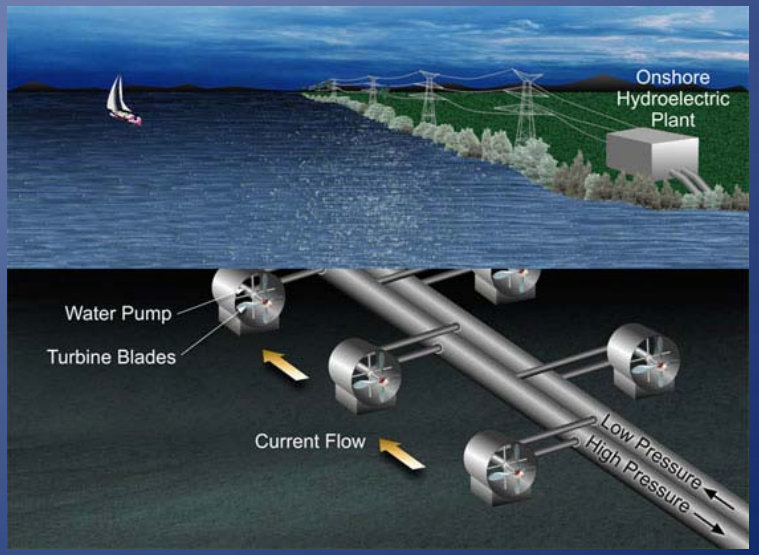
The Technical Side of Hydropower

From the Water Wheel to Hydro-Kinetics



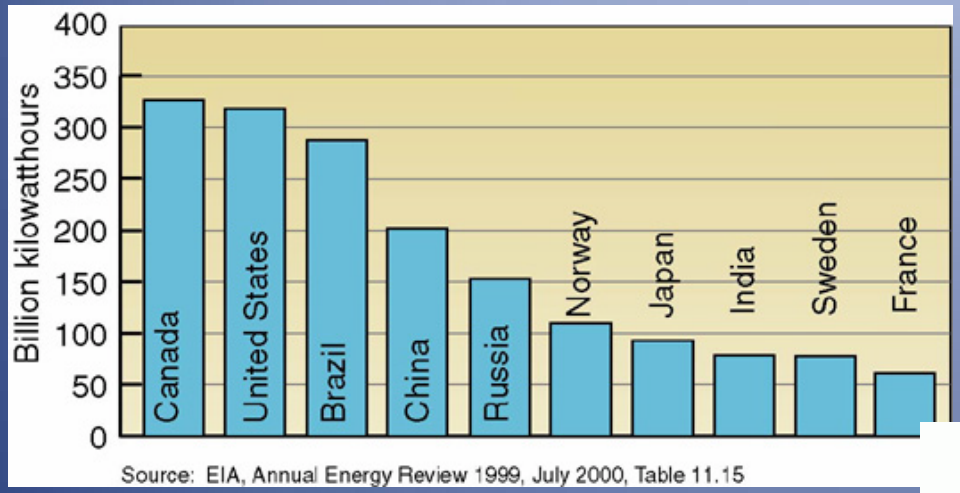
History of Hydropower

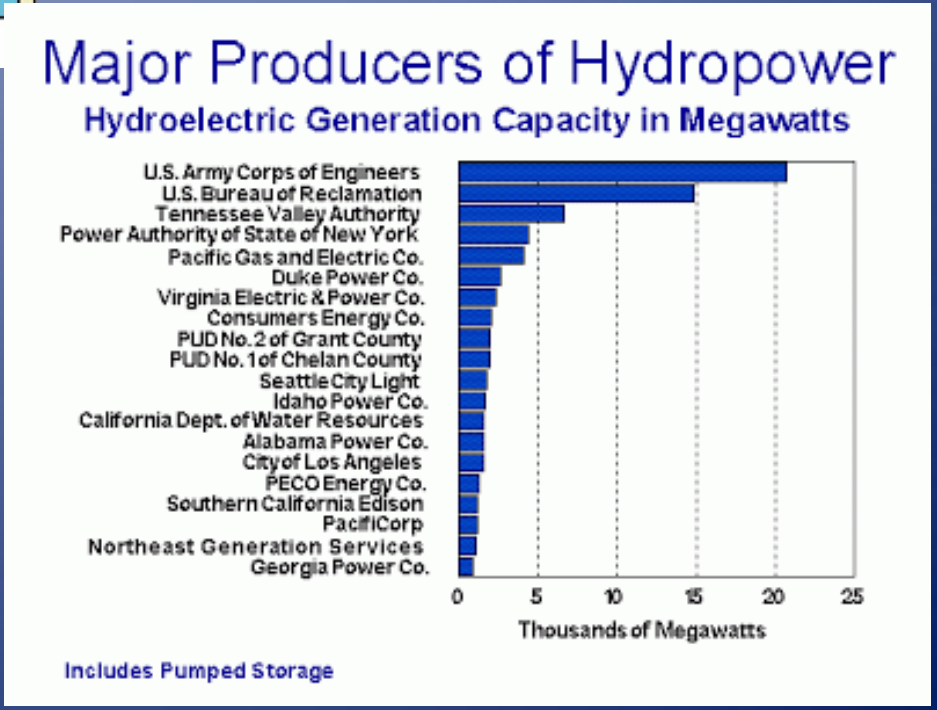
- B.C. Hydropower used by the Greeks to turn water wheels for grinding wheat into flour, more than 2,000 years ago.
- Mid-1770s: French hydraulic and military engineer Bernard Forest de Bélidor wrote *Architecture Hydraulique*, a four-volume work describing vertical- and horizontal-axis machines.
- 1775: U.S. Army Corps of Engineers founded, with establishment of Chief Engineer for the Continental Army.
- 1880: Michigan's Grand Rapids Electric Light and Power Company, generating electricity by dynamo belted to a water turbine at the Wolverine Chair Factory, lit up 16 brush-arc lamps.
- 1881: Niagara Falls city street lamps powered by hydropower.
- 1882: World's first hydroelectric power plant began operation on the Fox River in Appleton, Wisconsin.
- 1886: About 45 water-powered electric plants in the U.S. and Canada.
- 1887: San Bernardino, Ca., opens first hydroelectric plant in the west.
- 1889: Two hundred electric plants in the U.S. use waterpower for some or all generation.
- 1901: First Federal Water Power Act.

History of Hydropower

- 1902: Bureau of Reclamation established.
- 1907: Hydropower provided 15% of U.S. electrical generation.
- 1920: Hydropower provided 25% of U.S. electrical generation. Federal Power Act establishes Federal Power Commission authority to issue licenses for hydro development on public lands.
- 1933: Tennessee Valley Authority established.
- 1935: Federal Power Commission authority extended to all hydroelectric projects built by utilities engaged in interstate commerce.
- 1937: Bonneville Dam, first Federal dam, begins operation on the Columbia River. Bonneville Power Administration established.
- 1940: Hydropower provided 40% of electrical generation. Conventional capacity tripled in United States since 1920.
- 1980: Conventional capacity nearly tripled in United States since 1940.
- 2003: About 10% of U.S. electricity comes from hydropower.
- Today: There is about 80,000 MW of conventional capacity and 18,000 MW of pumped storage.

