources: published national sources; data reported for previous WEC *Surveys of Energy Resources*

Note: quantifications of proved recoverable reserves for Mongolia and Montenegro are not available

	million tonnes			
	Bituminous including anthracite	**Sub-bituminous**	**Lignite**	**Total**
Algeria	59			59
Botswana	40			40
Central African Republic			3	3
Congo (Democratic Rep.)	88			88
Egypt (Arab Rep.)	21			21
Malawi		2		2
Morocco	N			N
Mozambique	212			212
Niger	70			70
Nigeria	21	169		190
South Africa	30 408			30 408
Swaziland	208			208
Tanzania	200			200
Zambia	10			10
Zimbabwe	502			502
Total Africa	**31 839**	**171**	**3**	**32 013**
Canada	3 471	871	2 236	6 578
Greenland		183		183
Mexico	860	300	51	1 211
United States of America	108 950	99 119	30 239	238 308
Total North America	**113 281**	**100 473**	**32 526**	**246 280**
Argentina		424		424
Bolivia	1			1
Brazil		7 059		7 059
Chile		155		155
Colombia	6 434	380		6 814
Ecuador			24	24
Peru	50			50
Venezuela	479			479
Total South America	**6 964**	**8 018**	**24**	**15 006**

Table 1.1. cont.

Coal: proved recoverable reserves at end-2007

Sources: published national sources; data reported for previous *WEC Surveys of Energy Resources*

Note: quantifications of proved recoverable reserves for Mongolia and Montenegro are not available

	million tonnes			
	Bituminous including anthracite	**Sub-bituminous**	**Lignite**	**Total**
Afghanistan	66			66
China	62 200	33 700	18 600	114 500
India	54 000		4 600	58 600
Indonesia	1 721	1 809	798	4 328
Japan	355			355
Kazakhstan	28 170		3 130	31 300
Korea (Democratic People's Rep.)	300	300		600
Korea (Republic)	133			133
Kyrgyzstan			812	812
Malaysia	4			4
Mongolia				
Myanmar (Burma)	2			2
Nepal		1		1
Pakistan	1	255	1 814	2 070
Philippines	41	170	105	316
Taiwan, China	1			1
Thailand			1 354	1 354
Turkey			1 814	1 814
Uzbekistan	1 000		2 000	3 000
Vietnam	150			150
Total Asia	**148 144**	**36 235**	**35 027**	**219 406**
Albania			794	794
Bulgaria	5	63	1 928	1 996
Czech Republic	1 673	2 617	211	4 501
Germany	152		6 556	6 708
Greece			3 900	3 900
Hungary	199	170	2 933	3 302
Ireland	14			14
Italy		10		10
Montenegro				
Norway		5		5
Poland	6 012		1 490	7 502
Portugal	3		33	36
Romania	12	2	408	422
Russian Federation	49 088	97 472	10 450	157 010
Serbia	6	379	13 500	13 885
Slovakia	2		260	262
Slovenia		21	211	232
Spain	200	300	30	530
Ukraine	15 351	16 577	1 945	33 873
United Kingdom	155			155
Total Europe	**72 872**	**117 616**	**44 649**	**235 137**
Iran (Islamic Rep.)	1 386			1 386
Total Middle East	**1 386**			**1 386**
Australia	36 800	2 100	37 300	76 200
New Caledonia	2			2
New Zealand	33	205	333	571
Total Oceania	**36 835**	**2 305**	**37 633**	**76 773**
TOTAL WORLD	**411 321**	**264 818**	**149 862**	**826 001**

Table 1.2

Coal: 2007 production

Sources: published national sources; *World Mineral Production, 2003-2007*, British Geological Survey; BP *Statistical Review of World Energy*, 2008; estimates by the Editors

	million tonnes			
	Bituminous	**Sub-bituminous**	**Lignite**	**Total**
Botswana	0.8			0.8
Congo (Democratic Rep.)	N			N
Egypt (Arab Rep.)	0.1			0.1
Malawi		0.1		0.1
Mozambique	N			N
Niger	0.2			0.2
Nigeria		N		N
South Africa	247.7			247.7
Swaziland	0.3			0.3
Tanzania	N			N
Zambia	0.2			0.2
Zimbabwe	2.1			2.1
Total Africa	**251.4**	**0.1**		**251.5**
Canada	32.7	26.0	10.5	69.2
Mexico	2.0	10.5		12.5
United States of America	486.7	481.4	71.2	1 039.3
Total North America	**521.4**	**517.9**	**81.7**	**1 121.0**
Argentina	0.1			0.1
Brazil		6.0		6.0
Chile	0.2		0.1	0.3
Colombia	69.5	0.4		69.9
Peru	0.1			0.1
Venezuela	8.0			8.0
Total South America	**77.9**	**6.4**	**0.1**	**84.4**
Afghanistan	N			N
Bangladesh	0.5			0.5
Bhutan	0.1			0.1
China	2 470.0		66.0	2 536.0
Georgia	N			N
India	444.8		33.6	478.4
Indonesia	174.8			174.8
Japan	1.4			1.4
Kazakhstan	90.0		4.4	94.4
Korea (Democratic People's Rep.)	27.0	8.0		35.0
Korea (Republic)		2.9		2.9
Kyrgyzstan	0.1		0.3	0.4
Laos	0.6			0.6
Malaysia		1.1		1.1
Mongolia	0.1		8.7	8.8
Myanmar (Burma)			0.3	0.3
Nepal		N		N
Pakistan	0.3	2.6	1.0	3.9
Philippines		3.7		3.7
Tajikistan	0.3	N		0.3
Thailand			18.2	18.2
Turkey	3.2		74.4	77.6
Uzbekistan	0.1		2.7	2.8
Vietnam	39.8			39.8
Total Asia	**3 253.1**	**18.3**	**209.6**	**3 481.0**

Table 1.2 cont.

Coal: 2007 production

Sources: published national sources; *World Mineral Production, 2003-2007*, British Geological Survey; BP *Statistical Review of World Energy*, 2008; estimates by the Editors

	million tonnes			
	Bituminous	**Sub-bituminous**	**Lignite**	**Total**
Albania			N	N
Austria			N	N
Bosnia-Herzogovina			10.5	10.5
Bulgaria	N		28.3	28.3
Czech Republic	12.9	48.9	0.4	62.2
France			0.3	0.3
Germany	21.5		180.4	201.9
Greece			63.5	63.5
Hungary	0.8		9.7	10.5
Italy		0.2		0.2
Macedonia (Republic)			6.6	6.6
Montenegro			1.2	1.2
Norway		3.2		3.2
Poland	88.2		57.5	145.7
Romania	1.8		30.7	32.5
Russian Federation	230.0		85.0	315.0
Serbia	0.1		37.6	37.7
Slovakia			2.1	2.1
Slovenia			4.6	4.6
Spain	7.9	3.1	6.2	17.2
Ukraine	76.3		0.2	76.5
United Kingdom	17.0			17.0
Total Europe	**456.5**	**55.4**	**524.8**	**1 036.7**
Iran (Islamic Rep.)	1.5			1.5
Total Middle East	**1.5**			**1.5**
Australia	289.7	36.0	65.6	391.3
New Zealand	2.0	2.5	0.3	4.8
Total Oceania	**291.7**	**38.5**	**65.9**	**396.1**
TOTAL WORLD	**4 853.5**	**636.6**	**882.1**	**6 372.2**

2. Crude Oil and Natural Gas Liquids

Compared with coal, oil (and gas) reserves tend to be more subject to change from year to year, but fundamental restatements are fairly infrequent, as the principal sedimentary basins have been identified and, in most cases, explored, at least to some extent.

Fig. 2 shows that the end-2007 proved recoverable reserves of crude oil and NGLs compiled for the present review are 31.9 billion barrels (just over 4 billion tonnes) higher than the end-2005 total quoted in the 2007 SER. Thirteen countries account for the bulk of the 2.6% global increase. The chief quantitative increases in reserves are seen in Venezuela, the Russian Federation and Canada, while proved reserves in Mexico, Norway and Iran have each decreased by between 1.3 and 1.5 billion barrels. After allowing for the 13 countries specified in Fig. 2, the remainder of the 98 countries listed as possessing proved oil reserves in Table 2.1 effectively balance each other off.

Proved recoverable reserves of crude oil and NGLs are listed in Table 2.1, with the 2007 level of oil production shown in Table 2.2. The levels of NGL production are often at least partially estimated.

Brazil

Proved reserves have been derived from the level of 'measured/indicated/inventoried' reserves quoted in the *Balanço Energético Nacional 2008* (BEN), published by the Ministério de Minas e Energia. Compared with the level of oil reserves reported by the WEC Member Committee for the 2007 *Survey* (which was identical to the BEN figure for end-2005) the current level is some 850 million barrels (or just over 7%) higher.

Much interest is currently being shown in Brazil's offshore (especially deep-water) oil fields and in particular the massive reserves discovered in the pre-salt formation.

Canada

The levels of proved recoverable reserves adopted for this interim update correspond with the 'Remaining Reserves at 2007-12-31' reported by the Reserves Committee of the Canadian Association of Petroleum Producers (CAPP) in the *CAPP Statistical Handbook*, March 2009. These 'Remaining Reserves' comprise 797 million m^3 of conventional crude oil, 187 million m^3 of natural gas liquids (67 pentanes plus and 120 ethane/propane/butane) and 2 158 million m^3 oil sands and natural bitumen (1 371 'developed mining - upgraded and bitumen' and 787 'developed in-situ - bitumen').

In all, Canada's proved oil reserves now amount to 3 142 million m^3, equivalent to 19 762 million barrels. Compared with the end-2005 levels quoted in the 2007 *Survey*, total reserves have increased by 31.4%, owing almost entirely to a substantial rise in the amount of oil deemed to be recoverable from Canada's oil sands, with a 40.9% growth in developed synthetic oil reserves and a doubling of developed bitumen reserves.

The Energy Resources Conservation Board reports that in 2007 Canada had 27.45 billion m^3 (172.7 billion barrels) of 'established oil sands reserves'.

Figure 2
Crude oil and natural gas liquids: principal changes in proved recoverable reserves
Source: compiled by WEC, based on national sources

	SER '07	SER '09	change	
	million barrels			per cent
	(end-2005)	(end-2007)		
Venezuela	80 012	99 377	19 365	24.2
Russian Federation	74 400	79 400	5 000	6.7
Canada	15 034	19 762	4 728	31.4
Libya/GSPLAJ	41 464	43 663	2 199	5.3
China	16 189	18 052	1 863	11.5
Gabon	2 146	3 184	1 038	48.4
Malaysia	3 000	4 000	1 000	33.3
Brazil	11 772	12 623	851	7.2
United States of America	29 922	30 460	538	1.8
United Kingdom	4 020	3 390	- 630	-15.7
Iran (Islamic Rep.)	137 490	136 150	- 1 340	-1.0
Norway	9 547	8 163	- 1 384	-14.5
Mexico	13 671	12 186	- 1 485	-10.9
Other countries	776 519	776 663	144	N
TOTAL WORLD	1 215 186	1 247 073	31 887	2.6

This term is defined by the National Energy Board (June 2006) as 'the sum of the proven reserves and half probable reserves'. The ERCB figure amply illustrates the enormous extent of the oil sands resource.

China

China's reserves remain a state secret, and thus it is necessary to have recourse to published sources. For the purposes of the present interim update, *World Oil*'s estimates have been retained, involving an 11.5% increase from 16 189 million barrels at end-2005 to 18 052 million barrels at end-2007. Other published assessments of China's oil reserves range down to the figure of 15 500 million barrels quoted by BP and the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR).

Ecuador

Ecuador reactivated its membership of OPEC in October 2007, after suspending it in December 1992.

Gabon

The level adopted for Gabon's end-2007 reserves reflects that quoted by *World Oil*, as did the figure for end-2005 given in the 2007 *Survey.* The difference of over a billion barrels between the two assessments corresponds to a leap of over 48% and implies a significant reappraisal of Gabon's potential.

Ghana

The Jubilee field, a substantial oil discovery that straddles two deep water exploration licence areas (Deepwater Tano and West Cape Three Points) in Ghana's offshore, is being developed by the field

operator Tullow Oil, with first production scheduled for the second half of 2010. In March 2009, Tullow announced another promising discovery (Tweneboa-1) in the Deepwater Tano licence area, about 25 km west of the Jubilee field.

India

Cairn Energy has made 25 discoveries in Rajasthan (in India's northwest) and currently has six fields under development. Initial attention is being concentrated on Mangala, Bhagyam and Aishwariya (MBA). Production from Mangala is scheduled to begin in third quarter 2009. Output from the MBA fields is estimated to peak at 175 000 b/d, which would represent at least 20% of India's total oil production.

Indonesia

After being a member since 1962, Indonesia suspended its OPEC membership in December 2008.

Iran (Islamic Republic)

The OPEC *Annual Statistical Bulletin 2007* quotes Iran's proved crude oil reserves as 136 150 million barrels at end-2007, 1% lower than the end-2005 level of 137 490 reported by the Iranian WEC Member Committee for the 2007 *Survey*. With the exception of *World Oil* (137 000), the other published sources appear to follow OPEC, reproducing its end-2006 figure of 138 400, or in the case of the December 2008 *Oil & Gas Journal*, its end-2007 level.

Libya/GSPLAJ

The OPEC *Annual Statistical Bulletin 2007* quotes Libya's proved crude oil reserves as 43 663 million barrels at end-2007, 5.3% higher than the end-2005 level of 41 464 million barrels quoted in the 2007 *Survey*. Other published estimates of Libya's oil reserves, with the exception of a somewhat lower figure in *World Oil*, seem to fall into two camps, depending on whether they reflect OPEC's end-2006 or end-2007 level.

Malaysia

With a view to consistency, the *Survey of Energy Resources* has used the *Oil & Gas Journal*'s reserves report as its source for Malaysia for at least the last ten years. The latest OGJ assessment gives a figure of 4 billion barrels for both 1 January 2008 and 1 January 2009, an increase of one third over the 1 January 2007 level. The other published compilations range from OPEC's 2 840 million barrels to BP, BGR and *World Oil* at around 5 400.

Mexico

End-2007 proved reserves are based on information released by Petroleos Mexicanos (Pemex) on 26 March 2008 and reflect (in millions of barrels) the sum of 10 501.2 crude oil, 559.6 condensate and 1 125.7 natural gas liquids obtained from processing plants – a total of 12.186 billion barrels. Overall the level of oil reserves has fallen by nearly 1.5 billion barrels (-10.9%) from the end-2005 level reported for the 2007 *Survey* by the

Mexican WEC Member Committee (again using Pemex data).

In its report on reserves, Pemex also quotes 'probable' oil reserves totalling 12.173 billion barrels and 'possible' reserves totalling 11.305 billion barrels.

Neutral Zone

It was reported in March 2009 that Chevron would shortly begin large-scale testing of a heavy-oil extraction technique in the partitioned Neutral Zone between Saudi Arabia and Kuwait. The American company has recently been granted a 30-year extension to its Neutral Zone operating licence by the Saudi Government.

Norway

In this interim update, as for the 2007 *Survey*, Norway's oil reserves have been derived from a report of the Norwegian Petroleum Directorate. The publication *Facts 2008* quotes 'remaining reserves' of (crude) oil as 1 013 million cubic metres, NGL as 123 million tonnes and condensate as 51 million cubic metres. Converting these numbers into standard units, total oil reserves amount to 8 163 million barrels or 1 008 million tonnes. Compared with the end-2005 level reported in the 2007 *Survey*, this represents an overall fall of 1 384 million barrels, or 14.5%.

However, *Facts 2008* also reports substantial quantities of recoverable potential in lower-probability categories: namely, 'contingent resources in fields and discoveries', 'potential from improved recovery' and 'undiscovered oil'. Together, contingent resources and improved recovery could contribute an additional 632 million cubic metres of crude oil, 41 million tonnes of NGL and 49 million cubic metres of condensate – a total of some 4 773 million barrels. Undiscovered crude oil and condensate resources are estimated to add around 9.6 billion barrels to Norway's eventually recoverable potential.

Russian Federation

The level of proved recoverable oil reserves adopted for the present interim update is based, as was the corresponding figure in the 2007 *Survey*, on that given by BP in its *Statistical Review of World Energy*. The June 2008 edition quotes 79 400 million barrels, an increase of 5 billion barrels, or 6.7%, on the comparable end-2005 figure. Other published sources quote levels either close to BP's (*World Oil* and BGR) or a good deal lower (OAPEC and OGJ).

Uganda

The independent oil companies Heritage Oil and Tullow Oil are seeking to develop the promising oil fields that they have discovered in the vicinity of Lake Albert in Uganda. Full exploitation of these deposits would require the construction of an export pipeline to the Indian Ocean coast.

United Kingdom

The Department of Energy and Climate Change reported in September 2008 that total UK proven oil reserves (with a better than 90% chance of being produced) were 452 million tonnes (3 390

million barrels) at end-2007. 'Probable' reserves (with a better than 50% chance of being technically and economically producible) are put at 328 million tonnes, whilst 'possible' reserves (with a significant, but less than 50%, chance) are estimated at 399 million tonnes. Since the end of 2005, there has been an increase of 28 million tonnes (9.3%) in 'probable' reserves and a decrease of 52 million tonnes (-11.7%) in the 'possible' category.

United States of America

In its 2007 *Annual Report on U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves* (Advance Summary, October 2008), the Energy Information Administration reports that there was a small rise in proved reserves of crude oil in 2007, with additions of 2.0 billion barrels. After deduction of crude production of 1.7 billion barrels during the year, proved reserves at end-2007 were 21.3 billion barrels, an increase of 1.6% over the end-2006 level, but a decrease of 2.0% on the end-2005 total.

Approximately 39% of proved reserve additions were accounted for by discoveries arising from drilling exploratory wells – including extensions to known fields, discovery of new fields, and of new reservoirs in old fields. Most of the remaining additions were due to revisions arising during the development of previously discovered reservoirs or fields.

Proved reserves of natural gas liquids rose by 671 million barrels to 9 143 million barrels. Nearly three-quarters of the additions to proved NGL reserves were attributable to discoveries arising from drilling exploratory wells. Overall, U.S. proved reserves of crude oil and NGL have increased by 1.8% above the level quoted in the 2007 SER.

Venezuela

The OPEC *Annual Statistical Bulletin 2007* quoted in this interim review shows Venezuela's proved crude oil reserves as increasing from 80 012 million barrels at end-2005 to 99 377 million barrels at end-2007, a rise of just over 19 billion barrels, or more than 24%. Of the other major published sources, only the December 2008 *Oil & Gas Journal* was able to pick up the latest level: the other sources (apart from *World Oil*) reflect the end-2006 level quoted by OPEC.

Table 2.1

Crude oil and natural gas liquids: proved recoverable reserves at end-2007

Sources: published national sources; *Oil & Gas Journal*, December 2007 and December 2008; *World Oil*, September 2008; *Annual Statistical Report 2008*, OAPEC; *Annual Statistical Bulletin 2007*, OPEC; BP *Statistical Review of World Energy*, 2008; data reported for previous WEC *Surveys of Energy Resources*

	million tonnes	million barrels
Algeria	2 731	23 241
Angola	1 282	9 500
Benin	1	8
Cameroon	168	1 212
Chad	222	1 500
Congo (Brazzaville)	274	1 940
Congo (Democratic Rep.)	25	180
Côte d'Ivoire	64	471
Egypt (Arab Rep.)	561	4 200
Equatorial Guinea	231	1 705
Ethiopia	N	N
Gabon	436	3 184
Ghana	2	15
Libya/GSPLAJ	5 634	43 663
Mauritania	14	100
Morocco	N	1
Nigeria	4 860	36 500
Senegal	N	N
South Africa	2	15
Sudan	904	6 700
Tunisia	69	535
Total Africa	17 480	134 670
Barbados	N	2
Belize	1	7
Canada	2 818	19 762
Cuba	19	124
Guatemala	13	83
Mexico	1 645	12 186
Trinidad & Tobago	80	606
United States of America	3 717	30 460
Total North America	8 293	63 230
Argentina	358	2 616
Bolivia	54	465
Brazil	1 706	12 623
Chile	3	30
Colombia	184	1 358
Ecuador	668	4 780
Peru	124	1 121
Surinam	13	88
Venezuela	13 997	99 377
Total South America	17 107	122 458

Table 2.1 cont.

