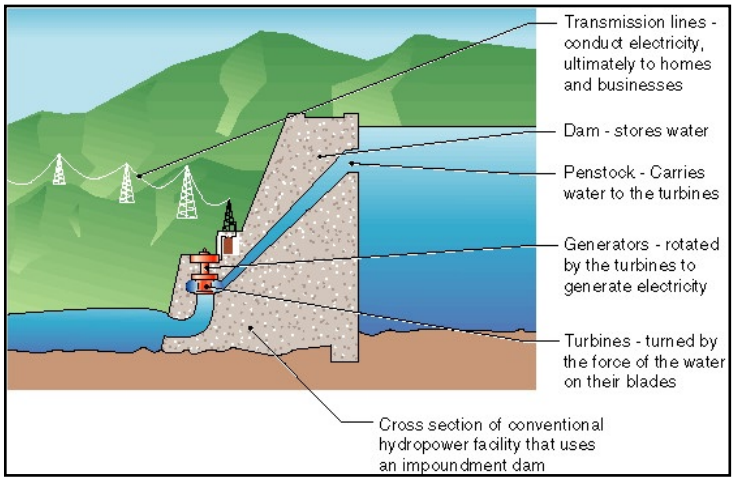
Advanced Hydropower

Technology Description



Hydroelectric power generates no greenhouse gas. To the extent that existing hydropower can be maintained or expanded through advances in technology, it can continue to be an important part of a greenhouse gas emissions-free energy portfolio. Advanced hydropower is technology that produces hydroelectricity both efficiently and with improved environmental performance. Traditional hydropower may have environmental effects, such as fish mortality and changes to downstream water quality and quantity. The goal of advanced hydropower is to maximize the use of water for generation while improving environmental performance.

System Concepts

- Conventional hydropower projects use either impulse or reaction turbines to convert kinetic energy in flowing or falling water into turbine torque and power. Source water may be from free-flowing rivers, streams, or canals, or water released from upstream storage reservoirs.
- New environmental and biological criteria for turbine design and operation are being developed to help sustain hydropower's role as a clean, renewable energy source – and to enable upgrades of existing facilities and retrofits at existing dams.

Representative Technologies

- New turbine designs that improve survivability of fish that pass through the power plant.
- Autoventing turbines to increase dissolved oxygen in discharges downstream of dams.
- Re-regulating and aerating weirs used to stabilize tailwater discharges and improve water quality.
- Adjustable-speed generators producing hydroelectricity over a wider range of heads and providing more uniform instream-flow releases without sacrificing generation opportunities.
- New assessment methods to balance instream-flow needs of fish with water for energy production and to optimize operation of reservoir systems.
- Advanced instrumentation and control systems that modify turbine operation to maximize environmental benefits and energy production.

Technology Applications

- Hydropower provides about 78,000 MW of the nation's electrical-generating capability. This is about 80 percent of the electricity generated from renewable energy sources.
- Existing hydropower generation faces a combination of real and perceived environmental effects, competing uses of water, regulatory pressures, and changes in energy economics (deregulation, etc.); potential hydropower resources are not being developed for similar reasons.
- Some new environmentally friendly technologies such as low head and low impact hydroelectric are being implemented in part stimulated by green power programs.
- DOE's Advanced Hydropower Turbine System (AHTS) program will be completing public-private partnerships with industry to demonstrate the feasibility of new turbine designs (e.g., aerating turbines at the Osage Dam, and a Minimum Gap Runner turbine at the Wanapum Dam).