World-wide/US Generation of Hydropower

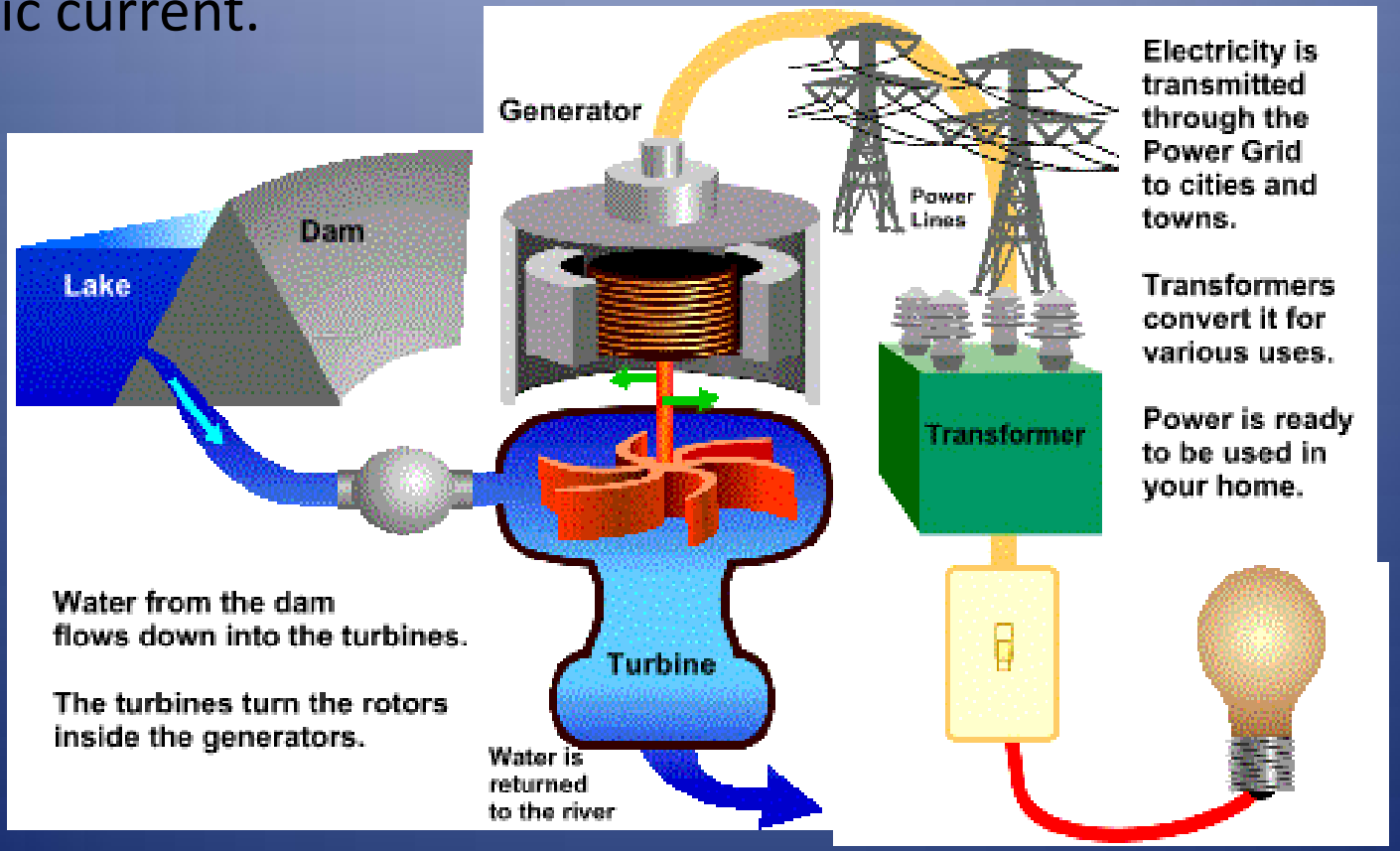




Source: NHA

How a Hydroelectric Power System Works

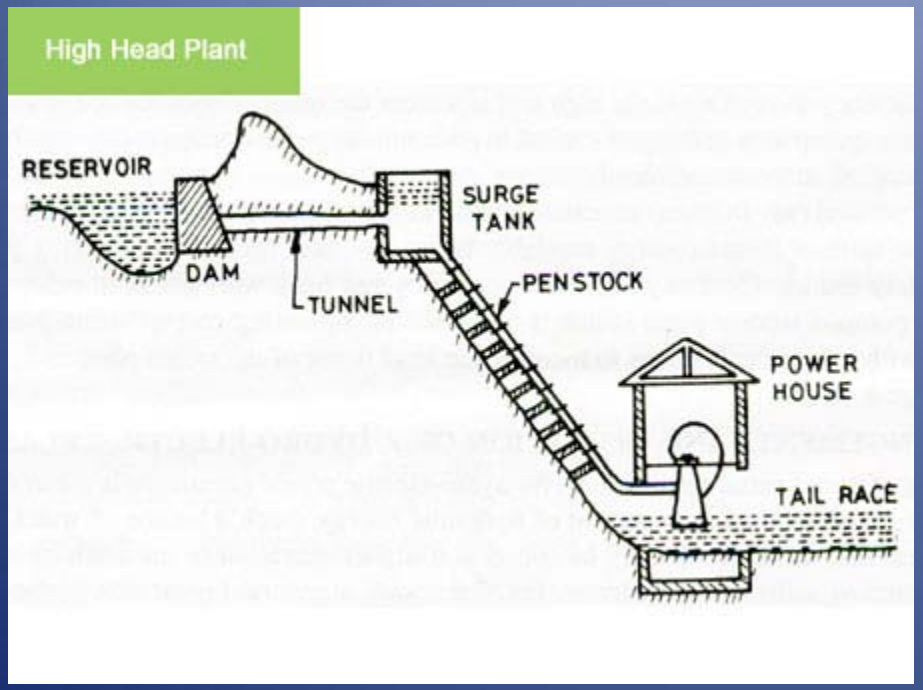
The mechanical energy produced by the turbine is converted into **electric energy** using a turbine generator. Inside the generator, the shaft of the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.