Crude oil and natural gas liquids: proved recoverable reserves at end-2007

Sources: published national sources; *Oil & Gas Journal*, December 2007 and December 2008; *World Oil*, September 2008; *Annual Statistical Report 2008*, OAPEC; *Annual Statistical Bulletin 2007*, OPEC; BP *Statistical Review of World Energy*, 2008; data reported for previous WEC *Surveys of Energy Resources*

	million tonnes	million barrels
Azerbaijan	950	7 000
Bangladesh	3	28
Brunei	147	1 100
China	2 466	18 052
Georgia	5	35
India	725	5 720
Indonesia	529	3 990
Japan	6	44
Kazakhstan	5 038	39 800
Kyrgyzstan	5	40
Malaysia	487	4 000
Myanmar (Burma)	7	50
Pakistan	40	327
Philippines	16	138
Taiwan, China	N	2
Tajikistan	2	12
Thailand	49	441
Turkey	165	1 201
Turkmenistan	81	600
Uzbekistan	70	594
Vietnam	453	3 400
Total Asia	11 244	86 574
Albania	30	199
Austria	7	50
Belarus	27	198
Bulgaria	2	15
Croatia	10	79
Czech Republic	9	61
Denmark	149	1 113
France	16	120
Germany	37	272
Greece	1	10
Hungary	20	167
Italy	106	744
Lithuania	64	467
Netherlands	12	93
Norway	1 013	8 163
Poland	16	116
Romania	53	397
Russian Federation	10 700	79 400
Serbia	11	78
Slovakia	1	9
Slovenia	N	N
Spain	20	150
Ukraine	151	1 290
United Kingdom	452	3 390
Total Europe	12 907	96 581
Bahrain	16	125
Iran (Islamic Rep.)	18 450	136 150
Iraq	15 478	115 000
Israel	N	2
Jordan	N	1
Kuwait	13 679	101 500
Oman	771	5 700
Qatar	1 853	15 210
Saudi Arabia	34 542	264 250
Syria (Arab Rep.)	335	2 459
United Arab Emirates	12 555	97 800
Yemen	345	2 670
Total Middle East	98 024	740 867
Australia	264	2 457
New Zealand	18	148
Papua New Guinea	11	88
Total Oceania	293	2 693
TOTAL WORLD	165 348	1 247 073

Table 2.2

Crude oil and natural gas liquids: 2007 production

Sources: published national sources; *Oil & Gas Journal*, December 2008; BP *Statistical Review of World Energy*, 2008; *Annual Statistical Bulletin 2007*, OPEC; *Annual Statistical Report 2008*, OAPEC; *Energy - Monthly Statistics, 1/2009*, Eurostat; estimates by the Editors

	thousand barrels per day		
	Crude oil	**NGLs**	**Total**
Algeria	1 388	600	1 988
Angola	1 698		1 698
Cameroon	85		85
Chad	145		145
Congo (Brazzaville)	222		222
Congo (Democratic Rep.)	20		20
Côte d'Ivoire	22		22
Egypt (Arab Rep.)	630	80	710
Equatorial Guinea	363		363
Gabon	230		230
Ghana	6		6
Libya/GSPLAJ	1 710	135	1 845
Mauritania	17		17
Morocco	N		N
Nigeria	2 130	225	2 355
South Africa	14	6	20
Sudan	457		457
Tunisia	96	1	97
Total Africa	**9 233**	**1 047**	**10 280**
Barbados	1		1
Canada	2 587	687	3 274
Cuba	54		54
Guatemala	15		15
Mexico	3 076	395	3 471
Trinidad & Tobago	105	49	154
United States of America	5 064	1 783	6 847
Total North America	**10 902**	**2 914**	**13 816**
Argentina	678	20	698
Bolivia	41	8	49
Brazil	1 753	47	1 800
Chile	3	12	15
Colombia	531	20	551
Ecuador	508	9	517
Peru	77	37	114
Surinam	15		15
Venezuela	2 413	200	2 613
Total South America	**6 019**	**353**	**6 372**
Azerbaijan	852	16	868
Bangladesh	1	4	5
Brunei	184	10	194
China	3 743		3 743
Georgia	1	N	1
India	689	112	801
Indonesia	838	131	969
Japan	17		17
Kazakhstan	1 138	352	1 490
Kyrgyzstan	1	N	1
Malaysia	535	220	755
Mongolia	2		2
Myanmar (Burma)	21	1	22
Pakistan	69	12	81
Philippines	1	16	17
Taiwan, China	N		N
Tajikistan	N	N	N
Thailand	134	166	300
Turkey	41		41
Turkmenistan	190	8	198
Uzbekistan	60	54	114
Vietnam	322	11	333
Total Asia	**8 839**	**1 113**	**9 952**

Table 2.2 cont.

Crude oil and natural gas liquids: 2007 production

Sources: published national sources; *Oil & Gas Journal*, December 2008; BP *Statistical Review of World Energy*, 2008; *Annual Statistical Bulletin 2007*, OPEC; *Annual Statistical Report 2008*, OAPEC; *Energy - Monthly Statistics, 1/2009*, Eurostat; estimates by the Editors

	thousand barrels per day		
	Crude oil	**NGLs**	**Total**
Albania	10		10
Austria	17	2	19
Belarus	35		35
Bulgaria	N		N
Croatia	16	5	21
Czech Republic	7		7
Denmark	312		312
France	20	1	21
Germany	67	2	69
Greece	2	N	2
Hungary	16	13	29
Italy	112	1	113
Lithuania	3		3
Netherlands	43	12	55
Norway	2 211	345	2 556
Poland	15		15
Romania	99	7	106
Russian Federation	9 380	598	9 978
Serbia	13		13
Slovakia	N		N
Slovenia	N		N
Spain	3		3
Ukraine	62	53	115
United Kingdom	1 446	192	1 638
Total Europe	**13 889**	**1 231**	**15 120**
Bahrain	35	10	45
Iran (Islamic Rep.)	4 031	370	4 401
Iraq	2 115	30	2 145
Israel	N		N
Jordan	N		N
Kuwait	2 575	40	2 615
Oman	710	6	716
Qatar	845	352	1 197
Saudi Arabia	8 966	1 447	10 413
Syria (Arab Rep.)	370	10	380
United Arab Emirates	2 529	386	2 915
Yemen	315	10	325
Total Middle East	**22 491**	**2 661**	**25 152**
Australia	340	200	540
New Zealand	41	4	45
Papua New Guinea	47		47
Total Oceania	**428**	**204**	**632**
TOTAL WORLD	**71 801**	**9 523**	**81 324**

3. Oil Shale

At the present time there are a very few countries that utilise their oil shale resource either for direct use in the generation of electricity or for conversion into petroleum products. However, during the period of high oil prices in 2007-2008, and for those countries which had previously quantified their resource or undertaken feasibility studies, development of their oil shale resource became closer to being economically viable. Lower oil prices have not only reduced that viability but the passage of time has seen the tightening of environmental regulations. In the case of both Australia and the U.S., the Government has declared that any development will move slowly, with the environmental impact being fully researched. Furthermore, the technology for in-situ processing still has some years of research before it could be considered for use on a commercial scale.

Australia

Queensland Energy Resources (QER) spent the period 2005-2007 testing indigenous Australian oil shale at a pilot plant in the U.S. State of Colorado. QER successfully demonstrated that, by using the Paraho Process, it could operate an oil shale-to-liquids business in Queensland.

Following QER's acquisition of the Stuart oil shale project from SPP, the company planned to replace the rotating horizontal Alberta-Taciuk Processor (ATP) retort, with the vertical Paraho retort. However, in August 2008 the Queensland Government announced that it had issued a 20-year moratorium on the development of QER's other oil shale resource, McFarlane. The McFarlane deposit, located some 15 km south of Proserpine in central Queensland, is considered a strategically important resource with the potential to supply in excess of 1.6 billion barrels of oil.

At the time of the State Government's legislation the company was carrying out pre-feasibility testing of the McFarlane resource and although development of the Stuart deposit is not precluded, the moratorium has caused QER to re-examine its plans for the future of both the Stuart and the McFarlane projects.

Brazil

The policy relating to the development of the oil shale resource has changed in the light of the discoveries of huge oil reserves in deep and ultra-deep water, and latterly the pre-salt.

The oil shale facilities within Brazil are currently operating at near design capacity: 3 800 b/d of shale oil (480 t/d shale fuel oil, 90 t/d naphtha), 120 t/d fuel gas, 45 t/d LPG and 75 t/d sulphur.

The intention of Petrobras is to maintain the technological expertise and development of its indigenous capacity but without expansion. However, the company will assist in feasibility studies and development of oil shale projects in countries which also have rich reserves of oil shale. At the present time a comprehensive feasibility study for a 50 000 b/d plant in Utah, USA is in progress, with a forecast completion date of September 2009. Additionally, studies on the Wadi Maghar project in Jordan and the Timahdit project

in Morocco are being undertaken and are forecast to be completed within 36 months.

China

During 2007, the Fushun Mining Group Co. (Liaoning Province) was operating 180 Fushun-type retorts, each capable of processing 100 tonnes of oil shale per day. Output totalled 300 000 tonnes shale oil. By end-2008 it was expected that 220 Fushun retorts would be operating, with an output of 330 000 tonnes shale oil. The shale ash by-product is utilised to produce building materials. It is predicted that a 6 000 t/d ATP retort, imported by Fushun will be operational by end-2009.

Many other retorts are either operating or being planned in the provinces of Gansu, Guangdong, Hainan, Heilongjiang and Jilin.

It was reported during 2007 that the Bureau of Geological Survey of China was undertaking a review of the oil shale resource and its utilisation.

Estonia

The Estonian oil shale industry remains of vital importance to the country and Eesti Energia (EE) is the largest oil shale processing entity in the world. EE continues to work on the technology of oil shale retorting including reducing the environmental impact. To this end the company plans to export its expertise to other oil shale-rich countries.

Following a decrease to 14.1 million tonnes of oil shale in 2006, output in 2007 rose 17.4% to 16.5 million tonnes. Consumption of oil shale for electricity generation amounted to 16.8 million tonnes during 2007, a rise of nearly 20%, and output of shale oil amounted to 77 thousand tonnes.

Israel

Whilst the country investigates the possibilities of harnessing its large oil shale deposits for producing shale oil, some of the resource is utilised for the production of electricity. In 1990 just over 300 000 tonnes were used and by 2006 consumption had risen to 450 000 tonnes.

Jordan

Jordan, with the help of other countries well-endowed with oil shale, continues to work towards the day when its vast oil shale resource can be exploited, both for the production of shale oil and also for electricity generation. In this respect the Jordan Oil Shale Energy Company (JOSECO) was established in 2006, with the express role of furthering this development.

In January 2009, it was reported that a contract between the Estonian company Eesti Energia (EE) and the Government had been signed for the exploration of oil shale in southern Jordan and for a power station to be constructed. EE will undertake a 3-year feasibility study.

Morocco

In order to confirm the findings of the feasibility studies undertaken during the 1980s, the Office National des Hydrocarbures et des Mines in mid-2008 engaged Petrobras and Total to re-evaluate the Timahdit oil shale deposits. The 2-year study

will look at all aspects of developing the resource, which will be examined in the light of current economic and environmental conditions. An oil-producing facility using Petrobras's Petrosix technology will be considered.

Thailand

The Thai Government has instituted a 4-year project to study the feasibility of developing and utilising the Mae Sot oil shale deposit. The 2008-2011 study will look at all aspects of exploration and development, including an investigation as to the suitability of using the retort ash in the building industry.

United States of America

The possibility of developing the vast oil shale resource of the U.S. remains the subject of much research and discussion. On the one hand, the in-situ process technologies being developed by, for example, Shell and ExxonMobil, must be proved on a commercial scale and on the other, the new Federal Administration must release land, in order for commercial development to occur. In mid-2008 the Department of the Interior's Bureau of Land Management (BLM) published proposed regulations to establish a commercial oil shale programme. The legislation was to provide a phased approach for the development on public lands in oil shale-rich western states. However, first in January 2009 and then again in February, the new Administration announced that it was withdrawing the previous Administration's expanded RD&D leases and that, although offering a second round of RD&D leases, the oil shale programme would progress much more slowly.

4. Natural Bitumen and Extra-Heavy Oil

Although many countries possess resources of natural bitumen/extra-heavy oil, it is Canada and Venezuela that dominate the market. Like oil shale, development was encouraged by high oil prices and subsequently adversely affected by the lower price and also environmental concerns. Both countries have large developments: Canada is seeing a rationalisation of its market players and the Venezuelan Government has taken the majority share in its Orinoco projects and has enlisted the help of foreign entities, many of them state oil companies, to re-evaluate and ultimately to increase its extra-heavy oil reserves.

Canada

The current global economic crisis and environmental concerns are affecting the rate of development of Canada's vast oil sands resource. The higher costs of capital, construction materials, labour and a new provincial royalty scheme which came into effect on 1 January 2009 are playing a significant role in deciding whether projects are scaled down, delayed or possibly suspended. From a financial viewpoint, mergers and acquisitions are occurring, particularly where the smaller market players are involved. Environmentally, the extraction of natural bitumen is complex and historically has required large amounts of water and natural gas - research is under way into ways to reduce both. Furthermore, greenhouse gases are emitted when upgrading technology is used and other methods of extraction are being studied.

In February 2009 the Government of Alberta released *Responsible Actions: a Plan for Alberta's Oil Sands*, a 20-year strategic plan. The aim of the Plan is to reduce the environmental footprint, to optimise economic growth and to increase the quality of life in oil sands regions.

Venezuela

The Venezuelan Government's *Plan Siembra Petrolera (Oil Sowing Plan)* 2005-2030 includes six development projects which are timed to take place in two stages: 2005-2012 and 2012-2030.

The Magna Reserva, the first of the six fundamental axes of the Plan, will ultimately certify and increase the oil reserves in the Orinoco Belt. The Orinoco Project, the second axis, concerns development of the Orinoco Belt. It covers the 27 development blocks which are being studied by the foreign, mostly state, oil companies working with PDVSA (Petróleos de Venezuela). During 2008 it was reported that the project had certified an additional 50 billion barrels of new reserves, about half of which was said to be in the Carabobo block.

In October 2008, a new round of bidding took place, centred specifically on 7 blocks in the Carabobo area. PDVSA will be the majority partner in each project, each of which will consist of integrated upstream and upgrading facilities.

5. Natural Gas

As is the case with oil, proved recoverable reserves of natural gas show a moderate (in this instance, 2.2%) overall increase between end-2005 as quoted in the 2007 SER and end-2007 as compiled for the present interim update. Fig. 3 demonstrates that gas reserves in three countries (Iran, the USA and Kuwait) have each risen by around a trillion cubic metres, while those of Kazakhstan have fallen by a similar amount. In all, eleven countries account for the bulk of the changes in reserve levels, with the changes in 41 other countries (out of a total of 103 listed as possessing gas reserves) effectively netting off to zero. Brief details of the principal movements in gas reserves are given in the Country Notes below.

Table 5.1 provides a country-by-country listing (in billion cubic metres and billion cubic feet) of proved recoverable natural gas reserves at end-2007. The 2007 levels of marketed gas production, after allowance for re-injection, flaring and shrinkage (due to extraction of NGLs), are shown in Table 5.2.

Australia

The latest data on natural gas reserves published by Geoscience Australia as a component of its report on the *Oil and Gas Resources of Australia* (OGRA) relates to the situation as at 1 January 2006. At this point in time there was a total of 906.54 bcm of sales gas in Category 1 (comprising 'current reserves of those fields which have been declared commercial. It includes both proved and probable reserves'). This figure compares with the 1 January 2005 total of 754.66 bcm in this category (also referred to as 'remaining commercial reserves') quoted in OGRA 2004.

Probably as a result of adopting differing definitions of 'proved reserves', other published sources tend to quote substantially higher levels (ostensibly for end-2007), and would appear to include either Category 2 (non-commercial reserves) or to have adopted the McKelvey classification, in which 'economic demonstrated resources' include an element of extrapolation.

China

So long as China's reserves remain a state secret, it is necessary to have recourse to published sources. For the purposes of the present interim update, Cedigaz estimates have been retained, involving an increase from 2 350 bcm at end-2005 to 3 000 bcm in 2007 (note that Cedigaz's latest published reserves relate to 1 January 2007). Other published assessments of China's gas reserves range from 1 750 to 2 500 bcm, with no two estimates being the same.

Egypt (Arab Republic)

A succession of gas discoveries has boosted Egypt's reserves in recent years. In December 2008, the Chairman of the Egyptian Natural Gas Holding Company (EGAS) stated that by June of that year gas reserves had reached 76 tcf (equivalent to around 2 150 bcm). This implies an increase of 9.1 tcf (258 bcm) over the end-2005 level of 66.9 tcf reported by the Egyptian WEC Member Committee for the 2007 *Survey.*

Figure 3

Natural gas: principal changes in proved recoverable reserves

Source: compiled by WEC, based on national sources

	SER '07	SER '09	change	
	billion cubic metres			per cent
	(end-2005)	(end-2007)		
Iran (Islamic Rep.)	26 740	28 080	1 340	5.0
United States of America	5 866	6 823	957	16.3
Kuwait	1 586	2 506	920	58.0
China	2 350	3 000	650	27.7
Venezuela	4 315	4 838	523	12.1
Saudi Arabia	6 848	7 153	305	4.5
Egypt (Arab Rep.)	1 894	2 152	258	13.6
Australia	755	907	152	20.1
United Kingdom	481	343	- 138	-28.7
Vietnam	365	220	- 145	-39.7
Kazakhstan	3 000	1 900	-1 100	-36.7
Other countries	122 262	122 350	88	0.1
TOTAL WORLD	176 462	180 272	3 810	2.2

Iran (Islamic Republic)

The OPEC *Annual Statistical Bulletin 2007* quotes Iran's proved natural gas reserves as 28 080 bcm at end-2007, 5% higher than the end-2005 level of 26 740 bcm reported by the Iranian WEC Member Committee for the 2007 *Survey*. There appears to be a high degree of consensus amongst the major published sources regarding Iran's gas reserves.

Kazakhstan

The estimates of proved recoverable reserves of gas adopted for the 2007 *Survey* and for the present update are derived from the *BP Statistical Review of World Energy.* The June 2008 edition of this publication quotes Kazakhstan's proved reserves as 1 900 bcm at end-2007 and also implies a retrospective scaling-down of the end-2006 estimate from 3 000 to 1 900 bcm.

While published figures vary widely, rising as high as 3 380 bcm in the 2007 reserves report from the BGR, it may be of some significance that *Oil & Gas Journal*'s latest tabulation of world gas reserves (December 2008) shows a decrease in Kazakhstan from 100 000 bcf (2 832 bcm) at 1 January 2008 to 85 000 bcf (2 407 bcm) at 1 January 2009.

Kuwait

The level of proved reserves of natural gas adopted for this review reflects the estimates compiled and published by OAPEC in its *Annual Statistical Report*, as did that in the 2007 *Survey*. The end-2007 figure is considerably higher than that for end-2005, reflecting major discoveries of non-associated gas in 2006, which have helped to increase Kuwait's proved reserves by 920 bcm, or 58%, over the two years.

Saudi Arabia

Proved reserves, as reported by OAPEC, rose from 6 848 bcm at the end of 2005 to 7 153 at end-2007, implying an increase of 4.5%. Other major published sources quote similar levels.

United Kingdom

The Department of Energy and Climate Change reported in September 2008 that total UK proven gas reserves (with a better than 90% chance of being produced) were 343 bcm at end-2007. This compares with a total of 481 bcm two years previously, and represented a decrease of 28.7%. The end-2007 reserves comprised 145 bcm of gas from dry gas fields, 129 bcm of gas from condensate fields and 69 bcm of associated gas from oil fields.

'Probable' reserves (with a better than 50% chance of being technically and economically producible) are put at 304 bcm, whilst 'possible' reserves (with a significant, but less than 50%, chance) are estimated at 293 bcm. Since the end of 2005, there has been an increase of 57 bcm (23.1%) in 'probable' reserves and one of 15 bcm (5.4%) in the 'possible' category.

United States of America

In its 2007 *Annual Report on U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves* (Advance Summary, October 2008), the Energy Information Administration (EIA) states that there was a significant increase in proved reserves of natural gas in 2007, with additions of 46.1 tcf (circa 1 300 bcm). After deduction of gas production of 19.5 tcf during the year, proved reserves at end-2007 were 237.7 tcf, an increase of 13% over the end-2006 level. The EIA attributes the record addition in reserves to the rapid development of coalbed methane resources and, with the use of advanced technologies, gas in shale reservoirs and tight formations.

Approximately 63% of proved reserve additions were accounted for by discoveries arising from drilling exploratory wells – including extensions to known fields, discovery of new fields, and of new reservoirs in old fields. Most of the remaining additions were due to revisions arising during the development of previously discovered reservoirs or fields.

Venezuela

The OPEC *Annual Statistical Bulletin 2007* shows Venezuela's proved gas reserves as increasing from 4 315 bcm at end-2005 to 4 838 bcm at end-2007, a rise of just over 12%. The later level is situated towards the middle of a range of published figures extending from *World Oil*'s 4 304 to BP's 5 150 bcm.

Vietnam

Cedigaz shows Vietnam's proved reserves of natural gas as falling by 145 bcm, from 365 bcm as reported in May 2007 to the latest level of 220 (as at 1 January 2007), which is now in line with the majority of published assessments. The proportionate decrease of 39.7% was the steepest fall among the principal changes in gas reserves identified in this period.

Table 5.1
Natural gas: proved recoverable reserves at end-2007

Sources: published national sources; *Oil & Gas Journal*, December 2007 and December 2008; Cedigaz; *Annual Statistical Report 2008*, OAPEC; *Annual Statistical Bulletin 2007*, OPEC; *World Oil*, September 2008; BP *Statistical Review of World Energy*, 2008; data reported for previous WEC *Surveys of Energy Resources*

Note: the relationship between cubic metres and cubic feet is on the basis of one cubic metre = 35.315 cubic feet throughout

	billion cubic metres	billion cubic feet
Algeria	4 504	159 069
Angola	161	5 700
Benin	1	40
Cameroon	150	5 300
Congo (Brazzaville)	91	3 200
Congo (Democratic Rep.)	1	35
Côte d'Ivoire	42	1 497
Egypt (Arab Rep.)	2 152	76 000
Equatorial Guinea	99	3 496
Ethiopia	25	883
Gabon	30	1 059
Ghana	24	848
Libya/GSPLAJ	1 420	50 147
Mauritania	28	1 000
Morocco	2	55
Mozambique	127	4 500
Namibia	21	750
Nigeria	5 308	187 440
Rwanda	57	2 000
Senegal	11	388
Somalia	6	200
South Africa	10	362
Sudan	84	2 966
Tanzania	24	846
Tunisia	92	3 257
Total Africa	**14 470**	**511 038**
Barbados	N	5
Canada	1 634	57 698
Cuba	71	2 500
Mexico	373	13 162
Trinidad & Tobago	481	16 997
United States of America	6 823	240 966
Total North America	**9 382**	**331 328**
Argentina	442	15 608
Bolivia	757	26 740
Brazil	365	12 890
Chile	45	1 589
Colombia	131	4 641
Ecuador	9	315
Peru	335	11 821
Venezuela	4 838	170 854
Total South America	**6 922**	**244 458**

Table 5.1 cont.