Current Status
• TVA has demonstrated that improved turbine designs, equipment upgrades, and systems optimization can lead to significant economic and environmental benefits – energy production was increased approximately 12% while downstream fish resources were significantly improved. • Field-testing of the Kaplan turbine Minimum Gap Runner design indicates that fish survival can be significantly increased, if conventional turbines are modified. The full complement of Minimum Gap Runner design features will be tested at the Wanapum Dam in FY 2005.
Technology History
• Since the time of ancient Egypt, people have used the energy in flowing water to operate machinery and grind grain and corn. However, hydropower had a greater influence on people's lives during the 20th century than at any other time in history. Hydropower played a major role in making the wonders of electricity a part of everyday life and helped spur industrial development. Hydropower continues to produce 24% of the world's electricity and supply more than 1 billion people with power. • The first hydroelectric power plant was built in 1882 in Appleton, Wisconsin, to provide 12.5 kilowatts to light two paper mills and a home. Today's hydropower plants generally range in size from several hundred kilowatts to several hundred megawatts, but a few mammoth plants have capacities up to 10,000 megawatts and supply electricity to millions of people. • By 1920, 25% of electrical generation in the United States was from hydropower; and, by 1940, it increased to 40%. • Most hydropower plants are built through federal or local agencies as part of a multipurpose project. In addition to generating electricity, dams and reservoirs provide flood control, water supply, irrigation, transportation, recreation, and refuges for fish and birds. Private utilities also build hydropower plants, although not as many as government agencies.
Technology Future
• Voith Siemens Hydro Power and the TVA have established a partnership to market environmentally friendly technology at hydropower facilities. Their products were developed partly by funding provided by DOE and the Corps of Engineers, as well as private sources. • In a competitive solicitation, DOE accepted proposals for advanced turbine designs from Voith Siemens, Alstom, American Hydro, and General Electric Co. Field verification and testing is underway with some of these designs to demonstrate improved environmental performance. • Flash Technology is developing strobe lighting systems to force fish away from hydropower intakes and to avoid entrainment mortality in turbines. Implementation at more sites may allow improved environmental performance with reduced spillage. Market Context • Advanced hydropower products can be applied at more than 80% of existing hydropower projects (installed conventional capacity is now 94 GW); the potential market also includes 15-20 GW at existing dams (i.e. no new dams required for development) and more than 30 GW of undeveloped hydropower. • Retrofitting advanced technology and optimizing system operations at existing facilities would lead to at least a 6% increase in energy output – if fully implemented, this would equate to 5 GW and 18,600 GWh of new, clean energy production.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

Hydroelectric Power

Market Data

U.S. Installed Capacity (MW)* Source: *Renewable Electric Plant Information System (REPiS)*, Version 7, NREL, 2003.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Annual	1,391	3,237	862	1,054	19.9	64.0	7.6	179.3	1.1	11	0.002	21.0
Cumulative	80,491	87,839	90,955	94,052	94,072	94,136	94,143	94,323	94,324	94,335	94,335	94,356

* There are an additional 21 MW of hydroelectric capacity that are not accounted for here because they have no specific online date.
2003 data not complete as REPiS database is updated through 2002.

Cumulative Grid-Connected Hydro Capacity (MW)[1] Source: U.S. data from EIA, AER 2004, Table 8.11a; World Total from EIA, International Energy Annual, 1996-2003, Table 6.4. International data from International Energy Agency, Electricity Information 2004.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
U.S.													
Conventional and other Hydro	81,700	88,900	73,923	78,562	76,437	79,415	79,151	79,393	79,359	79,484	79,354	78,694	78,703
Pumped Storage[2]	N/A	N/A	19,462	21,387	21,110	19,310	19,518	19,565	19,522	19,096	20,373	20,522	20,522
U.S. Hydro Total	81,700	88,900	93,385	99,948	97,548	98,725	98,669	98,958	98,881	98,580	99,727	99,216	99,225
OECD Europe[3]	124,184	124,577	130,886	132,893	134,902	135,939	133,307	136,251	140,779	141,913	147,580	NA	NA
IEA Europe[4]	123,960	124,357	130,663	132,666	134,038	135,074	132,315	135,254	138,093	138,912	144,010	NA	NA
Japan	21,377	19,980	20,825	21,171	21,222	21,277	21,477	21,555	22,019	22,081	21,690	NA	NA
OECD Total	286,969	300,725	316,291	340,259	342,893	346,342	342,673	346,446	351,513	352,564	338,130	NA	NA
IEA Total	286,745	300,505	316,068	330,703	331,947	335,395	331,930	335,768	339,145	339,880	324,920	NA	NA
World Total	470,669	537,734	600,206	650,936	661,237	673,797	680,610	697,749	712,689	723,581	NA	NA	NA

1. Excludes pumped storage, except for specific U.S. pumped storage capacity listed.

2. Pumped storage values for 1980-1985 are included in "Conventional and other Hydro"

3. OECD included 24 countries as of 1980. Mexico, Czech Republic, Hungary, Poland, South Korea, Slovak Republic joined after 1980. Countries' data are included only after the year they joined.