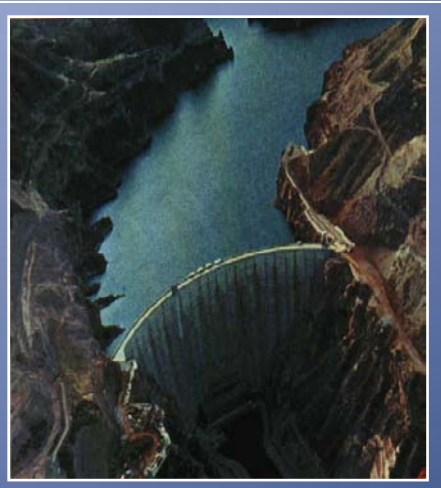


Source:

Types of Hydropower Projects

High Head:

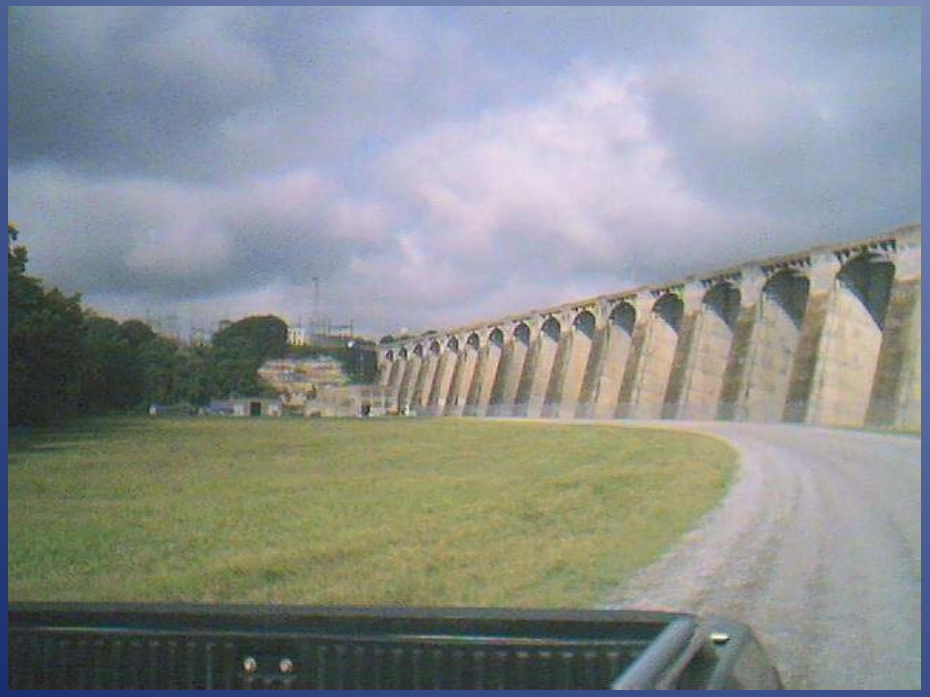




It is the technology that uses dams to store water at a high elevation. The dams store water during heavy rainfalls and release the water during the dry periods. The head height for this category is on the range of 100+ meters.

Types of Hydropower Projects

Medium Head:



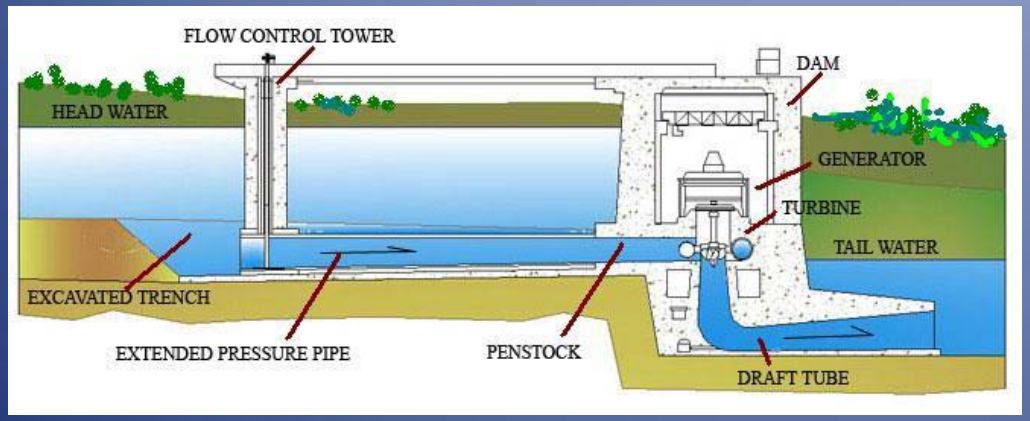
There are many dams in the United States that are not “low head” (less than 30 feet) or “high head” (greater than 300 feet) so we call these “Medium Head” projects.