Natural gas: proved recoverable reserves at end-2007

Sources: published national sources; *Oil & Gas Journal*, December 2007 and December 2008; Cedigaz; *Annual Statistical Report 2008*, OAPEC; *Annual Statistical Bulletin 2007*, OPEC; *World Oil*, September 2008; BP *Statistical Review of World Energy*, 2008; data reported for previous WEC *Surveys of Energy Resources*

Note: the relationship between cubic metres and cubic feet is on the basis of one cubic metre = 35.315 cubic feet throughout

	billion cubic metres	billion cubic feet
Afghanistan	50	1 750
Armenia	176	6 215
Azerbaijan	1 350	47 675
Bangladesh	392	13 843
Brunei	331	11 689
China	3 000	105 945
Georgia	8	300
India	1 055	37 257
Indonesia	2 754	97 260
Japan	51	1 808
Kazakhstan	1 900	67 100
Korea (Republic)	3	106
Kyrgyzstan	6	200
Malaysia	2 480	87 581
Myanmar (Burma)	515	18 187
Nepal	N	N
Pakistan	844	29 790
Philippines	95	3 355
Taiwan, China	70	2 472
Tajikistan	6	200
Thailand	317	11 198
Turkey	15	523
Turkmenistan	2 860	101 001
Uzbekistan	1 870	66 039
Vietnam	220	7 769
Total Asia	**20 368**	**719 263**
Albania	2	71
Austria	16	570
Belarus	3	100
Bulgaria	1	39
Croatia	27	939
Czech Republic	4	141
Denmark	83	2 943
France	10	341
Germany	218	7 699
Greece	2	70
Hungary	67	2 369
Ireland	10	350
Italy	170	6 004
Netherlands	1 271	44 885
Norway	2 313	81 684
Poland	75	2 632
Romania	121	4 269
Russian Federation	47 814	1 688 551
Serbia	48	1 700
Slovakia	15	530
Slovenia	N	N
Spain	3	90
Ukraine	787	27 804
United Kingdom	343	12 113
Total Europe	**53 403**	**1 885 894**
Bahrain	92	3 249
Iran (Islamic Rep.)	28 080	991 645
Iraq	3 170	111 949
Israel	34	1 200
Jordan	15	513
Kuwait	2 506	88 499
Oman	840	29 665
Qatar	25 636	905 335
Saudi Arabia	7 153	252 608
Syria (Arab Rep.)	290	10 241
United Arab Emirates	6 040	213 303
Yemen	473	16 704
Total Middle East	**74 329**	**2 624 911**
Australia	907	32 014
New Zealand	56	1 976
Papua New Guinea	435	15 362
Total Oceania	**1 398**	**49 352**
TOTAL WORLD	**180 272**	**6 366 244**

Table 5.2
Natural gas: 2007 marketed production

Sources: published national sources; BP *Statistical Review of World Energy*, 2008; Cedigaz; *Energy - Monthly Statistics, 1/2009*, Eurostat; *Annual Statistical Bulletin 2007*, OPEC; estimates by the Editors

	billion cubic metres	billion cubic feet
Algeria	84.8	2 995
Angola	0.8	28
Cameroon	N	N
Congo (Brazzaville)	0.2	7
Côte d'Ivoire	1.3	46
Egypt (Arab Rep.)	46.5	1 642
Equatorial Guinea	2.8	99
Gabon	0.1	4
Libya/GSPLAJ	15.3	540
Morocco	0.1	4
Mozambique	1.8	64
Nigeria	34.1	1 204
Senegal	N	N
South Africa	2.9	102
Tunisia	2.0	71
Total Africa	**192.7**	**6 805**
Barbados	N	N
Canada	174.4	6 159
Cuba	1.1	39
Mexico	50.5	1 783
Trinidad & Tobago	38.7	1 367
United States of America	545.9	19 278
Total North America	**810.6**	**28 626**
Argentina	44.8	1 582
Bolivia	14.1	498
Brazil	11.3	399
Chile	1.3	46
Colombia	7.8	275
Ecuador	0.3	11
Peru	2.7	95
Venezuela	26.5	936
Total South America	**108.8**	**3 842**
Afghanistan	N	N
Azerbaijan	10.3	364
Bangladesh	15.7	554
Brunei	12.3	434
China	67.9	2 398
Georgia	N	N
India	31.5	1 112
Indonesia	68.3	2 412
Japan	3.3	117
Kazakhstan	27.3	964
Kyrgyzstan	N	N
Malaysia	64.5	2 278
Myanmar (Burma)	13.2	466
Pakistan	30.8	1 088
Philippines	3.6	127
Taiwan, China	0.4	14
Tajikistan	N	N
Thailand	25.3	893
Timor Gap	5.5	194
Turkey	0.8	28
Turkmenistan	67.4	2 380
Uzbekistan	58.5	2 066
Vietnam	7.1	251
Total Asia	**513.7**	**18 141**

Table 5.2 cont.
Natural gas: 2007 marketed production

Sources: published national sources; BP *Statistical Review of World Energy*, 2008; Cedigaz; *Energy - Monthly Statistics, 1/2009*, Eurostat; *Annual Statistical Bulletin 2007*, OPEC; estimates by the Editors

	billion cubic metres	billion cubic feet
Albania	N	N
Austria	1.8	64
Belarus	0.2	7
Bulgaria	0.3	11
Croatia	2.9	102
Czech Republic	0.2	7
Denmark	9.2	325
France	1.0	35
Germany	14.3	505
Greece	N	N
Hungary	2.2	78
Ireland	0.5	18
Italy	9.7	343
Netherlands	68.3	2 412
Norway	89.7	3 168
Poland	4.3	152
Romania	12.2	431
Russian Federation	607.4	21 450
Serbia	0.3	11
Slovakia	0.1	4
Slovenia	N	N
Spain	N	N
Ukraine	19.0	671
United Kingdom	72.1	2 546
Total Europe	**915.7**	**32 338**
Bahrain	11.5	406
Iran (Islamic Rep.)	111.9	3 952
Iraq	1.5	53
Israel	2.3	81
Jordan	0.3	11
Kuwait	12.1	427
Oman	23.6	833
Qatar	59.8	2 112
Saudi Arabia	74.4	2 627
Syria (Arab Rep.)	6.0	212
United Arab Emirates	50.3	1 776
Total Middle East	**353.7**	**12 491**
Australia	40.0	1 413
New Zealand	4.4	155
Papua New Guinea	0.3	11
Total Oceania	**44.7**	**1 579**
TOTAL WORLD	**2 939.9**	**103 822**

6. Part I: Uranium

The data and other information summarised in this chapter have been very largely drawn from *Uranium 2007: Resources, Production and Demand* (the Red Book), a joint report of the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), published in 2008.

Uranium resources and reserves, like those of other energy minerals, are subject to changes over the course of time, due to new discoveries, the re-evaluation of known deposits, technological developments, depletion through production, and other factors. The latest assessments, referenced above, relate to the situation as at 1 January 2007 and are compared in this review with the 1 January 2005 estimates discussed in the 2007 SER.

The principal changes in uranium reserves are summarised in Table 6.1 and discussed in the Country Notes below. Ten countries account for most of the 41.6 thousand tonnes U increase in Reasonably Assured Resources (RAR), taken as broadly equivalent to proved reserves. The major increases in tonnage occurred in Ukraine, Niger and the Russian Federation, whilst Kazakhstan's RAR decreased appreciably. As is frequently observed in the fossil fuels, shifts in reserve levels are often due to movements between categories (e.g. some Inferred Resources reclassified as RAR, and vice versa).

The latest Red Book assessments of RAR are shown in Table 6.1 and 2007 uranium production in Table 6.2.

Australia

Whilst Australia's Reasonably Assured Resources (RAR) recoverable at below US$ 40/kgU show a marginal increase in the latest Red Book in comparison with the previous (2005) edition, the other cost bands exhibit decreases, so that there is an overall decline in RAR of 22 000 tU, or nearly 3%. On the other hand, the latest assessments show a substantial rise in Inferred Resources (IR): these are up by 122 000 tonnes overall, with a strong increase in the lowest cost category far outweighing decreases in the US$ 40-80 and US$ 80-130/kgU cost bands. These changes reflect the definition of additional resources at six Australian deposits, as at the beginning of 2007. Since then, additional reserves/resources have been announced for the Olympic Dam and Ranger 3 deposits and the first estimates released of resources at the recently-discovered Four Mile deposit, located 8 km northwest of the Beverley mine in South Australia. Geoscience Australia's estimate of RAR at up to US$ 80/kgU as at December 2007 was 983 000 tU, 269 000 tonnes (or 37.7%) more than at 1 January, while the corresponding IR level was 98 000 tonnes (nearly 20%) higher.

In May 2008 Uranium One announced the suspension of development work on its Honeymoon mine in South Australia.

Australia's total output of uranium recovered from its flood-affected level of 7 593 tU in 2006 to 8 611 in 2007. Early estimates of 2008 production point to a modest decline of about 2% for the year.

Bulgaria

According to the National Geo Fund, as quoted in the IAEA/NEA's 2007 Red Book, identified uranium resources in Bulgaria amounted to 19 809 tU (in situ) at the beginning of 2007, of which some 60% was underground-mineable and 40% amenable to in-situ leaching (ISL) extraction. However, mining costs are not available and as the resource is spread over a large number of small deposits the quantities involved are deemed to be 'economically and technologically unprofitable'.

The only uranium resources currently quoted for Bulgaria in the Red Book are 25 000 tU of Prognosticated Resources (PR), recoverable at less than US$ 130/kgU.

There is presently no production of uranium in Bulgaria: cumulative output to date has been 16 357 tonnes

Canada

The decrease of just over 20 000 tU in Canada's total Identified Resources since the level reported in the 2007 *Survey* is largely attributable to mining depletion – uranium output during 2006 and 2007 was some 19 300 tonnes.

In February 2009 Cameco stated that the Cigar Lake mine, whose development was seriously retarded by flooding in October 2006, was no longer expected to begin operating in 2011. A new production date would be set after the mine had been dewatered, the conditions underground evaluated and a new mining plan devised.

Canadian output declined by nearly 4% to 9 476 tU in 2007.

China

Total RAR at 1 January 2007 show an increase of over 10 000 tU in comparison with the comparable level reported for the 2005 Red Book. The increments in resources are concentrated in the less than US$ 40 and US$ 80-130/kgU cost bands and reflect increases in known ISL mining resources in the Erdos Basin (Inner Mongolia Autonomous Region) and the Yili Basin (Xinjiang Autonomous Region).

New production centres are under construction at Fuzhou and Chongyi, both in Giangxi province in southeast China.

China's production of uranium in 2007 has been reported by the World Nuclear Association to be 712 tonnes, marginally lower than the estimated level of 750 tonnes per annum quoted for the previous four years.

India

While India's recoverable Identified Resources, as reported in the 2007 Red Book, show moderate increases over the levels in the previous edition – RAR up 14.8%, IR up 7.6% - there has been a major change in PR, which have risen from 12.1 to 50.9 thousand tonnes (in situ).

The increase in RAR is largely due to the promotion of a number of deposits from the IR category. The smaller rise in IR reflects in turn the firming-up of a few deposits formerly categorised

as EAR-II (now termed Prognosticated Resources). The latter category has itself been substantially boosted by the identification of many new uranium-bearing areas in various parts of India.

The World Nuclear Association gives the estimated level of India's 2007 uranium production as 270 tonnes, somewhat higher than in recent years.

Jordan

Re-evaluation of Jordan's uranium resources, taking into account increased demand and higher prices on the world market, has resulted in a general uplift to resource levels. RAR and IR, each in the less than US$ 40/kgU bracket, have both been increased by around 40%, and now stand at 44 and 68 thousand tU respectively. Jordan's PR have more than doubled, and have now reached nearly 85 000 tU, 80% of which is deemed to be recoverable at less than US$ 80/kgU.

The estimated level of by-product resources associated with phosphate rocks has been reduced from 70 000 tU to 59 360 tonnes as at the beginning of 2007.

No production of uranium has yet taken place in Jordan.

Kazakhstan

The figures reported in the 2007 Red Book imply a substantial drop in Kazakhstan's RAR, particularly in the US$ 80-130/kgU bracket, which is over 100 000 tonnes lower. The net reduction in the less than US$ 80/kgU category is about 34 000 tU or some 9% - with output in 2006 and 2007 accounting for nearly 12 000 tonnes of the decrease.

At the beginning of 2007 there were six ISL production centres in operation in Kazakhstan, with an aggregate production capacity of 5 100 tU/yr, together with one production centre linked with the Vostok underground mine, with a capacity of 500 tU/yr. Eight more ISL production centres were in various stages of commissioning.

Uranium output has risen strongly in recent years, jumping by over 25% from 5 281 tU in 2006 to 6 637 in 2007. A provisional increase of some 28% has been reported for 2008, which would bring the year's total up to around 8 500 tU, thus edging Australia out of the number 2 slot among the world's uranium producers.

Namibia

Proved reserves, as represented by RAR, fell by 6 200 tU between 2005 and 2007, all within the lowest cost band. This reduction appears to be almost entirely attributable to the production of some 5 950 tU during 2006 and 2007.

UraMin Inc. (a Canadian mining company acquired by AREVA in 2007) is working to bring a new production facility at its Trekkopje mine into operation.

The Canadian company Forsys Metals Corporation (now part of the Forrest Group, based in the Congo D.R.) is developing an open pit mine at its Valencia deposit (in the vicinity of the Rössing and Langer

Heinrich deposits). It was granted a mining licence in August 2008.

Namibia's uranium output fell by just over 6% in 2007 to a total of 2 879 tU.

Niger

A major reappraisal of Niger's RAR has resulted in a total increase of nearly 35%, from about 180 000 to 243 000 tU, with a radically different breakdown over the cost bands. In contrast to the position shown in the 2005 Red Book, over 80% of these resources are now allocated to the US$ 80-130/kgU category, with the less than US$ 40/kgU band falling by more than 150 000 tonnes to around 21 000. IR show a 14 000 tU reduction overall, together with a reallocation over the cost bands.

Uranium exploration is being carried out by the existing two production companies, Somair and Cominak, as well as by two newcomers, AREVA NC Niger and China National Uranium Corporation. In August 2008 Cameco announced that it had taken an 11% interest in GoviEx, a company with exploration assets in Niger.

There was a decrease of over 8% in Niger's uranium production in 2007, to a total of 3 153 tU.

Russian Federation

Comparing the assessments of Russian uranium resources appearing in the 2005 and 2007 Red Books, all categories show substantial increases across virtually all cost bands. The latest Red Book reports that 'a comprehensive technical and economic evaluation of numerous stand-by uranium deposits discovered and explored in the past 50 years' was conducted in 2006, resulting in the reclassification of some of these 'non-balance-sheet resources'.

Russia's RAR recoverable at less than US$ 40/kgU show a reduction of 10 000 tonnes, owing mainly to mining depletion in 2006 and 2007; other RAR, recoverable at US$ 40-80/kgU, have increased by over 50 000 tonnes, or 68%. Total IR of uranium in the Federation have grown nine-fold from 40 700 to 373 300 tU. Undiscovered Resources, both Prognosticated and Speculative, have also been substantially increased.

Russian output recorded a 7% rise in 2007, reaching 3 413 tU compared with 3 190 in the previous year.

South Africa

As South African uranium production is a by-product of gold-mining, the substantial increase in exploration activity for gold that occurred during 2006, accompanied by the reopening of two gold mines, has been reflected in higher assessments of uranium resources. First Uranium reported in February 2009 that uranium recovery from the new plant at its Ezulwini gold mine is on schedule to commence during the last quarter of 2009.

Compared with the levels quoted in the 2005 Red Book, the main data source for the uranium chapter in the 2007 *Survey*, RAR recoverable at less than US$ 40/kgU have risen by more than 26 000 tU, to nearly 115 000 tonnes. Likewise, IR in the same

cost-band have been raised by over 65 000 tonnes to almost 120 000 tU.

Uranium output in 2007 was virtually unchanged from that in the previous year, at 539 tU.

Ukraine

According to the 2007 Red Book, Ukraine recorded the biggest national increase in RAR over the levels quoted in the previous edition. The principal shift was in the US$ 40-80/kgU category, where the assessment rose more than threefold to just over 99 000 tU, owing to the incorporation of the Novokonstantinovskoye and Central deposits, which had not previously been taken into account. Substantial increases were also recorded in Ukraine's IR, again mainly in the US$ 40-80/kgU band, and in PR at less than US$ 80/kgU.

Total production of uranium registered a moderate increase in 2007, with a 4.7% rise from 808 tU to 846 tU.

Table 6.1

Uranium: proved reserves (RAR) as of 1 January 2007

(conventional resources recoverable at up to US$130/kgU)

Source: *Uranium 2007: Resources, Production and Demand*, 2008, OECD Nuclear Energy Agency and International Atomic Energy Agency

Note: data for the intermediate cost-bands are not available for all countries; so regional and global aggregates have not been computed for these categories

	Recoverable at				Total recoverable at
	< US$40/kgU	US$40-80/kgU	<US$80/kgU	US$80-130/kgU	up to US$130/kgU
	thousand tonnes of uranium				
Algeria			19.5		19.5
Central African Republic			6.0	6.0	12.0
Congo (Democratic Rep.)			1.4		1.4
Gabon				4.8	4.8
Malawi			9.6	2.0	11.6
Namibia	56.0	89.1	145.1	31.3	176.4
Niger	21.3	23.0	44.3	198.8	243.1
Somalia				5.0	5.0
South Africa	114.9	91.0	205.9	78.5	284.4
Zimbabwe			1.4		1.4
Total Africa	**192.2**		**433.2**		**759.6**
Canada	270.1	59.1	329.2		329.2
Greenland				20.3	20.3
Mexico				1.3	1.3
United States of America			99.0	240.0	339.0
Total North America	**270.1**		**428.2**		**689.8**
Argentina	5.1	3.9	9.0		9.0
Brazil	139.6	17.8	157.4		157.4
Chile					0.8
Peru		1.4	1.4		1.4
Total South America	**144.7**		**167.8**		**168.6**
China	31.8	12.5	44.3	4.5	48.8
India					48.9
Indonesia		0.3	0.3	4.3	4.6
Japan				6.6	6.6
Kazakhstan	235.5	108.7	344.2	33.9	378.1
Mongolia	8.0	38.2	46.2		46.2
Turkey		7.3	7.3		7.3
Uzbekistan	55.2		55.2	17.2	72.4
Vietnam					1.0
Total Asia	**330.5**		**497.5**		**613.9**
Czech Republic		0.6	0.6		0.6
Finland				1.1	1.1
Germany				3.0	3.0
Greece	1.0		1.0		1.0
Italy			4.8		4.8
Portugal		4.5	4.5	1.5	6.0
Romania				3.1	3.1
Russian Federation	47.5	124.9	172.4		172.4
Slovenia		1.0	1.0		1.0
Spain		2.5	2.5	2.4	4.9
Sweden				4.0	4.0
Ukraine	27.4	99.1	126.5	8.5	135.0
Total Europe	**75.9**		**313.3**		**336.9**
Iran (Islamic Rep.)				0.5	0.5
Jordan	44.0		44.0		44.0
Total Middle East	**44.0**		**44.0**		**44.5**
Australia	709.0	5.0	714.0	11.0	725.0
Total Oceania	**709.0**		**714.0**		**725.0**
TOTAL WORLD	**1 766.4**		**2 598.0**		**3 338.3**

Table 6.2

Uranium: annual and cumulative production at end-2007

Sources: International Atomic Energy Agency; World Nuclear Association

Notes: 1. Data for China, India, Iran (Islamic Republic), Pakistan, Romania, Ukraine and Uzbekistan are estimated

2. The cumulative production shown for Kazakhstan, Uzbekistan, Russian Federation and Ukraine covers only the period 1992-2007 inclusive, as data for earlier years are not available

	2007 Production	Cumulative production to end-2007
	tonnes of uranium	
Congo (Democratic Rep.)		25 600
Gabon		25 403
Madagascar		785
Namibia	2 879	90 866
Niger	3 153	107 240
South Africa	539	155 746
Zambia		102
Total Africa	**6 571**	**405 742**
Canada	9 476	417 670
Mexico		49
United States of America	1 654	362 055
Total North America	**11 130**	**779 774**
Argentina		2 513
Brazil	299	2 367
Total South America	**299**	**4 880**
China	712	30 631
India	270	8 923
Japan		84
Kazakhstan	6 637	118 392
Mongolia		535
Pakistan	45	1 124
Uzbekistan	2 320	32 649
Total Asia	**9 984**	**192 338**
Belgium		686
Bulgaria		16 357
Czech Republic	306	110 151
Finland		30
Former Soviet Union (prior to 1992)		123 086
France	4	75 982
Germany	38	219 514
Hungary		21 050
Poland		650
Portugal		3 717
Romania	77	18 336
Russian Federation	3 413	136 214
Slovenia		380
Spain		5 028
Sweden		200
Ukraine	846	13 239
Total Europe	**4 684**	**744 620**
Iran (Islamic Republic)	20	25
Total Middle East	**20**	**25**
Australia	8 611	148 003
Total Oceania	**8 611**	**148 003**
TOTAL WORLD	**41 299**	**2 275 382**

6. Part II: Nuclear

When discussing energy resources, it is conventional to assess nuclear energy in terms of installed and planned electricity generating capacity and actual or potential power generation. The data on capacity and generation given in Table 6.3 have been largely drawn from *Nuclear Power Reactors in the World, 2008 Edition,* published by the International Atomic Energy Agency (IAEA).

The Country Notes below are for the most part based on news items reported in *WNN Weekly*, published by World Nuclear News.

Argentina

Atucha-II, a 692 MW_e PHWR which is being completed with assistance from Canada, is expected to begin operating by October 2010, according to a government minister in August 2008. Construction of the unit began in 1981 but work was halted for more than ten years from 1995.