4. IEA included 26 countries as of 2003. Countries' data are included only after the year they joined the OECD.

NA = Not Available; Updated international data not available at time of publication

Annual Generation from Cumulative Installed Capacity (Billion kWh)	Source: EIA, *International Energy Annual 2003*, DOE/EIA-0219(02), Table 1.5.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
United States	279	284	289	308	344	352	319	313	270	208	255
Canada	251	301	294	332	352	347	329	342	355	330	315
Mexico	17	26	23	27	31	26	24	32	33	28	25
Brazil		177	205	251	263	276	289	290	302	265	282
Western Europe		453	453	506	491	506	523	531	555	553	503
Former U.S.S.R.	128	205	231	238	215	216	225	227	228	239	243
Eastern Europe	432	26	23	34	34	36	35	35	31	30	32
China	184	91	125	184	185	193	203	211	241	258	309
Japan		82	88	81	80	89	92	86	86	83	81
Rest of World	27 273	328	435	504	515	522	533	541	558	571	581
World Total	58 88 1,736	1,973	2,167	2,466	2,511	2,564	2,571	2,609	2,658	2,565	2,627

State Generating Capability* (MW)	Source: EIA, Electric Power Annual 2004 – Spreadsheets, "1990 - 2002 Existing Nameplate and Net Summer Capacity by Energy Source and Producer Type (EIA-860)" http://www.eia.doe.gov/cneaf/electricity/epa/existing_capacity_state.xls										
Top 10 States	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Washington	19,935	20,487	20,431	20,923	21,012	21,011	21,011	21,006	21,016	21,018	20,941
California	12,687	13,519	13,500	13,475	13,383	13,445	13,475	13,471	13,523	13,306	13,323
Oregon	8,221	8,268	8,267	8,264	8,265	8,249	8,261	8,240	8,211	8,235	8,236
New York	5,345	5,545	5,557	5,565	5,668	5,662	5,659	5,712	5,804	5,842	5,891
Tennessee	3,717	3,818	3,818	3,937	3,950	3,950	3,950	3,948	3,948	3,948	3,948
Georgia	2,453	3,287	3,005	3,305	3,314	3,314	3,313	3,313	3,613	3,414	3,566
South Carolina	2,367	3,468	3,468	3,442	3,442	3,452	3,455	3,453	3,453	3,459	3,499
Virginia	3,072	3,126	3,149	3,082	3,093	3,090	3,091	3,088	3,088	3,088	3,088
Alabama	2,857	2,868	2,864	2,904	2,961	2,961	2,961	2,959	2,959	3,159	3,261
Arizona	2,685	2,885	2,885	2,893	2,893	2,890	2,890	2,890	2,893	2,899	2,903
U.S. Total	89,828	94,513	94,372	95,222	95,496	95,802	95,879	95,844	96,343	96,353	96,699

* Values are nameplate capacity for total electric industry

State Annual Generation from Cumulative Installed Capacity* (Billion kWh)	Source: EIA, *Electric Power Annual 2002* – Spreadsheets, "1990 - 2002 Net Generation by State by Type of Producer by Energy Source (EIA-906)" http://www.eia.doe.gov/cneaf/electricity/epa/generation_state.xls										
Top 10 States	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Washington	87.5	82.5	98.5	104.2	79.8	97.0	80.3	54.7	78.2	71.8	71.6
Oregon	41.2	40.8	44.9	46.7	39.9	45.6	38.1	28.6	34.4	33.3	33.1
California	24.8	50.5	46.9	42.1	50.8	40.4	39.3	25.2	30.9	36.4	34.1
New York	27.1	24.8	27.8	29.5	28.2	23.6	23.9	22.2	24.1	24.3	24.0
Montana	10.7	10.7	13.8	13.4	11.1	13.8	9.6	6.6	9.6	8.7	8.9
Alabama	10.4	9.5	11.1	11.5	10.6	7.8	5.8	8.4	8.8	12.7	10.6
Idaho	9.1	11.0	13.3	14.7	12.9	13.5	11.0	7.2	8.8	8.4	8.5
Arizona	7.7	8.5	9.5	12.4	11.2	10.1	8.6	7.9	7.6	7.1	7.0
Tennessee	9.5	9.0	10.8	10.4	10.2	7.2	5.7	6.2	7.3	12.0	10.4
South Dakota	3.9	6.0	8.0	9.0	5.8	6.7	5.7	3.4	4.4	4.3	3.6
U.S. Total	289.4	308.1	344.1	352.4	318.9	313.4	270.0	208.1	255.6	275.8	268.4

* Values are for total electric industry. Years before 1998 do not include nonutility generation.

Annual Hydroelectric Consumption for Electric Generation (Trillion Btu)	Source: *EIA, Annual Energy Review 2004, DOE/EIA-0384(2004) (Washington, D.C., August 2005) Table 8.4a*												
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
U.S. Total	2,900	2,970	3,046	3,205	3,590	3,640	3,297	3,268	2,811	2,201	2,689	2,825	2,725
Note: Conventional hydroelectric power only, for all sectors.													
Hydroelectric data through 1988 include industrial plants as well as electric utilities. Beginning in 1989, data are for electric utilities, independent power producers, commercial plants, and industrial plants.													