Armenia

It was reported in November 2007 that the Armenian Government had approved the closure of Medzamor-2, the country's sole NPP; no date for closure was given. The USA has indicated its support for the construction of a replacement plant.

Belarus

In October 2007 the President of Belarus stated that construction of the country's first NPP was planned to start in 2008. The Government has indicated that it envisages the installation of two units with a combined capacity of 1 000 MW_e between 2013 and 2015, with two more units planned for operation by 2025. High-level talks on the project have been held both with China and Russia.

Brazil

According to a press report in July 2008, the completion of Angra-3 has become more doubtful following the setting of 60 exacting conditions by Brazil's environment minister. However, Angra-3 took a step forward in March 2009 with the granting of an environmental licence.

In September 2008, the Brazilian nuclear energy company Eletronuclear submitted a plan for six new reactors to the Government.

Bulgaria

A contract for two Russian VVER-1000 reactors (each 953 MW_e net) to be installed at Belene was signed in January 2008. The Government issued a construction permit for the plant in July of the same year.

Canada

The Ontario provincial government announced in June 2008 that the Darlington NPP had been chosen as the site for two new reactors. A suitable site for further new reactors is being sought in the province of Alberta. Meanwhile, refurbishment continues at Bruce A1 and A2, scheduled for completion in 2009 and 2010 respectively.

Proposals have been made to use electricity and steam from nuclear plants in thermal in-situ

projects for the recovery of bitumen from oil sands, instead of using natural gas.

China

Tianwan 2, a Russian-built 1 000 MW_e (gross) WWER, began commercial operation on 16 August 2007. Excavation of the site for the Sanmen NPP in Zhejiang province got under way in February 2008. Shortly afterwards it was reported that an agreement had been signed for the construction of China's first inland NPP at Xianning City, Hubei. In November work commenced on new nuclear units at Ningde and Fuqing, both in Fujian province. Construction of two new reactors at Fangjiashan, near the existing NPP at Qinshan in Zhejiang, began just before the end of 2008.

Czech Republic

In July 2008 the Czech utility CEZ asked the Ministry of the Environment to carry out an environmental impact assessment for two additional reactors at the Temelin NPP site.

Estonia

The Ministry of Economic Affairs and Communication announced in March 2008 that it was going to compile a shortlist of possible sites for Estonia's first NPP.

Finland

The two reactors at Loviisa were granted licences in July 2007 allowing them to operate until 2027 and 2030 respectively. In October 2008 TVO announced a further delay in the construction of the third unit at Olkiluoto, which may not now be completed until 2012. Fennovoima, Fortum and TVO have each applied to the Government for a decision-in-principle on the construction of a new NPP.

France

Construction of the first EPR (1 650 MW_e) began at Flamanville (Normandy) towards the end of 2007, with completion scheduled for 2012. Work on a second EPR is planned to start at Penly in 2012.

Hungary

It was reported in July 2007 that Paks-1 and -4 had each been uprated to approximately 500 MW_e, some 8% higher than their original design capacity. Work on uprating Paks-2 and -3 was planned to start in 2008.

India

In June 2008 India was reported to be suffering from a chronic shortage of nuclear fuel, which had obliged its NPPs to run at about half their rated capacity. In December of the same year India reaffirmed its commitment to the thorium fuel cycle, proposing an eventual fleet of a dozen reactors using this principle.

Up to six of AREVA's EPRs could be constructed at Jaitapur, Maharashtra state, following the signing of an MOU in February 2009.

Indonesia

A preliminary deal signed in July 2007 envisages the use of Korean Republic technology for Indonesia's first two NPPs.

Iran (Islamic Republic)

The final shipment of nuclear fuel for Iran's first NPP, Bushehr-1, arrived from Russia in January 2008. During February 2009, a 'pre-commission' test was carried out using 'virtual' fuel.

Italy

Twenty years after the closure of Italy's nuclear power industry the current Government is strongly supportive of its revival. In February 2009 a government department for nuclear energy, renewables and energy efficiency was established.

Japan

In November 2008, the start-up of the Ohma NPP was put back from early 2012 to late 2014. Plans were announced in January 2009 for a 1 590 MW_e plant to be built at Sendai on Kyushu, to come into operation in 2019. Tomari-3 is scheduled to begin commercial operation in December 2009.

Extensive testing of the remodelled Monju fast-breeder reactor began at the end of August 2007 and was scheduled to last a year, with the restart set for October 2008. However in January 2009, further delays in safety checks were reported to have set back operational status by several months.

Jordan

In September 2007 the USA and Jordan agreed to cooperate on the peaceful use of nuclear energy. In July of the following year it was reported that Jordan had signed agreements with both Canada and the UK for assistance in advancing its plans for nuclear power and desalination. Jordan's target date for the operation of its first NPP is 2015.

Kazakhstan

A government plan to install two small VBER-300 nuclear reactors by 2015-2016 was announced in November 2007. The first was expected to be sited at Aktau, where the country's sole previous NPP, a small fast-breeder reactor, was sited.

Korea (Republic)

Ministerial approval was granted in September 2007 for the construction of two APR-1400 reactors, Shin Kori -3 and -4. A construction licence for the two units was issued in April 2008.

Libya/GSPLAJ

In July 2007 France and Libya signed a memorandum of understanding for a joint project to construct a nuclear-powered desalination plant in Libya.

Lithuania

On 4 July 2007 the President of Lithuania signed into law a bill for the construction of a new NPP, designed to replace the output of Ignalina-1 (shut

down in 2004) and Ignalina-2 (due for closure in 2009).

Malaysia

The Malaysian utility Tenaga was reported in July 2008 to have set up, at the request of the Government, a task force to examine the possibility of constructing an NPP in the interior of the country.

Nigeria

The Federal Government has approved the technical framework for fast-tracking the deployment of NPPs in Nigeria. The country's nuclear roadmap envisages the installation of 1 000 MW_e by 2017 and 4 000 MW_e by 2027.

Pakistan

It was reported in June 2008 that Pakistan was planning the construction of two new 320 MW_e NPPs at the Chasma site.

Philippines

After a government decision in 2007 to re-examine the scope for using nuclear power in the Philippines, the feasibility of rehabilitating the mothballed Bataan NPP was examined by an IAEA team early in the following year. The Korean Republic has reportedly also offered assistance.

Poland

In early 2009 the Polish Government was reported to be relying on nuclear to increase the country's energy security, with a plan for two NPPs in Poland and a share in a new one in Lithuania.

Romania

Cernavoda-2 entered commercial service in October 2007, having achieved grid connection on 7 August. Also in August 2007, the Government of Romania invited bids for the construction of Cernavoda-3 and -4. By March 2008 it was reported that negotiations had been completed for six European utilities to participate in a joint venture with Nuclearelectrica SA to complete and operate Cernavoda-3 and -4.

Russian Federation

Work was resumed in November 2007 on Kalinin-4, originally begun in 1986 but halted in 1991. In March 2008 an overall plan for siting new NPPs was announced, involving up to 42 new reactors by 2020.

Construction officially started in June 2008 on the first reactor at Novovoronezh Phase II. Approval was given in August for the construction of the 2 400 MW_e Baltic NPP in Kaliningrad; the first unit is planned to start up in 2015. It was reported in October 2008 that construction of the first new reactor at Leningrad Phase II had begun.

Slovakia

Under a contract awarded in September 2007, Bohinice-3 and -4 will be uprated by a total of 120 MW_e in 2010. A tender was launched in August 2008 for the completion of two reactors at the

Mochovce site and by November work was reported to be under way.

South Africa

Work on the demonstration Pebble Bed Reactor continued throughout 2008. In December 2008 Eskom cancelled the construction of a second NPP and froze long-term plans for up to 17 more. Retrofitting the low-pressure turbines at the Koeberg NPP will lead to a 65 MW_e increase in generating capacity.

Sweden

The uprating of Sweden's reactors is proceeding. Work on the four-unit site at Ringhals to raise its capacity by 495 MW_e was carried out in 2007, while there is to be a 160 MW_e uprate of the Forsmark-3 reactor. Sweden's coalition government annulled the country's anti-nuclear policies early in 2009.

Switzerland

In December 2008 framework permit applications were filed for new NPPs to replace three of Switzerland's ageing reactors at Beznau and Mühleberg.

Thailand

The Thai energy minister announced in November 2007 that between 2008 and 2011 Thailand would carry out preparatory work on nuclear projects.

Turkey

A tender was launched in March 2008 for the construction of a nuclear power plant at Akkuyu on the Mediterranean coast. By April, four companies were reported to have already submitted bids in this connection.

Ukraine

According to a government minister, speaking in September 2008, construction of two new NPPs at Khmelnitsky will commence in 2010, with completion of the first unit expected by the end of 2016.

United Arab Emirates

In April 2008 the Government of the UAE published a comprehensive national policy on nuclear energy, which envisages the eventual installation of a series of NPPs in the Emirates.

United Kingdom

Near the end of 2008 it was announced that Oldbury, the UK's oldest operational NPP, which had been due to close down at the end of 2008, would continue in service for about another two years. In January 2009 the UK Government invited the nuclear industry to nominate (within two months) sites for the first wave of new NPPs.

United States of America

Approval was given in August 2007 for the completion of Watts Bar unit 2, 35 years after construction began. It was reported in September 2008 that the Nuclear Regulatory Commission had approved uprates totalling 249 MW_e to seven reactors over the last year.

Table 6.3

Nuclear Energy: capacity and generation in 2007

Source: *Nuclear Power Reactors in the World*, 2008 Edition, International Atomic Energy Agency

Notes: 1. The capacity and output of the Krsko nuclear power plant, shown against Slovenia in the table, is shared 50/50 between Slovenia and Croatia

2. Japan includes the Monju FBR (246 MW_e net), which is being remodelled (see Country Notes) after being shut-down since December 1995

	In operation in 2007		Under construction at end-2007		Net generation in 2007	Nuclear share of electricity generation in 2007
	Units	Capacity	Units	Capacity		
	number	MW_e	number	MW_e	TWh	%
South Africa	2	1 800			12.6	5.5
Total Africa	**2**	**1 800**			**12.6**	
Canada	18	12 610			88.2	14.7
Mexico	2	1 360			9.9	4.6
United States of America	104	100 582	1	1 165	806.6	19.4
Total North America	**124**	**114 552**	**1**	**1 165**	**904.7**	
Argentina	2	935	1	692	6.7	6.2
Brazil	2	1 795			11.7	2.8
Total South America	**4**	**2 730**	**1**	**692**	**18.4**	
Armenia	1	376			2.3	43.5
China	11	8 572	5	4 220	59.3	1.9
India	17	3 782	6	2 910	15.8	2.5
Japan	56	47 833	1	866	267.3	27.5
Korea (Republic)	20	17 451	3	2 880	136.6	35.3
Pakistan	2	425	1	300	2.3	2.3
Taiwan, China	6	4 921	2	2 600	39.0	19.3
Total Asia	**113**	**83 360**	**18**	**13 776**	**522.6**	
Belgium	7	5 824			45.8	54.1
Bulgaria	2	1 906	2	1 906	13.7	32.1
Czech Republic	6	3 619			24.6	30.3
Finland	4	2 696	1	1 600	22.5	28.9
France	59	63 260	1	1 600	420.1	76.9
Germany	17	20 430			133.2	27.3
Hungary	4	1 829			13.9	36.8
Lithuania	1	1 185			9.1	64.4
Netherlands	1	482			4.0	4.1
Romania	2	1 305			7.1	13.0
Russian Federation	31	21 743	6	3 639	148.0	16.0
Slovakia	5	2 034			14.2	54.3
Slovenia	1	666			5.4	41.6
Spain	8	7 450			52.7	17.4
Sweden	10	9 034			64.3	46.1
Switzerland	5	3 220			26.5	40.0
Ukraine	15	13 107	2	1 900	87.2	48.1
United Kingdom	19	10 222			57.5	15.1
Total Europe	**197**	**170 012**	**12**	**10 645**	**1 149.8**	
Iran (Islamic Rep.)			1	915		
Total Middle East			**1**	**915**		
TOTAL WORLD	**440**	**372 454**	**33**	**27 193**	**2 608.1**	

7. Hydropower

The sources of energy provided by river flows and falling water are, like nuclear energy, usually discussed in terms of installed and planned electricity generating capacity and actual or potential power generation.

The information on hydro-electric capacity developments and plans summarised in the Country Notes below has been very largely derived from the *Hydropower & Dams World Atlas 2008*, published by Aqua~Media International. The estimates of hydro potential given in the 2008 *Atlas* show a number of variations from those in the 2006 edition which provided input (along with information reported by WEC Member Committees) to the 2007 SER, but the global totals of hydropower potential are little changed.

Table 7.1 gives the 2007 level of capacity and hydro-electric generation in each of the 161 countries with operating hydro plants. As far as possible, the output data quoted relate to net generation (i.e. excluding station use) and exclude pumped-storage plants. Where actual data for 2007 generation were not available at the time of preparation of the Table, average levels for recent years have been included.

Argentina

The only sizeable hydro plant under construction is Los Caracoles (132 MW). The level of the Yacyréta reservoir is being raised, which will increase the bi-national power plant's capacity (see note on Paraguay). Planned hydro developments total around 9 000 MW, including two major bi-national projects – Garabí on the river Uruguay (a joint project with Brazil) and Corpus Christi on the Paraná (jointly with Paraguay).

Australia

Two hydro plants are under construction, the larger of which is the 140 MW Bogong plant in the state of Victoria.

Bhutan

Bhutan is reported to have had two major HPPs under construction in 2008 – Punatsangchhu I (1 095 MW) and Dagachhu (114 MW). A further 2 400 MW of capacity was at the planning stage, notably Punatsangchhu II (circa 1 000 MW) and Mangdechhu (circa 720 MW).

Bolivia

Bolivia is working with Brazil on a mammoth joint project to exploit the hydro-electric potential of the Rio Madeira complex in the Amazon region. Within this project are the 800 MW Cachuela Esperanza plant sited entirely in Bolivia and the Guajara-Mirim plant (3 000 MW) to be located on the border between the two countries.

Brazil

Brazil's participation with Bolivia in the Rio Madeira scheme comprises the Jirau (3 326 MW) and Santo Antonio (3 168 MW) projects, which have recently been auctioned to different consortia for development. In the country as a whole there are numerous hydro plants in the course of construction, totalling some 5 500 MW, while planned capacity is in the order of 33 000 MW.

Cambodia

The Kamchay hydro scheme (194 MW), which will on completion virtually double Cambodia's hydro capacity, is under construction.

Cameroon

A contract was signed in August 2007 for the construction of the 200 MW Memve'ele hydro plant.

Canada

In Québec, Péribonka (385 MW) is now in operation, while Eastmain 1A (893 MW) is scheduled for completion in 2011-2012. The 120 MW Brilliant expansion scheme in British Columbia was finished in 2007, while construction of the 200 MW Wuskwatim hydro project in northern Manitoba is on course for completion in 2012. A considerable amount of refurbishment and upgrading of hydro plants is being carried out at various locations.

Chile

The principal schemes under construction are La Higuera (155 MW) and La Confluencia (145 MW).

China

China leads the world in hydro-electric development, with some 80 GW under construction. Besides the 22 500 MW Three Gorges project, which is scheduled for completion in 2009, there are many other massive plants in hand. Examples of such projects include Xiluodu (12 600 MW), Xiangjiaba (6 000 MW), Longtan (5 400 MW), Laxiwa (4 200 MW) and Pubugou (3 600 MW); the last three are all due for completion in 2009-2010, the other two in 2015-2016. Planned schemes include two huge hydro plants on the Jinsha Jiang (River Yangtze): Wudongde (9 000 MW) and Baihetan (12 600 MW).

Colombia

The Porce III hydro plant (660 MW) is scheduled for completion in mid-2010. Approximately 10 000 MW of hydro capacity is planned for medium/long-term implementation.

Congo (Democratic Republic)

The World Energy Council is facilitating the development of the Congo River hydropower projects. WEC states that 'the Inga Projects offer a unique opportunity to provide affordable and clean electricity to more than 500 million Africans who do not have it today'.

A WEC Workshop on 'Financing the Inga hydropower Projects' was held in London in April 2008. The main objective of the Workshop was to identify the key requirements and potential partners for an accelerated and sustainable development of the overall Inga hydropower projects, namely: the rehabilitation of existing installations including Inga 1 & 2 and the development of Inga 3 (4 320 MW) and Grand Inga (40 000 MW). The WEC also identified basic principles to move forward the Inga Projects. The Workshop recognised the sense of urgency to progress the projects and to coordinate the planning process in an orderly and timely manner. But these will highly depend on factors

such as the improvement of the political situation in the DRC, strong government support for the projects and a high level of cooperation/integration with the key stakeholders.

Costa Rica

Out of over 200 MW of hydro capacity under construction, Costa Rica's major current project is the 128 MW Pirris plant, which is due for completion in 2010. Large schemes reported to be at the feasibility stage in 2008 were Diquís (622 MW) and Reventazón (298 MW).

Ecuador

Ecuador has a number of small-to-medium sized hydro schemes under construction, including San Francisco (230 MW), Toachi-Pilaton (228 MW) and Mazar (190 MW). It is also planning to build a further eight HPPs, with an aggregate capacity of 2 766 MW. The largest of the planned plants is Coca Coda Sinclair (1 500 MW).

Ghana

The Bui HPP (400 MW) is under construction on the Black Volta, with completion scheduled for 2012.

Guyana

Construction of the 100 MW Amaila Falls run-of-river hydro project on the Kuribrong River may get under way in 2009.

Iceland

The 690 MW Kárahnjúkar hydro scheme came into operation in November 2007. A number of other projects have been awarded licences or are at the planning stage.

India

A number of large schemes have been completed recently, including Dul Hasti (390 MW) and Omkareshwar (520 MW). India has a massive programme of hydro-electric development in hand, with around 7 000 MW under construction. Among the larger projects are Subansiri Lower (2 000 MW), Parbati II (800 MW) and the Kol dam (800 MW). Work is now going ahead at Rampur (412 MW) and Baglidar (450 MW), along with many others.

Indonesia

Two medium-sized projects under construction are Asahan 3 (154 MW), due to be completed in 2011, and Asahan 1 (180 MW), for completion in 2012.

Iran (Islamic Republic)

In 2008, *Hydropower & Dams World Atlas* reported that Iran had 7 442 MW of hydro capacity under construction and a further 17 500 MW in an advanced stage of planning.

Japan

In 2008 Japan had about 7 GW of hydro capacity under construction, of which nearly 90% was

accounted for by four large pumped-storage schemes.

Laos

Six hydro schemes, with a total capacity of 2 131 MW, were under construction in 2008, with twelve more totalling 3 230 MW reported by *Hydropower & Dams World Atlas* to be 'at advanced stages of negotiation'.

Macedonia (Republic)

Out of a number of hydro plants at the tendering stage in 2008, the largest were Chebren (330 MW) on the Black river and Galishte (195 MW) on the river Vardar.

Malaysia

Construction of the 2 400 MW Bakun hydro plant continued throughout 2008; completion is scheduled for 2010.

Mexico

The El Cajón HPP (750 MW) commenced commercial operation in 2007. Construction has begun at La Yesca (750 MW) and La Parota (900 MW). Generating capacity at La Villita Michoacán is being boosted by 400 MW, and at Infiernillo Guerrero by 200 MW, through refurbishment and uprating programmes.

Mozambique

The South Bank Powerhouse (5 x 415 MW) at Cahora Bassa on the Zambezi has been refurbished in recent years. A project for a 1 245 MW North Bank Powerhouse is under study.

Nepal

Although only about 135 MW of hydro capacity was under construction in 2008, at least three large projects – West Seti (750 MW), Upper Karnali (300 MW) and Upper Tama Koshi (309 MW) – were expected to go ahead in the near term.

Norway

Two major HPPs currently under construction in Norway – Nit Tying (168 MW) and Over Otta (171 MW) – are among the largest hydro projects under way in Western Europe.

Pakistan

In 2008 the 963 MW Neelum Jhelum hydro scheme was reported to be going ahead, with contractors and consultants appointed. The 5 400 MW Bunji project has been the subject of a feasibility study. A number of other very large hydro projects are being studied, including the 4 000 MW Dasu scheme.

Panama

A 223 MW hydro station is under construction at Changuinola in western Panama, near the border with Costa Rica.

Paraguay

The level of the Yacyréta reservoir is being raised, which will enable the bi-national plant's 20 turbines

to operate at or near their design capacity of 155 MW each.

Peru

In May 2008 Peru agreed with Brazil to build the 1 400 MW Inambari hydro plant in eastern Peru, to help serve the Brazilian electricity market.

Philippines

The 225 MW Agus III hydro scheme on Mindinao is being carried out by a private company, with completion scheduled for 2011.

Portugal

Government approval has been given for the construction of the 170 MW Baixo Sabor dam and hydro plant on the river Sabor, a tributary of the Douro in northern Portugal. Several other schemes are likely to go ahead in the short/medium term, including Alqueva II (240 MW) at an existing hydro site in the south of the country.

Russian Federation

Some 7 000 MW of hydro plant is under construction, including two very large schemes which had both been stalled for many years: the 3 000 MW Boguchany plant on the river Angara in central Siberia, and the 2 000 MW Bureya project on the Far Eastern river of the same name.

Sudan

The 1 250 MW Merowe hydro plant was reported in 2008 to be nearing completion, with impounding under way.

Tajikistan

The Sangtuda I plant (670 MW) on the river Vakhsh has been completed, with the first of its four 167.5 MW turbines starting up in January 2008. Work on the Rogun dam, also on the Vakhsh, has been halted again. A number of medium- and large-sized hydro projects are under planning or being considered.

Tanzania

The 900 MW Stieglers Gorge hydro project on the river Rufiji appears to be moving ahead, with the Canadian-registered company Energem Resources acquiring a 40% stake in the scheme.

Turkey

Turkey has a large programme of hydro building, with some 4 000 MW under construction and about 19 000 MW planned. After much debate, engineering and consultancy contracts were awarded for the Ilisu scheme (1 200 MW) in late 2007.

Uganda

Following a successful financial closure at the end of 2008, contracts have been awarded for the 250 MW Bujagali scheme.

United Kingdom

Work continued throughout 2008 on the construction of the 100 MW Glendoe hydro scheme in Scotland, the first sizeable such plant to be built in the UK for fifty years. The scheme is expected to begin operating in 2009.

Venezuela

The two large hydro schemes under construction in Venezuela are Tocoma (2 160 MW), the last major project on the lower Caroní, and La Vueltosa (514 MW) in the Andean region.

Vietnam

A massive programme of hydro development is being carried out, with around 7 500 MW under construction and many other schemes at the feasibility stage. The largest hydro project currently under way is the 2 400 MW Son La scheme.

Zambia

Economic and technical feasibility studies are being conducted on the Kafue Lower IPP project (750 MW), which would provide a much-needed boost to Zambia's hydro capacity.

Table 7.1
Hydropower: capacity and generation in 2007

Sources: Installed capacity: *Hydropower & Dams World Atlas 2008*, supplement to *The International Journal on Hydropower & Dams*, Aqua~Media International; Net generation: published national sources; *Hydropower & Dams World Atlas 2008*, Aqua~Media International; *Electricity Information 2008*, International Energy Agency; BP *Statistical Review of World Energy*, 2008; estimates by the Editors

	Installed capacity	Net generation
	MW	GWh
Algeria	280	226
Angola	790	2 800
Benin	1	N
Burkina Faso	32	111
Burundi	32	150
Cameroon	721	3 800
Central African Republic	19	130
Comoros	1	2
Congo (Brazzaville)	89	400
Congo (Democratic Rep.)	2 410	8 000
Côte d'Ivoire	606	1 510
Egypt (Arab Rep.)	2 793	14 075
Equatorial Guinea	1	2
Ethiopia	669	3 265
Gabon	170	900
Ghana	1 198	5 600
Guinea	129	519
Kenya	677	3 383
Lesotho	76	200
Madagascar	105	540
Malawi	285	1 100
Mali	155	500
Mauritania	30	120
Mauritius	59	83
Morocco	1 500	1 318
Mozambique	2 179	15 000
Namibia	249	1 500
Nigeria	2 000	7 900
Réunion	125	658
Rwanda	54	130
São Tomé & Príncipe	6	10
Senegal	66	293
Sierra Leone	< 5	18
Somalia	5	15
South Africa	687	751
Sudan	323	1 300
Swaziland	60	165
Tanzania	579	1 800
Togo	> 66	100
Tunisia	62	49
Uganda	318	1 650
Zambia	1 120	9 729
Zimbabwe	754	5 750
Total Africa	**21 486**	**95 552**

Table 7.1 cont.
Hydropower: capacity and generation in 2007

Sources: Installed capacity: *Hydropower & Dams World Atlas 2008*, supplement to *The International Journal on Hydropower & Dams*, Aqua~Media International; Net generation: published national sources; *Hydropower & Dams World Atlas 2008*, Aqua~Media International; *Electricity Information 2008*, International Energy Agency; BP *Statistical Review of World Energy*, 2008; estimates by the Editors

	Installed capacity	Net generation
	MW	GWh
Belize	32	160
Canada	72 660	365 271
Costa Rica	1 509	6 771
Cuba	57	85
Dominica	8	25
Dominican Republic	470	1 701
El Salvador	472	1 735
Greenland	40	219
Guadeloupe	7	25
Guatemala	644	3 031
Haiti	70	275
Honduras	525	2 223
Jamaica	24	175
Mexico	11 310	26 815
Nicaragua	105	302
Panama	858	3 301
Puerto Rico	85	300
St Vincent & the Grenadines	6	35
United States of America	78 200	248 312
Total North America	**167 082**	**660 761**
Argentina	9 920	37 295
Bolivia	477	2 297
Brazil	83 752	370 275
Chile	4 977	22 763
Colombia	9 023	41 823
Ecuador	1 747	7 200
French Guiana	116	500
Guyana	1	1
Paraguay	8 410	53 458
Peru	3 230	23 884
Surinam	120	600
Uruguay	1 538	7 515
Venezuela	14 597	83 032
Total South America	**137 908**	**650 643**
Afghanistan	> 200	500
Armenia	1 000	500
Azerbaijan	1 020	2 750
Bangladesh	230	1 300
Bhutan	1 488	4 519
Cambodia	12	55
China	147 000	478 100
Cyprus	1	2
Georgia	2 720	6 764
India	37 000	121 186
Indonesia	4 500	8 550
Japan	22 000	74 718
Kazakhstan	2 248	7 900
Korea (Democratic People's Rep.)	4 780	12 750
Korea (Republic)	1 584	3 578
Kyrgyzstan	2 910	14 500
Laos	673	3 777
Malaysia	1 910	4 950
Mongolia	16	5
Myanmar (Burma)	803	3 538
Nepal	590	2 710
Pakistan	6 543	30 027
Philippines	2 450	8 478
Sri Lanka	1 281	3 769
Taiwan, China	1 399	4 398
Tajikistan	4 037	16 930
Thailand	2 976	8 033
Turkey	13 608	35 492
Turkmenistan	1	3
Uzbekistan	1 704	6 242
Vietnam	4 583	25 000
Total Asia	**271 267**	**891 024**

Table 7.1 cont.
Hydropower: capacity and generation in 2007

Sources: Installed capacity: *Hydropower & Dams World Atlas 2008*, supplement to *The International Journal on Hydropower & Dams*, Aqua~Media International; Net generation: published national sources; *Hydropower & Dams World Atlas 2008*, Aqua~Media International; *Electricity Information 2008*, International Energy Agency; BP *Statistical Review of World Energy*, 2008; estimates by the Editors

	Installed capacity	Net generation
	MW	GWh
Albania	1 450	5 370
Austria	11 853	33 970
Belarus	12	35
Belgium	95	362
Bosnia-Herzogovina	2 380	5 950
Bulgaria	1 434	2 258
Croatia	2 076	4 123
Czech Republic	1 014	2 114
Denmark	9	30
Estonia	8	20
Faroe Islands	31	104
Finland	3 049	13 991
France	25 200	57 383
Germany	4 525	19 370
Greece	3 060	2 942
Hungary	48	205
Iceland	1 873	8 336
Ireland	249	697
Italy	17 459	32 944
Latvia	1 500	2 600
Lithuania	120	451
Luxembourg	40	105
Macedonia (Republic)	540	1 220
Moldova	60	33
Montenegro	90	360
Netherlands	38	112
Norway	29 040	133 397
Poland	839	2 331
Portugal	4 922	9 846
Romania	6 346	15 740
Russian Federation	47 000	177 200
Serbia	2 820	9 844
Slovakia	1 776	4 162
Slovenia	846	3 215
Spain	18 446	27 125
Sweden	16 300	65 515
Switzerland	13 356	34 873
Ukraine	4 500	10 000
United Kingdom	1 368	4 854
Total Europe	**225 772**	**693 187**
Iran (Islamic Rep.)	7 442	18 117
Iraq	2 225	500
Israel	7	28
Jordan	12	61
Lebanon	280	1 050
Syria (Arab Rep.)	1 505	4 000
Total Middle East	**11 471**	**23 756**
Australia	7 670	16 871
Fiji	> 85	421
French Polynesia	46	164
New Caledonia	78	386
New Zealand	5 346	23 283
Palau	10	30
Papua New Guinea	222	650
Solomon Islands	N	1
Vanuatu	1	5
Western Samoa	12	51
Total Oceania	**13 470**	**41 862**
TOTAL WORLD	**848 456**	**3 056 785**

8. Peat

The world's peat resources are widespread but, owing to their comparatively shallow depth below the earth's surface, generally well-defined. There is thus little prospect of radical new discoveries or major revisions to the resource base. Moreover, the current and prospective extraction of peat, and especially the fraction destined to be consumed for energy purposes, represents a very small proportion of the overall resource. However in a few countries, most of which are in Western Europe, peat plays an important role in the energy scene.

Up-to-date information on the supply and consumption of peat for energy purposes is frequently hard to find, and consequently Table 8.1 shows data for 2006 (the latest year for which worldwide data are available), largely derived from statistics published by the IEA.

The Country Notes below relate to three major producers and consumers of energy peat.

Finland

According to the Association of Finnish Peat Industries, quoted by Statistics Finland, 2007 peat production in Finland was 66% lower than in the previous year. On the other hand, Finnish consumption of peat fuel grew by about 9%. This apparent discrepancy between supply and demand is an excellent illustration of one of peat's special features. Owing to the vagaries of the weather, in particular the amount of sunshine, wind and rainfall during the peat harvesting, milling and drying season, annual production levels vary greatly. In order to cope with such circumstances, the principal peat-consuming countries maintain large buffer stocks, which enable them to smooth out supplies to power plants and other consumers.

Ireland

As in Finland, bad weather seriously reduced Ireland's peat harvest in 2007. The Irish state peat authority Bord na Móna's 2007/2008 Annual Report indicates a 31% reduction in its milled peat production compared with 2006/2007, but only a 1% drop in its sales to power stations and other consumers.

Sweden

Sweden's reliance on peat as a fuel is considerably lower than that of Finland or Ireland, and moreover it imports about a third of its requirements. Energy peat production in 2008 was 1.99 million cubic metres, 22.8% higher than the corresponding level in 2007. The Government's energy and climate policy (February 2009) points out that, 'under certain conditions and to a limited extent, peat can be used with a positive net climate impact'. It therefore considers that Sweden should take action to ensure that this point is taken into account by the IPCC and in the EU's regulatory framework.

Table 8.1
Peat: production and consumption for fuel in 2006

Sources: *Energy Statistics of OECD Countries*, 2008 Edition, International Energy Agency; *Energy Statistics of Non-OECD Countries*, 2008 Edition, International Energy Agency; estimates by the Editors

Notes: 1. Data on production relate to peat produced for energy purposes; data on consumption (including imported peat) similarly relate only to fuel use

2. Tonnages are generally expressed in terms of air-dried peat (35%-55% moisture content)

	production	consumption
	thousand tonnes	
Burundi	5	5
Total Africa	**5**	**5**
Falkland Islands	13	13
Total South America	**13**	**13**
Austria	1	1
Belarus	2 125	2 205
Estonia	507	371
Finland	13 235	9 230
Germany	101	8
Ireland	3 694	3 481
Latvia	14	7
Lithuania	55	47
Romania	9	28
Russian Federation	1 362	1 492
Sweden	621	887
Ukraine	627	726
United Kingdom	20	20
Total Europe	**22 371**	**18 503**
TOTAL WORLD	**22 389**	**18 521**

9. Solar Energy

The harnessing of the solar resource has made much progress in recent years. The cumulative installed PV power in the countries participating in the International Energy Agency-Photovoltaic Power Systems Programme (IEA-PVPS) was nearly 8 GW_p at end-2007, over one-third higher than at end-2006. Of this total, over 90% was grid-connected.

In terms of large national markets Germany and Japan led the world's installed solar capacity – 3.9 and 1.9 GW_p respectively. However, it was Spain that saw the highest annual growth. The 2010 target set by the Spanish Government's Plan for Renewable Energy was exceeded long before. A new Plan for 2011-2020 aims to perpetuate the growth in the share of renewables in the energy mix.

Government policy in Germany has helped the country to maintain its lead position, which was strengthened in 2008 when an estimated 1.4 GW_p was added to installed capacity.

Both Australia and the USA have instituted Solar Cities. Australia now has 7 such cities, the USA, 25. These programmes have helped to greatly raise awareness of photovoltaic technology and are promoting its implementation. India also has a Solar Cities programme.

Australia

Australia saw an increase of over 17% in installed PV capacity between 2006 and 2007. Although the country has an excellent solar resource and low electricity prices the cost of developing photovoltaic power is relatively high. However, the Government ratified the Kyoto Protocol in late-2007 and this has resulted in a planned increase to the Renewable Energy Target by 2020.

By end-2007, installed PV power was 82 MW_p, of which 28 MW_p was off-grid domestic, 39 MW_p off-grid non-domestic, 15 MW_p grid-connected distributed and 1 MW_p grid-connected centralised.

The Renewable Remote Power Generation Program (RRPGP), the Solar Homes and Communities Plan (formerly the Photovoltaic Rebate Program), the Low Emissions Technology and Abatement (LETA) program and, to some extent, the Mandatory Renewable Energy Target have all played their part in the developmental role of PV in recent years but, together with climate change in general, the subject has now attained a much higher status in the national consciousness.

Photovoltaic components are now widely available in the established retail sector, finding a ready market after the residential grant was doubled in 2007 to 8 000 AUD for the first kW installed. The second half of the year saw many new businesses created and a rise in the accreditation of PV installers. PV systems in schools and community schemes also benefited by being able to apply for 50% of costs up to 2 kW_p.

The Solar Cities program has helped enormously to raise the profile of PV in the cities of Adelaide, Townsville, Blacktown, Alice Springs and Central Victoria. During 2008 the 94 million AUD program added Coburg and Perth as the 6^{th} and 7^{th} Solar Cities. In addition to residential installations,

commercial and public buildings are having PV systems incorporated as part of a plan to reduce greenhouse gas emissions.

In addition to the PV schemes, the Solar Hot Water Rebate Program is currently offering households a rebate of 1 000 AUD where an existing electric storage hot water system is replaced by a solar or heat pump hot water system.

Following the installation of the Australian National University's 400 m^2 solar dish concentrator in 1994, a second ANU dish is under construction. It is part of a project to bring to commercial fruition the technology of solar thermal energy storage combined with generation of electricity.

France

Following an annual average increase of about 24% in installed PV capacity in France (including its overseas Departments) between 2000 and 2005, the rate increased to 33% in 2006 and 71% in 2007. Furthermore, in 2008 applications for connections to the electricity grid continued to accelerate. The feed-in tariff and tax credit measures set in 2006 have proved to be successful incentives in stimulating the market. Two further initiatives were begun in 2007: in March the Government adopted the European Commission's SET plan which has as one of its objectives to raise the share of renewable energy to 20% by 2020; in October a series of round-table discussions within the *Grenelle de l'environnement* (public meetings involving stakeholders in the environment field) established a development plan for renewable energies including PV.

As a result of governmental support for building-integrated PV (BIPV), the technology is fully in the minds of all parties involved in building design and development – from architects to financial institutions.

With the assistance of tax credits and support programmes, a total of 329 000 m^2 of solar thermal collectors (including 70 000 m^2 in overseas Departments) was installed during 2007. Although this level represents a more moderate rate of growth than that achieved during 2006, France (including overseas Departments) is the second largest European market for solar thermal collectors.

Germany

Germany continues to occupy the leading position for installed capacity amongst the European members of the IEA-PVPS. In 2007, the country added 1 135 MW_p, bringing the total to 3 862 MW_p installed PV capacity, of which 35 MW_p was off-grid and 3 827 MW_p was grid-connected. It is estimated that by end-2008 capacity stood at 5.3 GW_p.

The Länder and the Federal German Environmental Foundation (DBU) have their own incentive programmes to support the implementation of PV but it is the Renewable Energy Act (EEG) with its feed-in tariffs which continues to be the driver behind the strong growth in Germany.

The principle of the EEG is to stimulate lower prices in the market by reducing the feed-in tariff (guaranteed over a period of 20 years) which, since

2004, has dropped by 5% per annum for roof-top modules (6.5% for ground modules). A modification was made to the EEG during 2008 so that the degression rate is reduced more rapidly from 2009 onwards. The new feed-in tariff was set at 8% for up to 100 kW_p and 10% for over 100 kW_p in 2009/2010. In the period 2011/2012 the rate will become 9%.

Owing to an increase in the rate of VAT, lower investment subventions and a decline in the heating equipment sector, the market in 2007 for solar thermal technology declined by 37% from 2006. By end-2007 940 000 m^2 capacity had been added, bringing the total to 8 994 000 m^2 (giving a capacity of 6 296 MW_t). Germany retains its position as leader of the solar thermal market in Europe; the German Solar Industry Association estimates that 2008 will see a growth of +40%.

The 40 MW_p Waldpolenz Solar Park, the fourth largest solar power array in the world, began generating electricity in June 2008. The final solar modules were put in place in December 2008 and the plant is expected to generate some 40 million kWh annually.

India

The work of Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), originally launched by the Government in early 2005, to provide access to electricity for all households within five years, has continued and gained approval for financing under the Eleventh Five Year Plan (2007-2012).

For those villages too remote ever to be considered for an electricity supply, the Ministry of New and Renewable Energy (MNRE) has continued with its Electrification of Villages Programme, ensuring the distribution of decentralised renewable energy sources. By end-2007 some 110 MW_p of solar PV had been installed under the MNRE Programmes, including just under 70 000 solar street lighting systems, in excess of 360 000 home lighting systems, nearly 600 000 solar lanterns and a 2.18 MW_p power plant. Additionally, 7 068 solar PV pumps were active and in total some 4 200 villages and hamlets had become electrified. Under the Solar Thermal programme 2.15 million m^2 of solar water heating systems and over 600 000 solar cookers had been installed.

Although by end-2007 there was only 2.12 MW_p of grid-interactive solar power, the Government announced in January 2008 a new initiative to harness the solar potential of the country (up to a maximum of 50 MW_p). Each State would be allowed a maximum of 10 MW_p capacity.

On the occasion of the 2008 Rajiv Gandhi Akshay Urja Divas, it was announced that tariffs for developing and demonstrating grid interactive generation would come into effect: a maximum of Rs 12/kWh for electricity generated by photovoltaic power plants and a maximum of Rs 10/kWh for solar thermal generated power. The incentives are to be at a fixed rate for 10 years and apply to plants of 1 MW_p and above.

In February 2009 the MNRE launched a programme to develop solar cities throughout India. In the 11th Plan Period, 60 cities will attain the

status of Solar City with each State having at least one, with a maximum of 5. By 2012 Nagpur in Maharashtra will be the first of the 15 cities so far given 'in principle' approval: Agra, Rajkot, Moradabad, Gandhinagar, Kalyan-Dombiwali, Indore, Imphal, Kohima, Dehradun, Chandigarh, Gurgaon, Ciombtore, Visakhapattanam and Thane. Each city's Master Plan will set out how renewable energy and energy efficiency measures will supply at least 10% of its 5-year forecast conventional energy demand. The Ministry will choose two of the cities to act as Modal Solar Cities and thus be an example for others.

Italy

The Italian feed-in tariffs have provided the impetus to the growth of the PV market. 2007 saw an additional 70.2 MW_p installed up from just 6.8 MW_p in 2005 and 12.5 MW_p in 2006. Of the 120.2 MW_p total at end-year, 89% represented grid-connected capacity.

New tariffs were adopted during 2007, increasing in value as the degree of PV incorporated increases (up to € 0.49/kWh and valid for 20 years). Small plants are entitled to receive a higher tariff than a large plant but all rates are reduced by 2% per annum after 2008.

During 2009 an initiative will come into force which will require at least 1 kW_p of PV to be installed in new buildings.

The total glazed area of solar thermal collectors in operation in 2007 was 1 100 230 m^2, giving an output capacity of about 770 MW_t.

Japan

At end-2007 Japan had the second largest installed PV capacity in the group of 19 participating members of the IEA-PVPS. A total of 1 919 MW_p had been installed, over twice that of the next largest country, the USA. Grid-connected capacity at 1 829 MW_p represented 95% of the total.

The ending of government funding for residential PV systems in March 2006 resulted in a levelling-off of the market for privately-installed systems during 2007. The Ministry of Economy, Trade and Industry (METI) began instead to support non-residential facilities through its Field Test Project on New Photovoltaic Power Generation Technology. During 2007 the Project applied to systems with a capacity of 10 kW_p or more but during 2008 it was extended to systems of 4 kW_p or more where they demonstrated new module types, building material integration and new control methods.

In 2007 METI revised the Renewables Portfolio Standard (RPS) Law, whereby new and renewable energy will account for 16 billion kWh in 2014. It has also developed the Cool Earth 50 policy, which includes a strategy for PV cells to achieve conversion efficiencies of 40% by 2050.

In July 2008 the Japanese Cabinet approved the Government's *Action Plan for Achieving a Low-Carbon Society*. The Action Plan includes a target for increasing solar power generation capacity by tenfold by 2020 (about 14 GW_p) and 40-fold by 2030 (about 50 GW_p). A second target of the Plan is to roughly halve the current price of the solar power generation system within three to five years.

In order to achieve a low-carbon society, the Comprehensive Immediate Policy Package was formulated in August 2008 and includes the *Action Plan for Promoting the Introduction of Solar Power Generation*. Measures will be taken to stimulate both demand and supply.

METI announced in December 2008 that ¥ 9 billion would be made available during first quarter 2009 for the renewed support of residential solar systems. This funding could be increased from April 1, at the beginning of the new fiscal year.

The electric utilities have announced that they will cooperate in the building of 140 MW_p PV power across 30 locations by 2020.

Korea (Republic)

Between end-2006 and end-2007, installed PV capacity rose by 123% to 77.6 MW_p. Of the total, grid-connected capacity accounts for 92% and has become the main area of the market to be targeted by the companies involved.

Of the large number of support measures driving 2007's strong growth, the feed-in tariff and the 100 000 rooftop programme were particularly successful. The former assisted in the installation of 28.6 MW_p in 2007 and the latter with in excess of 9.2 MW_p on single-family houses and rental apartments. The General Deployment Progamme, the Public Building Obligation Programme and the Local Deployment Programme are designed to promote the increased use of solar PV in the public sector and to raise the awareness of solar PV within the population.

In September 2008 the Ministry of Knowledge Economy presented its long-term strategy, *Korea Goes for "Green Growth": sustainable development in a low carbon society,* in which it predicts that by 2030 the Government will achieve a 44-fold increase in the use of photovoltaic energy, compared with 2007.

Asia's largest PV power plant, situated in SinAn, became fully operational in June 2008. An extension completed in September 2008 enlarged the 19.6 MW_p plant to 24 MW_p, sufficient to generate 35 000 MWh per annum, supplying some 7 200 households.

Spain

Spain increased its installed PV power by 512 MW_p during 2007, bringing the cumulative capacity to 655 MW_p of which 95% is grid-connected. The total cumulative installed capacity in 2007 was nearly five times higher than the comparable figure for 2006.

The main thrust in the growth of the Spanish PV market has been in large installations rather than in the residential sector. This is largely because the feed-in tariff has favoured large-scale plants.

The targets set by the Government's Plan for Renewable Energy covering the period to 2010 have already been exceeded. The Government is now formulating a *Plan de Energías Renovables* (PER) 2011-2020 which will fix binding objectives and obligatory minima regarding the share of energy derived from renewables in total energy consumption. Moreover, the PER will include

individual targets for the various technologies. The details of the PER will be contained in the Ley de Eficiencia Energética y Energías Renovables, the draft of which is due to be presented during the first quarter of 2009.

The great majority of the world's largest PV power plants are located in mainland Spain. In July 2008, Nobesol announced the completion of Olmedilla de Alarcón, the world's largest PV power plant. At 60 MW_p, the plant is capable of producing 85 GWh annually.

In 2007 an area of 262 000 m^2 was added to the total of solar thermal collectors, for a cumulative total of 964 166 m^2. The newly-installed capacity represented an increase of 50% over 2006. Total capacity in 2007 was 675 MW_t. A revised building code (CTE) brought into force in September 2006 was too late to have an effect on most properties planned to be built during 2007. However, it is expected that the solar obligations contained in the CTE will have had a positive effect on the market during 2008, albeit in the context of a slow-down in the Spanish construction sector.

United States of America

Of the 19 participating members of the IEA-PVPS the USA, by end-2007, ranked third in terms of cumulative installed PV power. Some 206.5 MW_p capacity was installed during the year, bringing the total to 830.5 MW_p, of which 61% was grid-connected.

In 2007 California led the way with additional installed PV capacity of 81 MW_p and was expected to add in excess of 133 MW_p during 2008. California represents 70% of all PV installations in the U.S. and 4% of the world.

Federal tax credits, effective since 2006, helped the development of the U.S. market but were excluded from the Energy Independence and Security Act of 2007. Moreover, the Federal tax credits for both residential and commercial installations expired at end-2008. However, the Emergency Economic Stabilization Act of 2008 has extended the Production Tax Credit by one year, the Investment Tax Credit by eight, eliminated the US$ 2 000 cap on tax credits for residential solar-electric installations, ceased the prohibition on utilities from benefiting from the tax credit and authorised US$ 800 million for clean energy bonds for renewable generation facilities including solar power.

More than thirty State governments have set requirements for utilities to generate a percentage of electricity from renewable energy during the coming years and several States have set ambitious goals. For example the California Solar Initiative has a goal of 1 940 MW_p installed PV by end-2016.

In June 2007, 13 U.S. cities were selected by the U.S. Department of Energy to be inaugural members of *Solar America Cities*. The objective of the scheme is to 'Partner with cities committed to achieving a sustainable solar infrastructure through a comprehensive, city-wide approach to solar technology that facilitates mainstream adoption and provides a model for others'. In March 2008, an additional 12 cities joined the programme. The 25 cities now involved are located in 16 States and six are among the 10 largest cities in the USA.

Table 9.1

Solar Energy: photovoltaic capacity at end-2007

Sources: published national sources; *Trends in Photovoltaic Applications - Survey report of selected IEA countries between 1992 and 2007*, IEA-PVPS; *The State of Renewable Energies in Europe* - 8th EurObserv'ER Report

Notes: 1. The data shown below constitute a sample, reflecting the information available: they should not be considered as complete or necessarily representative of the situation in each region. For this reason, regional and global aggregates have not been computed

2. The data shown for France include French Overseas Departments (DOM)

	Installed capacity
	MW_p
Africa	
Egypt (Arab Rep.)	5.2
North America	
Canada	25.8
Mexico	20.7
United States of America	830.5
Asia	
China	78.0
India	110.0
Japan	1 918.9
Korea (Republic)	77.6
Thailand	32.0
Europe	
Austria	27.7
Belgium	6.2
Czech Republic	4.0
Denmark	3.1
Finland	5.0
France	75.2
Germany	3 862.0
Greece	9.2
Italy	120.2
Luxembourg	23.9
Netherlands	53.3
Norway	8.0
Portugal	17.9
Spain	655.0
Sweden	6.2
Switzerland	36.2
United Kingdom	18.1
Other Europe	52.4
Middle East	
Israel	1.8
Oceania	
Australia	82.5

10. Geothermal Energy

The world has a huge geothermal resource that can be, and in many instances is, utilised for direct use, but there are just 24 countries which experience temperatures high enough for the generation of electricity. Of these 24, just 3 saw a very significant increase in capacity between 2005 and 2007.

The USA led with an estimated increase of nearly 375 MW_e, but a proportion of the country's capacity is considered to be on standby. Iceland more than doubled its installed capacity between 2005 and 2007 and although the country already uses both its geothermal and hydro resource to a very large degree, government policy is set to expand renewable energy usage still further, as witnessed by the Iceland Deep Drilling Project. Indonesia, now a net oil importer, has turned to its enormous geothermal resource to provide a source for electricity generation. The country saw an increase of 25% in capacity between 2005 and 2007 and there are many projects either under construction or planned.

Australia, which at the present time has a negligible amount of geothermally-derived electricity generation, is currently undertaking an assessment of its vast hot-rock resources.

El Salvador

During 2007 units 3 and 4 were brought into commercial operation at El Salvador's Berlín plant, bringing the country's total geothermal capacity to 204.4 MW_e. The Ahuachapán plant consists of 2 x 30 MW_e and 1 x 35 MW_e units, whilst the Berlín plant now has 2 x 28.12 MW_e, 1 x 44 MW_e and 1 x 9.2 MW_e. SIGET (Superintendencia General de Electricidad y Telecomunicaciones) reports that actual capacity available was 70 MW_e at Ahuachapán and 103.8 MW_e at Berlín. However, at end-June 2008 available capacity had increased by 10 MW_e at Ahuachapán.

Net electricity generation during 2007 increased 21% to 1 293 GWh and whilst power output at Ahuachapán decreased by just over 3%, that at Berlín increased by 56%. Geothermal energy provides nearly 25% of El Salvador's total generation.

LaGeo, owner of the two existing geothermal plants, plans to increase generation. It was reported in 2007 that its subsidiary San Vicente 7 was exploring its concession areas of San Vicente and Chinameca. However, based on initial drilling results, the prospect for power generation in the former area was not high.

France

During 2008, the planned 1.5 MW_e Phase II of the HDR project sited at Soultz-sous-Forêts became operational. A period of testing of this pilot plant is being undertaken prior to the installation of a 6 MW_e power plant.

Guatemala

During 2007, a 20 MW_e binary plant was commissioned at Amatitlán, adding to the existing 5 MW_e back-pressure unit and bringing the country's total installed power to 53 MW_e. Together with output from the Zunil 1 plant (28 MW_e), total

electricity generated amounted to 263.07 GWh (from a running capacity of 49 MW_e), a rise of 61% over 2006.

On 12 December 2008 the Executive Board of the UN Framework Convention on Climate Change (UNFCCC) approved and officially registered the Amatitlán plant under the Clean Development Mechanism (CDM).

Guatemala has many geothermal areas which have either undergone, or are undergoing, study and evaluation: since 1992 five areas have been in reserve (Zunil, Amatitlán, Tecuamburro, San Marcos and Moyuta) with, according to the Instituto Nacional de Electrificación (INDE), an estimated capacity of 430 MW_e. Preliminary studies have been conducted on a further six areas (Atitlán, Los Achiotes, Retana, Motagua, Ayarza, Palencia), which have been found to have favourable conditions. The Totonicapan and the Ixtepeque-Ipala areas have not progressed further than preliminary studies.

Direct use of geothermal heat is limited but the 1.6 MW_t Bloteca plant is used in the process of curing concrete construction blocks and in another instance Agro-Industrias La Laguna uses a 0.5 MW_t unit to dehydrate fruit.

Iceland

Iceland's geothermal capacity for electricity generation has increased dramatically in recent years. Following an increase of 190 MW_e in 2006 and 63 MW_e in 2007, a further 90 MW_e was added during 2008, bringing the total to 575 MW_e, about 2.5 times the end-2005 capacity. There were commensurate rises in electricity output with a 58% increase in 2006 (to 2 631 GWh) and 36% in 2007 (to 3 579 GWh).

HS Orka hf, owner and operator of Svartsengi, brought the sixth phase of the plant into use in December 2007, adding 30 MW_e to the existing capacity of 46 MW_e.

Reykjavik Energy, the utility provider for the Reykjavik metropolitan area, brought a 33 MW_e low-pressure turbine into use at its Hellisheidi plant in 2007 and added an additional 90 MW_e in 2008. In early 2009, total capacity stood at 213 MW_e.

The policy of the Iceland Government is to expand the use of renewable energy to an even greater extent. With respect to utilising the country's geothermal resource, Environment Impact Assessments (EIA) representing 395 MW_e capacity have been carried out at the Bjarnaflag field, in the Hengill area and at Reykjanes; EIAs which envisage 300 MW_e have been started on the Krafla and Theistareykir fields and some 2 000 MW_e additional capacity is thought to be feasible.

Direct use of geothermal power has not grown to the same extent as electricity generation but it remains of major importance, especially in the residential sector. It is estimated that during 2007, direct use amounted to 26 PJ, of which 19 PJ was for space heating.

The Iceland Deep Drilling Project (IDDP) began in 2000. The main purpose of the IDDP is to find out if it is economically feasible to extract energy and

chemicals out of hydrothermal systems at supercritical conditions. Drilling will occur below areas that have already been exploited down to 4-5 km, with boreholes at Krafla, Nesjavellir and Reykjanes. Following a feasibility study undertaken by Deep Vision (a consortium of Sudurnes Regional Heating, the National Power Company, Reykjavik Energy and the National Energy Authority, representing the Government), the project became operational during 2003 and international partners sought. Drilling of the first well, IDDP-1, began at Krafla in early 2008 (down to 800 m) and continued in March 2009. The programme is expected to continue until 2020.

Iceland's economy has been seriously impacted by the current global economic situation which has slowed the pace of geothermal development. Reykjavik Energy has revised its drilling plan for the Hellisheidi field and although the company will continue with the project, it will be delayed.

Indonesia

Having become a net oil importer early in the 21st century, Indonesia took the view that it was essential to harness the enormous geothermal resource at its disposal. The Government's *National Energy Management Blueprint 2005-2025*, contained a target of 9 500 MW_e geothermal capacity by 2025. The national geothermal potential has been estimated at some 27 GW_e but at the present time only a tiny fraction of this has been realised.

In recent years the Indonesian Government has passed a raft of laws and regulations in order to better regulate both the upstream and downstream side of the sector and to better utilise its geothermal power. Additionally, the Japan International Cooperation Agency, at the request of the Government, was engaged to formulate a Master Plan Study for Geothermal Power Development. A period of 18 months in 2006/2007 was used to assess the fields and formulate a development plan.

By end-2007, a total of 992 MW_e geothermal capacity was installed, the majority of which was based on the island of Jawa-Bali. A further 80 MW_e was under construction and 110 MW_e was under preparation prior to construction. It has been forecast that by 2010 capacity will have reached 1 192 MW_e.

Kenya

There was no change in Kenya's total installed geothermal capacity between end-2005 and end-2007, despite the country's huge potential. Generally, development of the geothermal resource has been impeded by financial constraints. However, in mid-2008 the Government launched *Kenya Vision 2030* and its first *Medium Term Plan 2008-2012*. The programme aims to transform all aspects of the Kenyan economy. Reforms in the energy sector will include for example, building a strong regulatory framework, encouraging more independent power producers and separating generation from distribution, and it is expected that the exploitation of the geothermal resource will progress. Kenya Electricity Generating Company (KenGen) is planning to add 1 260 MW_e of geothermal generating capacity by 2018.

During June 2007, drilling of the first of six directional wells in the Olkaria Domes area commenced. The project, following well appraisal, is expected to result in the Olkaria IV plant being constructed.

In December 2008, the Phase II expansion of the privately-owned Olkaria III was completed. A 35 MW_e unit was connected to the grid, with the electricity sold to the Kenya Power & Lighting Company under a 20-year Power Purchase Agreement.

In order to utilise excess steam from Olkaria I and II fields, a 3rd 35 MW_e unit is being installed at the Olkaria II plant, with completion due in May 2010.

New Zealand

Contained in the document *New Zealand Energy Strategy to 2050* (published October 2007) is a governmental target that 90% of electricity is to be generated from renewable sources by 2025. With the country's rich geothermal resource, it has been estimated that there could be about an additional 1 000 MW_e capacity that is commercially viable.

A 2002 assessment of the high-temperature resource suggests that the total resource is estimated as equivalent to a median value of 3 600 MW_e of electrical generation, based on current technology.

Installed geothermal capacity was increased during 2007 by the addition of the third unit at Mokai, a 17 MW_e binary plant extension. Furthermore, the Ohaaki plant, originally commissioned in 1989, has had a series of deratings and decommissioning of high-pressure turbines over the years but a 10 MW_e unit installed in 2007 now maintains the level of production at 60 MW_e. By year-end, national capacity had reached a nominal 461 MW_e, but actual running capacity was less.

During 2008 plants in the Kawerau and Ngawha geothermal fields were either brought on line or expanded: the 100 MW_e Kawerau station was officially opened in November and is the largest single condensing geothermal turbine in New Zealand's history; an 8.3 MW_e binary unit was installed to utilise production from the KA24 well, and the 15 MW_e Ngawha power station came on line during October.

Nga Awa Purua, a new 132 MW_e plant currently being constructed in the Rotokawa field, is due for completion in 2010.

In September 2008, consent for the initial phase of a replacement for the 51 year-old Wairakei station was granted. It is expected that the 220 MW_e first stage of the Te Mihi power plant will be commissioned by 2011 and, from 2016 onwards, will gradually replace Wairakei, which will cease operation in 2026.

There are a considerable number of other electricity generation projects under consideration, ranging from consented to those in the planning process.

Direct use of geothermal heat remains strong. Often tourist areas and commercial facilities are supplied by fluids and heat from areas associated

primarily with generation. In the past year, the 100 MW_t Tauhara Centennial Tenon Mill wood-drying facility became operational and a 50 MW_t waste wood pellet-drying facility at Tauhara is in an advanced planning stage.

Nicaragua

Despite the country's great geothermal potential, the past three years have seen a very limited amount of development. By end-2007, total installed capacity had only risen by 10 MW_e - 2 x 5 MW_e backpressure units had been installed at the San Jacinto-Tizate site. However, Polaris Geothermal Inc., the Canadian operator of San Jacinto-Tizate reports that it is on target to increase capacity to 72 MW_e early in 2010.

Two of the ten identified areas of geothermal potential are currently being explored. GeoNico, a joint venture between the Italian company Enel and LaGeo of El Salvador, are exploring areas located in El Hoyo-Monte Galáan and Managua-Chiltepe.

Papua New Guinea

At end-2005 the 36 MW_e Lihir Gold (LGL) geothermal plant supplied the mining company with 10% of its power needs. In early 2007 an additional 20 MW_e unit was commissioned and by year-end 75% of the electrical requirement was being met. The original 6 MW_e plant was relocated during 2007 to enable the mining area to be expanded.

During 2008 LGL approved a project to increase the annual processing capacity of its gold mining facility to approximately one million ounces per year, a rise of up to 240 000 ounces. The expansion is expected to be completed during 2011. Drilling is currently being undertaken to ascertain whether there are further reserves of geothermal steam that can be harnessed to supply the expanded facility with power.

Turkey

Turkey continues to harness the huge low-medium enthalpy resource at its disposal. By end-2007, it was estimated that direct use installed capacity had risen to 1 385 MW_t, of which 983 MW_t was utilised for the heating of houses, thermal facilities and greenhouses and 402 MW_t for balneological purposes.

Installed electricity generating capacity at end-2007 totalled 38 MW_e but the new 47.4 MW_e Aydin Germencik plant became operational in February 2009, with a forecast of March 2009 for it to be grid-connected.

The 9th Development Plan (2007-2013) contains 2013 targets for both electricity production and direct use. The former predicts 550 MW_e, based on the potential from 13 fields and the latter, 8 000 MW_t, of which 4 000 MW_t would be for district heating, 1 100 MW_t for balneology, 1 700 MW_t for greenhouse heating, 300 MW_t for cooling, 500 MW_t for drying and 400 MW_t for fish farming and other applications.

United States of America

The Geothermal Energy Association (GEA) reports that in August 2008, U.S. geothermal power capacity on line totalled 2 958 MW_e, although a proportion of this capacity is on standby or at least less than nameplate capacity and net electrical power output is thus somewhat less.

Seven States (Alaska, California, Hawaii, Idaho, Nevada, New Mexico and Utah) harness their geothermal resource, but at the present time it is California that has the majority share at 86% (2 555 MW_e). Nevada follows with 318 MW_e or 11% and at the other end of the spectrum, New Mexico has just 0.24 MW_e in a first-stage pilot project and Alaska's Hot Springs Resort has a capacity of 0.4 MW_e. The States of Oregon and Wyoming are presently working on bringing geothermally-produced electricity on line.

The GEA has identified 97 projects in 13 States, totalling some 3 960 MW_e, at different stages of development – from site selection and exploratory drilling to the facility being under construction. A further 10 unconfirmed projects could bring the total to 3 980 MW_e. At present the development plan for Nevada is larger than that for California. Whereas ultimately 1 million Californian homes could be supplied with electricity, in Nevada the eventual total could be 2 million.

A number of factors will help to ensure that the potential of the U.S. geothermal resource is realised in the coming years.

In December 2008 the Department of the Interior's Bureau of Land Management (BLM) published the *Record of Decision and Approved Management Plans Amendments* for geothermal leasing in the western U.S. The Record of Decision amends 114 BLM resource management plans and allocates about 111 million acres of public lands and a further 79 million acres of National Forest System lands as open for leasing. The amended plan foresees 5 500 MW_e of new generation in the 12 western states by 2015 and estimates a further 6 600 MW_e by 2025.

Both the Federal Government and many State Governments have instituted renewable portfolio standards in which suppliers of electricity are required to purchase 25% of their power supply from renewable energy. This policy will help the development of geothermal in those states well-endowed with the resource.

In February 2009, the new federal administration legislated the American Recovery and Reinvestment Act 2009. This measure not only includes US$ 16.8 billion for the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) but specifically US$ 400 million for the Geothermal Technologies Program.

Direct use of geothermal heat is of very great importance in the U.S. and the International Energy Agency (IEA) Implementing Agreement for Cooperation in Geothermal Research & Technology (GIA) estimates that installed capacity in 2007 is about 10 897 MW_t.

In February 2008, work on the first example in the U.S. of an enhanced geothermal system (EGS) applied to an existing geothermal site began at the Desert Peak plant in Nevada. If after testing and evaluation, the process is found to be successful, the output could be boosted from the current 11 MW_e to 50 MW_e. Later in the year it was announced that the second EGS application would take place at the Brady plant, also in Nevada.

A 2007 assessment of EGS undertaken by MIT concluded that the technology could provide at least 10% of the country's future electricity power needs (100 000 MW_e) in the next 50 years. The EERE has devised a Draft Multi-Year Research, Development and Demonstration Plan, 2009-2015 with program activities to 2025. In partnership with the geothermal sector, it plans to demonstrate by 2015 that EGS is technically feasible.

Table 10.1
Geothermal energy: capacity and generation in 2007

Sources: published national sources; *IEA Geothermal Energy Annual Report 2007*, IEA-GIA; estimates by the Editors

	Installed capacity	Annual output	Annual capacity factor
	MW_e	GWh	
Ethiopia	7		
Kenya	129	911	0.81
Total Africa	**136**	**911**	**0.77**
Costa Rica	166	1 239	0.85
El Salvador	204	1 293	0.83
Guadeloupe	15	95	0.74
Guatemala	53	263	0.70
Mexico	960	7 404	0.88
Nicaragua	87	243	0.34
United States of America	2 937	14 839	0.59
Total North America	**4 422**	**25 376**	**0.67**
China	28	96	0.39
Indonesia	992	5 000	0.64
Japan	535	3 102	0.66
Philippines	1 970	10 215	0.60
Thailand	N	2	0.68
Turkey	38	158	0.62
Total Asia	**3 563**	**18 573**	**0.62**
Austria	1	2	0.21
Germany	3	N	0.10
Iceland	485	3 579	0.90
Italy	810	5 233	0.74
Portugal	23	178	0.88
Russian Federation	79	85	0.12
Total Europe	**1 401**	**9 077**	**0.78**
Australia	N	1	0.60
New Zealand	461	3 272	0.83
Papua New Guinea	56	250	0.62
Total Oceania	**517**	**3 523**	**0.82**
TOTAL WORLD	**10 039**	**57 460**	**0.67**

11.Wind Energy

Like solar energy, the wind energy sector has seen very significant global growth in recent years. By end-2006, installed capacity was some 25% higher than at the end of the previous year; by end-2007 capacity had increased by a further 27% and it is estimated that 2008 saw an increase approaching 30%.

Prior to 2008 Germany led the world in terms of installed capacity, adding about 12% in 2006 and 8% in 2007. Although Spain was ahead of the USA at the end of 2006 and despite growing by some 30% in 2007, by end-2007 the USA had overtaken it, having grown some 45%. By end-2008, having increased its capacity by nearly 50%, the USA took over the world lead.

One country has demonstrated spectacular growth during the past three years: China has more than doubled its wind turbine capacity and now lies in fourth place.

Although other countries do not have as high a total installed capacity, nevertheless they have witnessed considerable growth, very often as a direct result of national renewable energy policies with defined targets.

China

At the beginning of 2007 the strategic wind energy target for 2010 set by the Energy Bureau of the National Development and Reform Commission (NDRC) was revised upwards to 8 GW. Already by year-end Chinese installed capacity had reached 5 905 MW, more than doubling end-2006 capacity. It is estimated that by end-2008 capacity had reached some 12.2 GW, thus exceeding the planned target and being well on the way to meeting the planned 2020 figure of 30 000 MW.

The regions with the highest wind resource do not always have the highest concentration of population, and furthermore transmission lines in these areas are often in short supply. Although the achievement of installed capacity has been great, it has been reported that at the present time there is a discrepancy between the theoretically possible generation and what can actually be achieved.

In late 2007, the country's first offshore wind power plant came into operation. The 1.5 MW plant is installed on the Bohai Suizhong 36-1 oil platform belonging to the China National Offshore Oil Corporation.

France

The near-doubling of installed wind capacity witnessed during 2005 was repeated during 2006. By end-2007 capacity in metropolitan France had reached 2 200 MW, demonstrating further strong growth, albeit at a lower rate than in earlier years.

L'Association France Energie Eolienne (FEE), representing the wind sector of the Syndicat des Energies Renouvelables, reports that, with the exception of five regions, wind installations are distributed throughout the country.

At the present time wind satisfies approximately 15% of electricity supply in the regions of Centre, Champagne-Ardenne, Lorraine and Picardie, but by 2010 it is expected that this percentage will

have risen to 40% in Picardie and Champagne-Ardenne.

The objective of the *Grenelle de l'environnement* (public meetings involving stakeholders in the environment field) relating to wind energy foresees that by 2020 it will supply 25 GW, of which 6 GW will be offshore. It is estimated that of the order of 55 TWh will be produced from wind energy, some 10% of national electricity consumption.

In 2005 the scheme for approximately 100 *Zones de Développement Eolien* (ZDE) was initiated, with the aim of assisting local communities to develop wind installations, whilst preserving their heritage. ZDEs permit the installations to benefit from the right to have the electricity they produce purchased at a fixed price.

In July 2008 EDF announced that one of France's largest wind farms was under construction in the first ZDE. The 50.6 MW Villesèque-des-Corbières (Aude Department) plant consists of 22 x 2.3 MW units. During the year EDF also commissioned the 52 MW Chemin d'Ablis plant (Eure-et-Loir Department) and in December announced that the 87 MW Salles-Curan plant had entered service in the Aveyron Department.

Germany

Up to end-2007 Germany was world leader in installed wind capacity. During 2007, 19 460 turbines with a total capacity of 22 247 MW generated 39.5 TWh, representing some 7% of the electricity consumption. By end-2008 the German Wind Energy Institute was reporting that the number of turbines had risen to 20 301, with a capacity of 23 902 MW.

In 2008 the state of Brandenburg led the way with 408 MW new installations followed by Niedersachsen with 384 MW and Sachsen-Anhalt with 227 MW. However, Niedersachsen led the ranking of total installed capacity - 6 028 MW – some 60% higher than Brandenburg, and is progressing towards its target of 10 000 MW by 2020.

The states of Sachsen-Anhalt, Mecklenburg-Vorpommern and Schleswig-Holstein obtained around 40% of their net electricity consumption from wind during 2008.

Offshore capacity remains somewhat limited for reasons of nature conservancy. However, current projections see about 500 MW by 2010 and about 3 000 MW by 2015.

The strong growth in German wind power installations seen in recent years has been due to governmental legislation and this is likely to continue with the new German Renewable Energy Sources Act which came into force on 1 January 2009. The Act replaces the 2004 Act and, although the basic structure has been maintained, the share of renewable energy in electricity generation has been further increased. The re-powering arrangements have been made more attractive; there are improved conditions for offshore installations and an improved grid integration structure for generating electricity from renewable energy, including provisions on feed-in management. Thus growth during 2009 is

expected, despite the current global financial situation.

In addition to 10 000 MW of potential new capacity build, it has been estimated that re-powering could bring the total installed onshore wind capacity up to some 45 000 MW by 2020. This would be achieved with significantly fewer turbines and furthermore, the energy yield could be tripled. However, to date building restrictions have resulted in only a limited amount of re-powering.

There is also a need for the grid to be expanded, with new transmission lines and underground cabling where necessary. The overall grid transport capacity could be much improved by the introduction of temperature monitoring of short and medium length overhead lines.

As raw material costs have risen greatly in recent years, the targets set will only be met if favourable tariffs are implemented as part of the new Act. The new tariff for onshore wind has been set at € 0.092/kWh and, for new installations, will decrease every year by 1%. For re-powering projects, the tariff has been increased by € 0.005/kWh, with the restrictions that the turbines are required to be located in the same administrative district and be at least 10 years old, and the new ones need to have at least twice (but not more than five times) the original capacity. Offshore wind turbines will attract remuneration of € 0.15/kWh until 2015, after which it will fall to € 0.13/kWh for new turbines, decreasing by 5% per annum.

It was announced in November 2008 that the first German offshore wind farm, the Alpha Ventus plant, will consist of 12 x 5 MW turbines and will be located in an area of four square kilometres, approximately 45 km to the north of Borkum in the German Bight. The joint venture project is between E.ON Climate & Renewables GmbH, EWE AG and Vattenfall Europe New Energy GmbH. Initial offshore work began during summer 2008. It is expected that installation of the first 6 turbines will begin in April 2009, followed by the remaining 6 turbines in July 2009.

India

At end-2007 India had installed grid-connected wind capacity of 7 844 MW and retained its 4th position in the world ranking, behind Germany, USA and Spain. Additionally, there were 1 284 rural and decentralised wind pumps. By end-September 2008, capacity had risen to 9 522 MW, spread across 10 states. However, 90% is located in just four states, of which Tamil Nadu, at 43%, has the largest share. The number of wind pumps had grown to 1 342.

The 11th Five Year Plan (2007-2012) states that a further 10 500 MW of grid-connected wind capacity is anticipated during the period covered. By the end of the 11th Plan it is foreseen that some 17 500 MW will have been installed. However, the target of 1 500 MW during the 10th Five Year Plan was exceeded by a factor of 3.6, so it is possible that the 11th Five Year Plan will also be exceeded.

Although India possesses a coastline in excess of 7 500 km, research has shown that the wind resource at the majority of the 54 locations studied is not sufficient for offshore wind turbines. The one

area that does have promising potential is the southern tip of the sub-continent, from Kanyakumari, northeast to Rameshwaram. Further investigation and data collection are required in order to establish the feasibility of establishing a demonstration offshore wind farm.

Italy

The target for wind energy as stated in the Italian White Paper for the period 2008-2012 (2 500 MW) had already been met during 2007. By year-end installed capacity stood at 2 726 MW with 4.1 TWh electricity generated. Of the total, the Puglia region accounted for one quarter of capacity, followed by Sicily, Campania and Sardinia.

The Italian Wind Energy Association (ANEV) reports that the current target for installed capacity by end-2020 is 16 200 MW, with generation of 27.2 TWh.

Spain

Between end-2006 and end-2007 Spain added just over 3 500 MW to its installed wind capacity, bringing the total to 15 145 MW. A total of 16 103 turbines were distributed over 672 wind farms.

By end-2008, a lower but still impressive 1 609 MW had been added, bringing the total to 16 740 MW. In terms of capacity Spain ranks second within Europe and third in the world (behind Germany and the USA).

The 30% increase in 2007 was largely because the level of government subsidies was lowered in 2008. A Royal Decree (RD 661 of 25 May 2007) specified that wind farms coming into operation before 1 January 2008 could choose to receive (until end-2012) the more favourable level of subsidy previously in force.

All but two of Spain's 17 regions have installed wind power. Cantabria added capacity for the first time in 2007 and Extremadura is expected to begin harnessing its wind resource during 2009. During 2008 the region of Castilla y León saw the largest absolute increase of 519 MW but it was the Comunidad Valenciana where capacity rose by the largest percentage increase (28%), to reach 710 MW. Three regions (Castilla-La Mancha, Castilla y León and Galicia) now all have in excess of 3 000 MW.

The current level of Spanish wind capacity is likely to ensure that the target of 20 155 MW by end-2010 set by the Spanish Renewable Energy Plan (PER) 2005-2010 will be met. It will only be necessary to install 1 700 MW per annum during the remaining two years, a figure that the wind industry foresees as achievable. The Spanish Wind Energy Association (AEE) has set its own target of 40 000 MW wind capacity by 2020 which would meet the EU objective of 20% of final energy consumption.

Generation during 2007 rose by 18% over 2006, to 27 026 GWh, well on the way to making the PER target of 40 996 GWh in 2010 achievable.

Royal Decree 1028/2007 established the process necessary for the authorisation of offshore wind turbines, with the further Royal Decree 1029/2007

requiring that environmental studies be undertaken to establish the suitability of an offshore site.

Spain's offshore wind potential has been estimated to be in the region of 4 GW, which is targeted for exploitation by 2020. Experimental installations of 10 MW will be permitted but full-scale farms will have a minimum capacity of 50 MW. At the present time the first offshore wind farm is expected to be established in around 2014.

United Kingdom

By end-2007 installed capacity in the UK stood at 2 477 MW, of which 2 083 MW was onshore and 394 MW offshore. In October 2008, the British Wind Energy Association (BWEA) was estimating that capacity had risen to 3 156 MW, of which 2 590 MW was onshore and 566 MW offshore. Turbines are distributed throughout the United Kingdom but Scotland contributes approximately half of the installed capacity. Wind-generated electricity in 2007 rose by 25% over the previous year to 5 274 GWh.

The Government's target of 10% of electricity to come from renewable energy by 2010 translates into 6 GW of wind energy. The planning process for approving wind projects can be difficult in the UK, but by late 2008 some 800 MW onshore and 800 MW offshore capacity was under construction and, additionally, 3.2 GW onshore and 1 GW offshore capacity had been consented. However, it is likely that not all of the consented projects will be operational by 2010.

A new official target of 15% of all energy to be powered from renewable energy translates into the country generating 35% of its electricity by 2020. For this to be achieved it will be necessary to remove the blocks in the planning system, so that the 33 GW of wind power required to be consented can be put in place. The Planning Act 2008, which built on the objectives set out in the Planning White Paper of May 2007, now ensures that the approval process for new capacity will be conducted more speedily and smoothly. The planning process in Scotland comes under the jurisdiction of the Scottish Executive but after review in 2006 it also now ensures a degree of expeditiousness.

The London Array, a 341-turbine offshore project developed by partners E.ON and Dong Energy (originally also with Shell Wind Energy, which later withdrew) was granted planning permission at the end of 2006. Permission for an onshore substation to feed the electricity generated to the national grid followed in August 2007. The wind farm will be located more than 20 km off the Kent and Essex coastlines in the outer Thames Estuary. When complete an average of 3.1 TWh per annum will be generated, sufficient for 0.75 million homes. Construction of the onshore components is estimated to begin during June 2009. Full operation is scheduled for 2013.

United States of America

The rapid rise in U.S. installed wind capacity between 2000 and 2005 continued through 2006, but the following two years saw unprecedented growth: an increase of 45% during 2007 and a further increase of 50% in 2008. The American

Wind Energy Association (AWEA) quotes that 8 358 MW were installed during 2008 bringing the end-year capacity to 25 170 MW.

Thirty five states have wind power capability, with the top five totalling 15 550 MW. Texas tops the list with 7 116 MW, followed by Iowa with 2 790 MW; California, 2 517 MW; Minnesota, 1 752 MW and Washington, 1 375 MW. At the present time there are no offshore wind turbines.

Three factors have helped in the expansion of the US wind sector:

- The Wind Energy Production Tax Credit (PTC) of US$ 0.021/kWh for the production of electricity from utility-scale turbines has been particularly important. The credit was due to expire at end-2008 but in October Congress extended it to end-2009.
- The Renewable Portfolio Standards (RPS) adopted by 26 States and the District of Columbia. RPS policies can be adopted at both Federal and State level and use market mechanisms to ensure that renewable energy is increasingly used for the production of electricity.
- The Small Wind Systems Tax Credit provides a federal tax credit for purchasers of wind turbines for home, farm or business use.

Following the 2006 Advanced Energy Initiative, which suggested that areas of good wind resources had the potential to supply up to 20% of electricity consumption, the report, *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to US Electricity Supply*, was published in 2007. A collaborative effort by the U.S. Government and industry, it contained one scenario examining the challenges associated with achieving the 20% goal, whilst another looked at no further increase in wind capacity. The report concluded that the U.S. had wind potential far in excess of that needed for the 20% goal to become a reality. However, to be implemented it would be necessary to overcome the challenges that were identified and for approximately 16 GW to be installed each year from 2018 onwards, bringing the total to more than 300 GW by 2030. The discussion continues.

Table 11.1
Wind energy: capacity and generation in 2007

Sources: published national sources; *IEA Wind Energy Annual Report 2007*; World Wind Energy Association; *Windpower Monthly*; African Wind Energy Association; European Wind Energy Association; data reported for the 2007 WEC *Survey of Energy Resources*

* Where data on wind energy output are not available, estimates have been calculated by applying a 22% capacity factor to the estimated mid-2007 installed capacity

	Installed capacity	Annual output *
	MW_e	GWh
Algeria	1	1
Cape Verde Islands	3	6
Egypt (Arab Rep.)	310	741
Eritrea	1	3
Kenya	N	N
Mauritius	N	N
Morocco	124	279
Namibia	N	N
Nigeria	2	4
Réunion	10	10
Senegal	N	N
South Africa	3	6
Tunisia	20	43
Uganda	N	N
Total Africa	**474**	**1 093**
Canada	1 845	4 300
Costa Rica	70	241
Guadeloupe	21	56
Jamaica	21	40
Martinique	1	2
Mexico	85	248
Netherlands Antilles	12	60
Nicaragua	N	N
United States of America	16 904	32 143
Total North America	**18 959**	**37 090**
Argentina	30	61
Bolivia	N	N
Brazil	247	97
Chile	20	3
Colombia	18	35
Cuba	7	12
Ecuador	2	2
Falkland Islands	1	1
Guyana	13	25
Peru	1	2
Uruguay	1	1
Total South America	**340**	**239**
Bangladesh	1	2
China	5 905	8 200
Cyprus	N	N
Hong Kong, SAR	1	2
India	7 844	13 600
Indonesia	1	2
Japan	1 538	2 207
Kazakhstan	1	1
Korea (Democratic People's Rep.)	N	N
Korea (Republic)	193	399
Nepal	1	2
Pakistan	N	N
Philippines	25	58
Sri Lanka	3	2
Taiwan, China	224	444
Thailand	N	N
Turkey	192	265
Total Asia	**15 929**	**25 184**

Table 11.1 cont.
Wind energy: capacity and generation in 2007

Sources: published national sources; *IEA Wind Energy Annual Report 2007*; World Wind Energy Association; *Windpower Monthly*; African Wind Energy Association; European Wind Energy Association; data reported for the 2007 WEC *Survey of Energy Resources*

* Where data on wind energy output are not available, estimates have been calculated by applying a 22% capacity factor to the estimated mid-2007 installed capacity

	Installed capacity	Annual output *
	MW_e	GWh
Austria	982	1 875
Belarus	1	2
Belgium	287	455
Bulgaria	62	47
Croatia	17	35
Czech Republic	56	110
Denmark	3 124	7 171
Estonia	58	188
Faroe Islands	4	16
Finland	110	188
France	2 200	4 050
Germany	22 247	39 500
Greece	873	2 328
Hungary	65	100
Ireland	803	1 790
Italy	2 726	4 073
Latvia	27	50
Lithuania	52	100
Luxembourg	35	65
Netherlands	1 745	3 400
Norway	385	899
Poland	280	465
Portugal	2 125	4 036
Romania	8	11
Russian Federation	17	30
Slovakia	5	10
Spain	15 145	27 026
Sweden	788	1 429
Switzerland	12	16
Ukraine	86	165
United Kingdom	2 477	5 274
Total Europe	**56 802**	**104 904**
Iran (Islamic Rep.)	67	125
Israel	8	15
Jordan	1	3
Lebanon	N	N
Syria (Arab Rep.)	N	1
Total Middle East	**76**	**144**
Australia	824	2 526
New Caledonia	24	37
New Zealand	322	928
Total Oceania	**1 170**	**3 491**
TOTAL WORLD	**93 750**	**172 145**

12. Tidal Energy

Historically, the harnessing of tidal energy has occurred in a very limited number of locations, but with the preference of countries to move away from a dependence on fossil fuels, many suitable sites are being re-examined. Both Canada and France, where the commercial generation of electricity from tidal energy has been proved over many years, are planning to install further schemes. The first commercial-scale project in the UK became operational in late-2008. Prospective tidal energy projects, particularly tidal barrage schemes, are very often planned to be sited where the ecology is finely balanced. Currently many environmental impact studies are being undertaken.

Canada

The harnessing of the tidal energy resource in the Minas Passage is one of the commitments the Government of Nova Scotia made in response to the Strategic Environmental Assessment for offshore renewable energy in the Bay of Fundy. The Fundy Tidal Institute has been established to facilitate the work of the three companies appointed by the Government of Nova Scotia, allowing them to test their respective technologies and to share costs, potential impact and testing conditions.

The three companies are employing different techniques in the demonstration pilot-scale project: Clean Current Power Systems of Canada is using a Clean Current Mark III Turbine; Minas Basin Pulp and Power is using Marine Current Technology's SeaGen turbine and NSPI has chosen an Irish OpenHydro turbine.

Minas Basin Pulp and Paper has reported that, following a scientific marine survey during July 2008 and data analysis in subsequent months, a specific site for locating the turbines has been chosen. NSPI/OpenHydro is expected to install their turbine during 2009; Clean Current and Minas Basin Pulp and Paper in Spring 2010. During the project, destined to last at least two years, the electricity produced will be fed onshore via underwater cables and then into the grid.

The province of New Brunswick which borders the landward side of the Bay of Fundy also conducted a Strategic Environmental Assessment of In-Stream Energy Generation Development during 2008. At the present time a tidal energy development policy is being considered.

Verdant Power of the USA has announced its Cornwall Ontario River Energy (CORE) scheme on the St Lawrence River. Phase 1 – Demonstration Pilot (2009-2010) will be followed by Phase 2 – Commercial Field Build-Out. The project could ultimately generate up to 15 MW of electricity.

France

It was announced during 2008 that EDF, the leading electricity producer in France, plans a pilot tidal turbine system off the coast of Brittany. The project, consisting of 4 to 10 turbines, with a total capacity of between 2 and 4 MW will be sited at Paimpol-Bréhat (Côtes d'Armor). In October 2008, EDF stated that the company had appointed OpenHydro of Ireland to equip the demonstration tidal farm, which is scheduled to be connected to the grid from 2011 onwards.

United Kingdom

The UK's Energy Act 2008 became law in November 2008 and will implement the legislative aspects of the 2007 Energy White Paper: *Meeting the Energy Challenge*. In part, the Act will strengthen the Renewables Obligation to drive greater and more rapid deployment of renewable energy in the UK. In December 2008 a draft Renewables Obligation Order 2009 was published.

In October 2007 the Sustainable Development Commission (SDC), on behalf of the Government, published the results of a year-long study looking at the full range of tidal power technologies available. The Commission was charged with examining the sustainable use of the UK's tidal resource, in particular how the power of the Severn Estuary, with its British and European legal conservation protection, could be used. It will be necessary for any ensuing development to first clear the hurdles of the many environmental concerns.

In late January 2009 the Government announced that it was halfway through a feasibility study looking at all aspects of a tidal plant in the Severn Estuary. After studying 10 possible schemes there will now be a three-month consultation period studying a short list of five proposals using a range of options: three using a barrage scheme and two, a lagoon.

2008 saw the first UK grid-connected 250 kW tidal turbines. In May, the Irish company OpenHydro began producing electricity for national consumption at its European Marine Energy Centre (EMEC) site off the southwestern coast of the island of Eday, Orkney. Later in the year, also at EMEC, OpenHydro installed the world's first specialist barge for deployment of full-scale seabed-mounted tidal turbines.

Work on surveying the waters surrounding the island of Alderney and the preparation of environmental studies have taken place over a period of three years and involved OpenHydro and Alderney Renewable Energy Ltd. (ARE). This cooperation resulted in 2008 in OpenHydro acquiring a 20% shareholding in ARE. Moreover, ARE received an exclusive 65-year licence from the States of Alderney for electricity generation from tidal (and wave) energy in the island's territorial waters.

Following Marine Current Turbines' (MCT) development of its Seaflow turbine and the experience gained from its deployment offshore from Lynmouth, Devon, the next-generation SeaGen turbine achieved a world first during 2008. In May a 1.2 MW, 16 m diameter, twin rotor system was installed in Strangford Narrows, Northern Ireland. After a period of testing, the world's first commercial-scale tidal stream project achieved power generation at maximum capacity in December 2008. The electricity produced is being purchased by the Irish company ESB Independent Energy, for customers in both Northern Ireland and the Republic of Ireland.

Early in 2008, MCT joined in partnership with npower renewables to develop a tidal stream project under the management of a newly-created company, SeaGen Wales. The plan is for a 10.5 MW farm to be located in The Skerries, off the

northwest coast of Anglesey. Evaluation of the site during 2008 is expected to be followed by an application for planning permission during 2009 and a completion date in 2011/2012. The electricity generated would feed into the national grid.

Another venture for MCT, announced in November 2008, is a tidal scheme for the Pentland Firth, Scotland. The company will apply for a lease from the Crown Estate and, subject to finance and gaining consent, plans a 50 MW plant by 2015.

United States of America

Phase 2 (2006-2008) of Verdant Power's Roosevelt Island Tidal Energy Project (RITE) encountered some unexpected problems when both the first and second set of turbine blades were destroyed by the strong tides of New York City's East River. In early September 2008, a third and stronger set of blades was installed. The project is presently being tested, and also monitored for its effect on fish and water birds. The electricity produced is being supplied to two consumers on Roosevelt Island. It is intended that Phase 3 (2009-2012) will represent commercial development.

Preliminary Permits have been obtained by ORPC (Ocean Renewable Power Company) from the Federal Energy Regulatory Commission (FERC) for proposed tidal energy projects in offshore waters in Maine (Western Passage or Cobscook Bay, near the mouth of the Bay of Fundy), Alaska (Cook Inlet, near Anchorage) and Florida (Florida Current or Gulf Stream off the east coast). It is planned that following demonstration and testing of pilot plants, prototype commercial-scale OCGen™ turbines will be installed.

13. Wave Energy

The global wave resource is extremely high and in recent years, the technology to harness it has, to some extent, moved from academia to commercial-scale installations. However, the European Marine Energy Centre (EMEC) has enumerated approximately 100 wave energy concepts, with many of them still at the R&D stage. A considerable amount of time is still required for the technology to fully mature.

Prototype devices are being tested across the world but there are two countries which occupy the leading developmental positions: Portugal and the United Kingdom. In the case of Portugal, the country saw the world's first commercial wave power project become operational in late 2008. In the case of the UK, EMEC has become a centre of excellence and provides testing facilities for project developers. The UK has many coastal opportunities for wave energy installations and the Energy Act 2008, with its strengthening of the Renewables Obligation, will assist in the sector's development.

Australia

The Australian Federal Government and the State Governments are currently supporting the development of wave energy by issuing licences and by being party to MOU's. There has been considerable testing and development of the various wave schemes in recent years.

Energetech (Australia) Pty Ltd.

Energetech Australia Pty Ltd. changed its name to Oceanlinx in April 2007. The company reports that a power purchase agreement has been signed with the utility Integral Energy for the supply of electricity from the 450 kW prototype Port Kembla wave project which is undergoing an extended production test. Oceanlinx also reports progress in obtaining the necessary permits required for the installation of the 27 MW Portland wave scheme in Victoria.

Carnegie Corporation Ltd.

The first and second pilot-scale CETO 2 wave energy units, developed by Seapower Pacific, a subsidiary of Renewable Energy Holding Plc/Carnegie Corporation Ltd., were deployed in January and February 2008 respectively at the CETO test site in Fremantle, Western Australia. Subsequent units were deployed later in the year. Testing of CETO 2 is occurring concurrently with the development of CETO 3. A full-scale, deepwater, commercial demonstration version of the latter is expected during 2009.

In August 2008 Carnegie Corporation announced that the company had been awarded a wave energy licence and an option to lease a site off Albany by the Western Australia State Government. The company hopes to develop a commercial wave farm.

An MOU between the Australian Department of Defence and Carnegie will allow Carnegie to determine the feasibility of a WA wave project which would ultimately supply electricity and/or desalinated water to the Stirling Naval Base on Garden Island.

Early in 2009 Carnegie and Synergy, Western Australia's largest electricity retailer, signed an

MOU. Carnegie would sell wave-generated electricity to Synergy from its CETO projects in Western Australia.

Carnegie has signed a Licence Agreement with the South Australia State Government to investigate an 17 000 hectare offshore area in the region of Port MacDonnell, suitable for a 50 MW demonstration wave scheme.

BioPower Systems

The MOU signed between BioPower Systems and Hydro Tasmania in May 2008 will allow BioPower to test its pilot bioWAVE™ device in the waters off King Island. The 250 kW unit will feed the electricity generated into the grid. The company has stated that it hopes to launch its first commercial units in 2010.

Denmark

The emphasis in the Danish wave sector is currently on developing the technology by private enterprise, rather than on a governmental policy for utilising wave energy.

Until January 2005 Wave Dragon was tested at its location in Nissum Bredning. A modified prototype was re-sited and subsequently tested. In mid-2008, the unit underwent maintenance and repairs; re-deployment and final testing in its original site is planned for March 2009.

In December 2008 WavePlane A/S reported that it was ready to deploy its first full-scale prototype. After initial testing it will be towed to an anchorage site at Hanstholm where further testing and connection to the grid will take place.

Wave Star Energy has been extensively testing its Wave Star plant, also anchored at Nissum Bredning. The original unit was a 1:10 scale model, producing 5.5 kW, but the company is now working to construct a 1:2 scale model. The plan is ultimately to build and market a 6 MW unit.

Floating Power Plant A/S deployed its demonstration Poseidon 37 floating power plant in the Vindeby offshore wind park in September 2008. Following testing, the company plans to develop hybrid power plants which act as a floating foundation for offshore wind turbines.

Ireland

Sustainable Energy Ireland (SEI, Ireland's national energy agency) and the Marine Institute prepared the National Strategy for Ocean Energy in 2006. The aim is to introduce ocean energy and then to develop the sector as part of the renewables portfolio. To this end, the Strategy has four phases - Phase 1: 2005-2007, a test site for quarter-scale prototypes developed in Galway Bay, R&D; Phase 2: 2008-2010, continues work of Phase 1 together with demonstration of pre-commercial single devices and establishment of a grid-connected test site; Phase 3: 2011-2015, testing and evaluation of pre-commercial small array wave units; Phase 4: 2016 onwards, formulation of strategies for commercial development of wave power.

The Ocean Energy Development Unit (OEDU) was created to assist with the implementation of the

Government's policy to hasten the development of ocean energy in Ireland. The current targets for wave and tidal are 75 MW by 2012 and 500 MW by 2020. Furthermore it is planned that Ireland will become a centre of excellence for ocean technologies. It is hoped that several sites on the west coast of Ireland will be granted permission for development.

Wavebob Ltd.

In January 2009, it was announced that the Swedish utility Vattenfall had acquired 51% of Pandion Ltd, an ocean energy site development company. The remaining 49% is owned by Wavebob Ltd. The Wavebob device continues to be tested and evaluated.

Ocean Energy

During mid-2008 Ocean Energy successfully completed first sea trials of its OE Buoy prototype wave energy converter. At the beginning of 2009 the company reported that it was finalising its strategic business plan prior to raising capital for developing a full-scale device.

Portugal

Portugal plays a leading role in the wave energy sector and saw the world's first commercial wave power project installed during 2008. The Wave Energy Centre (WavEC), founded in 2003, continues to promote and support the implementation of wave energy technology and the commercialisation of devices.

At the beginning of 2007, Government approval was given for the creation of a Pilot Zone at São Pedro de Muel, Marinha Grande, 150 km north of Lisbon. The Zone was set up in January 2008 and later, in December, a Decree approved the bases of concession to harness the wave energy resource and also granted this concession to the national grid operator, Redes Energéticas Nacionais (REN) to manage the site. The stated objectives of the Pilot Zone are: to create an industrial cluster by attracting demonstration and development to the country; to increase renewable energy production and to promote innovation, supported by R&D. The area covered by the Zone is approximately 400 km^2, lying between 5 and 8 km from the coastline. It will be connected to both the local distribution network and the national grid.

Pelamis Wave Power (PWP)

On 23 September 2008, the world's first commercial wave power project was inaugurated at the Aguçadoura Wave Park in northern Portugal. The three semi-submerged, articulated 750 kW Pelamis Wave Energy Converters (PWEC) lie 5 km off the Atlantic coastline and are connected to shore where generated electricity is fed to the national grid. The Scottish company, PWP (formerly Ocean Power Delivery) will supply a further 25 PWECs bringing the total capacity to 21 MW in the second phase of the project.

WaveRoller

Testing followed the successful deployment of a WaveRoller 13 kW prototype at Peniche, 100 km north of Lisbon in April 2007. WaveRoller, a product of the Finnish company AW-Energy Oy is a

bottom-mounted flat plate oscillating device. By mid-2007 AW-Energy had formed a partnership with the Lena Group of Portugal to create a new entity to finance and develop a 1 MW power plant based on the WaveRoller technology. In April 2008 a second WaveRoller prototype was deployed in Peniche, where it is undergoing testing and evaluation.

United Kingdom

Globally, the UK remains at the forefront of the development of wave energy technology.

The UK's Energy Act 2008 became law in November 2008 and will implement the legislative aspects of the 2007 Energy White Paper: *Meeting the Energy Challenge*. In part, the Act will strengthen the Renewables Obligation to drive greater and more rapid deployment of renewable energy in the UK. In December 2008 a draft Renewables Obligation Order 2009 was published.

The European Marine Energy Centre (EMEC), completed in late 2003 in Orkney, Scotland, provides developers with the wherewithal to test full-scale grid-connected prototype wave and tidal devices. A first of its kind in the world, EMEC's wave test centre is sited off Billia Croo, Mainland island, Orkney.

Although not all wave energy devices conform, EMEC has identified six main types of wave energy converter (attenuator, point absorber, oscillating wave surge converter, oscillating water column, overtopping device and submerged pressure differential) and approximately 100 wave energy concepts. However, many concepts are still at the R&D stage.

England's South West Regional Development Agency (SWRDA) exists to promote and develop a sustainable economy in the region by identifying its business potential. Having established the SWRDA in 1999, the Government announced in August 2006 that funding would be available for a seabed unit for connecting wave energy converters. Located 16 km offshore from the north Cornish coast, Wave Hub is planned to have up to four devices connected to it, ultimately sending up to 20 MW of generated electricity ashore by sub-sea cable to Hayle. The objective of Wave Hub is that whilst connected, the devices can be tested and evaluated in a pre-commercial environment.

Approval for the construction of Wave Hub was given in September 2007 and, subject to the necessary approvals, it is hoped that the project will be operational in early 2010 with electricity generated by end-2011. Covering a total area 4 km x 2 km, each device will be granted a lease of between 5 and 10 years in an area of 2 km^2. The initial four companies to deploy their devices have been chosen: Oceanlinx, Ocean Power Technologies, Fred. Olsen and WestWave (a consortium of E.ON and Ocean Prospect, using a Pelamis device). In time, up to 30 wave devices are expected to be deployed.

The Scottish company Pelamis Wave Power (PWP) was the first to see its technology deployed in the commercial Aguçadoura wave farm (see Portugal). Within the UK, ScottishPower Renewables was granted planning permission in

September 2007 to install a wave farm at the EMEC test centre. Four Pelamis devices generating approximately 3 MW of electricity will utilise EMEC's infrastructure to send power to the grid.

In February 2009 it was announced that the utility, E.ON had ordered a next-generation wave device from PWP. Known as P-2, the 750 kW unit will be installed and tested at EMEC before the expected fully operational date of 2010.

Wave Dragon Wales, a subsidiary of the Danish company Wave Dragon, has been granted funding for its Welsh Demonstrator project. The intention is for the site of the Wave Dragon device to be some 3-5 km offshore from Milford Haven and to be tested for 3-5 years.

In early 2009 the Scottish Assembly consented to the Siadar Wave Energy Project (SWEP). The near-shore SWEP will be located on the western coast of the Isle of Lewis, in the Outer Hebrides. When operational – expected 2010-2011, the 3-4 MW project will be one of the first to operate under the Scottish Government's proposed multiple Renewable Obligation Certificates (ROC)4 scheme. SWEP is a joint project between npower renewables (RWE Innogy's UK operating company) and Wavegen (the Scottish subsidiary of Voith Siemens Hydro Power Generation) and is based on the latter's 100 kW LIMPET device.

14. Ocean Thermal Energy Conversion

Some subtropical/tropical islands have particularly favourable conditions for harnessing the temperature differential between the surface water of the ocean and water at a depth of approximately 1 000 m. Moreover, where they have a high dependence on the importation of petroleum products for electricity generation, OTEC could be a desirable substitute. However, the capital cost of installation is extremely high and at the present time the global development of the technology remains at the planning/feasibility study stage.

Cuba

It is reported that in 2006 the Cuban National Energy Program included details of the development of OTEC demonstration plants. The following year investigative studies were carried out by Xenesys (a private Japanese company). In early 2008, Xenesys reported that the company together with the Ministries of Basic Industry, and of Science, Technology and Environment and the University of Matanzas were working together to further the project.

French Polynesia

As has been demonstrated, the ocean thermal energy resource of the region is suitable for harnessing. To this end the Japanese company Xenesys reported early in 2008 that it had signed an MOU with Pacific Petroleum Company (PPC) to develop OTEC in French Polynesia, New Caledonia and Vanuatu. Later in 2008, a joint venture between Xenesys and PPC was established to carry out the necessary research into the project.

India

In late 2008, the Indian press reported that a 1 MW floating OTEC plant had been piloted off the coast of Tamil Nadu. The plant was designed in collaboration with Saga University of Japan, and the Japanese company Xenesys is also actively working on the project. The unit, situated 60 km from Tuticorin, is installed on a 68.5 m barge, the Sagar Shakthi, which houses a Rankine Cycle-based power plant.

Indonesia

Although a Dutch study suggested that Bali was a suitable site for an OTEC plant, none has ever resulted. However, in late 2008 a projected 100 MW plant off the coast of Indonesia was publicised. The plan is for hydrogen to be produced in order to power zero-emission vehicles.

New Caledonia

See French Polynesia.

Palau

Palau depends heavily on fossil-fuel generated electricity and in order to decrease this dependence, a plan for an OTEC plant has once again been mooted. In early 2008 a request was made to the U.S. Trade and Development Agency to finance a feasibility study for a plant to produce both electricity and fresh water.

Puerto Rico

Although in 1979-1980 Puerto Rico was found to have suitable conditions for harnessing its ocean thermal energy resource, the proposed Punta Tuna 40 MW prototype plant never received funding. However, during 2008 the subject of an OTEC installation was raised again, as part of the country's move away from fossil-fuel generated electricity. In July 2008 it was reported that the Puerto Rico Electric Power Authority had signed a letter of intent with a developer for a 75 MW unit. A viability study for this plant, to be located in the southeast of the island, has been completed.

United States of America

As part of its plan to use renewable energy to power the Natural Energy Laboratory of Hawaii Authority (NELHA) by 2012, the Laboratory has created a Green Energy Zone whose goal is to develop a range of projects using a variety of renewable energies. One such project is the installation of a 1 MW OTEC plant, which NELHA continues to work towards. In February 2009 and after an administrative setback to the project, NELHA was waiting for the Department of Business, Economic Development & Tourism (DBEDT) to issue a Request for Proposal (RFP). However, possible completion of the scheme is still several years hence.

Another Green Energy Zone project envisages a 50-100 MW offshore OTEC plant. In addition to the ship becoming a centre of excellence, it would be capable of exporting hydrogen to the NELHA station, producing drinking water and supporting surrounding Aqua farms (algae and biodiesel).

It has also been reported that Lockheed Martin and Sea Solar Power are developing plans for OTEC schemes, initially of 10 MW and 25 MW respectively, for installation in Hawaii. The Lockheed Martin project would feed electricity to the electricity grid via submarine cables.

As part of the U.S. Military's requirement to reduce its fossil-fuel consumption, the U.S. Navy has a research project for electricity generation and production of potable water from an OTEC plant at its base on Diego Garcia. Phases I (initial concept) and II (computer modelling) have been completed. Phase III currently involves contractual arrangements regarding terms and price for the design and construction, after which the final design can be drawn up. In early 2009 it was suggested that the plant could be installed during 2011.

Vanuatu

See French Polynesia.

Abbreviations and Acronyms

10^3	kilo (k)
10^6	mega (M)
10^9	giga (G)
10^{12}	tera (T)
10^{15}	peta (P)
10^{18}	exa (E)
10^{21}	zetta (Z)
ABWR	advanced boiling water reactor
AC	alternating current
AHWR	advanced heavy water reactor
API	American Petroleum Institute
APR	advanced pressurised reactor
APWR	advanced pressurised water reactor
b/d	barrels per day
bbl	barrel
bcf	billion cubic feet
bcm	billion cubic metres
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
billion	10^9
BIPV	building integrated PV
BNPP	buoyant nuclear power plant
boe	barrel of oil equivalent
BOO	build, own, operate
BOT	build, operate, transfer
bpsd	barrels per stream-day
bscf	billion standard cubic feet
Btu	British thermal unit
BWR	boiling light-water-cooled and moderated reactor
C	Celsius
CBM	coal-bed methane
cf	cubic feet
CHP	combined heat and power
CIS	Commonwealth of Independent States
cm	centimetre
CNG	compressed natural gas
cP	centipoise
CSP	centralised solar power
d	day
DC	direct current
DOWA	deep ocean water applications
ECE	Economic Commission for Europe
EIA	US Energy Information Administration / environmental impact assessment
EPR	European pressurised water reactor
ETBE	ethyl tertiary butyl ether
EU	European Union
F	Fahrenheit
FAO	UN Food and Agriculture Organization
FBR	fast breeder reactor
FID	final investment decision
FSU	former Soviet Union
ft	feet
g	gram
gC	grams carbon
GEF	Global Environment Facility
GHG	greenhouse gas
GTL	gas to liquids
GTW	gas to wire
GW_e	gigawatt electricity
GW_p	gigawatt peak
GWh	gigawatt hour
h	hour
ha	hectare
HDR	hot dry rocks

hm^3	cubic hectometre
HPP	hydro power plant
HTR	high temperature reactor
HWR	heavy water reactor
Hz	hertz
IAEA	International Atomic Energy Agency
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
IPS	International Peat Society
J	joule
kcal	kilocalorie
kg	kilogram
km	kilometre
km^2	square kilometre
kPa	kilopascal
kV	kilovolt
kW_e	kilowatt electricity
kWh	kilowatt hour
kW_p	kilowatt peak
kW_t	kilowatt thermal
lb	pound (weight)
LNG	liquefied natural gas
LPG	liquefied petroleum gas
l/s	litres per second
l/t	litres per tonne
LWGR	light-water-cooled, graphite-moderated reactor
LWR	light water reactor
m	metre
m/s	metres per second
m^2	square metre
m^3	cubic metre
mb	millibar
MJ	Megajoule
Ml	megalitre
mm	millimetre
MOU	memorandum of understanding
MPa	megapascal
mPa s	millipascal second
MSW	municipal solid waste
mt	million tonnes
mtpa	million tonnes per annum
mtoe	million tonnes of oil equivalent
MW	megawatt
MW_e	megawatt electricity
MWh	megawatt hour
MW_p	megawatt peak
MW_t	megawatt thermal
N	negligible
NEA	Nuclear Energy Agency
NGLs	natural gas liquids
NGO	non governmental organisation
Nm^3	normal cubic metre
NPP	nuclear power plant
OAPEC	Organisation of Arab Petroleum Exporting Countries
OECD	Organisation for Economic Co-operation and Development
OGJ	Oil & Gas Journal

OPEC	Organisation of the Petroleum Exporting Countries
OTEC	ocean thermal energy conversion
OWC	oscillating water column
p.a.	per annum
PBMR	pebble bed modular reactor
PDO	plan for development and operation
PFBR	prototype fast breeder reactor
PHWR	pressurised heavy-water-moderated and cooled reactor
ppm	parts per million
ppmv	parts per million by volume
psia	pounds per square inch, absolute
PV	photovoltaic
PWR	pressurised light-water-moderated and cooled reactor
RBMK	reaktor bolchoi mochtchnosti kanalni
R&D	research and development
RD&D	research, development and demonstration
R/P	reserves/production
rpm	revolutions per minute
SER	Survey of Energy Resources
t	tonne (metric ton)
tb/d	thousand barrels per day
tC	tonnes carbon
tce	tonne of coal equivalent
tcf	trillion cubic feet
tcm	trillion cubic metres
toe	tonne of oil equivalent
tpa	tonnes per annum
TPP	tidal power plant
tpsd	tonnes per stream day
tscf	trillion standard cubic feet

trillion	10^{12}
ttoe	thousand tonnes of oil equivalent
tU	tonnes of uranium
TWh	terawatt hour
U	uranium
U_3O_8	uranium oxide
UN	United Nations
UNDP	United Nations Development Programme
VAT	Value Added Tax
vol	volume
W	watt
WEC	World Energy Council
W_p	watts peak
wt	weight
WTO	World Trade Organization
WWER	water-cooled water-moderated power reactor
yr	year
—	unknown or zero
~	approximately
<	less than
>	greater than
≥	greater than or equal to

Conversion Factors and Energy Equivalents

Basic Energy Units

1 joule (J) = 0.2388 cal

1 calorie (cal) = 4.1868 J

(1 British thermal unit [Btu] = 1.055 kJ = 0.252 kcal)

WEC Standard Energy Units

1 tonne of oil equivalent (toe) = 42 GJ (net calorific value) = 10 034 Mcal

1 tonne of coal equivalent (tce) = 29.3 GJ (net calorific value) = 7 000 Mcal

Note: the tonne of oil equivalent currently employed by the International Energy Agency and the United Nations Statistics Division is defined as 10^7 kilocalories, net calorific value (equivalent to 41.868 GJ).

Volumetric Equivalents

1 barrel = 42 US gallons = approx. 159 litres
1 cubic metre = 35.315 cubic feet = 6.2898 barrels

Electricity

1 kWh of electricity output = 3.6 MJ = approx. 860 kcal

Representative Average Conversion Factors

1 tonne of crude oil = approx. 7.3 barrels

1 tonne of natural gas liquids = 45 GJ (net calorific value)

1 000 standard cubic metres of natural gas = 36 GJ (net calorific value)

1 tonne of uranium (light-water reactors, open cycle) = 10 000–16 000 toe

1 tonne of peat = 0.2275 toe

1 tonne of fuel wood = 0.3215 toe

1 kWh (primary energy equivalent) = 9.36 MJ = approx. 2 236 Mcal

Note: actual values vary by country and over time.

Because of rounding, some totals may not agree exactly with the sum of their component parts.

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