They can use either vertical or horizontal Kaplan or Francis turbine generating units

Source: GRDA

Types of Hydropower Projects

Low Head:

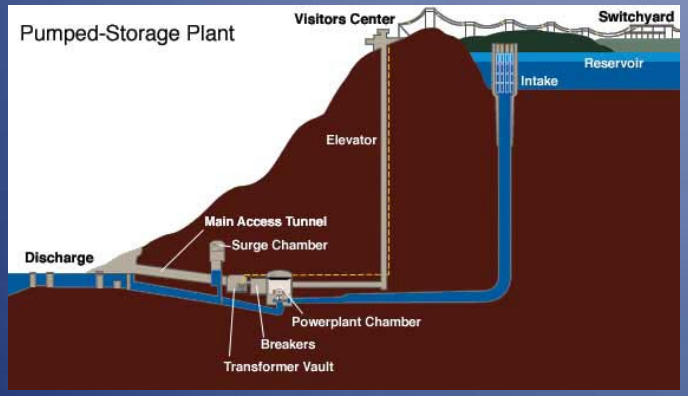


Low head plants are power plants that use a head height of less then a few meters. This type of plant will use a low-level dam, or even just a running river itself.

Source: The Bowersock Mills & Power Co.

Types of Hydropower Projects

Pumped Storage:



The United States has more than 20 gigawatts (GW) of pumped-storage capacity in use today, with facilities in every region. Developers have proposed an additional 31 GW, primarily in the West, to serve the rapid increase in variable energy resources coming online.

There are some 150 operational pumped-storage facilities in the United States, with a total capacity of over 25 GW. The largest facilities are as follows:

Location Facility	Capacity
• California Castaic Dam	1,566 MW
• California Edward C. Hyatt	780 MW
• California Helms	1,200 MW
• California John S. Eastwood	200 MW
• California Pyramid Lake	1,495 MW
• California San Luis Dam	424 MW
• Colorado Cabin Creek	324 MW
• Colorado Mount Elbert	1,212 MW
• Connecticut Rocky River/Candlewood Lake	31 MW
• Georgia Rocky Mountain Pumped Storage Station	848 MW
• Georgia Wallace Dam, Lake Oconee/Lake Sinclair	208 MW
• Massachusetts Bear Swamp	600 MW
• Massachusetts Northfield Mountain	1,080 MW
• Michigan Ludington	1,872 MW
• New Jersey Mt. Hope	2,000 MW
• New Jersey Yards Creek Generating Station	400 MW
• New York Blenheim-Gilboa	1,200 MW
• New York Lewiston Pump-Generating Plant	240 MW
• Oklahoma Salina Pumped Storage	260 MW
• Pennsylvania Muddy Run	1,071 MW
• Pennsylvania Seneca	435 MW
• South Carolina Fairfield/Lake Monticello Reservoir	512 MW
• South Carolina Bad Creek/Lake Jocassee	1,065 MW
• South Carolina Lake Jocassee	610 MW
• Tennessee Raccoon Mountain	1,530 MW
• Virginia Bath County	2,772 MW
• Virginia Smith Mountain Lake	n/a
• Virginia Leesville Lake	n/a
• Washington Grand Coulee Dam	314 MW

Source: GRDA

Types of Hydropower Projects

Conduit Projects:

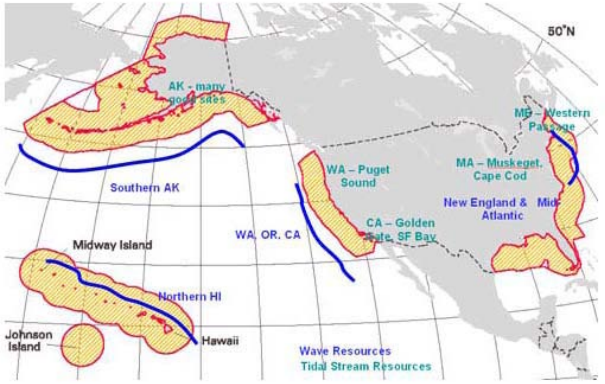
Source: NHA

In conduit hydropower, existing tunnels, canals, pipelines, aqueducts and other manmade structures that carry water are fitted with electric generating equipment. Conduit projects often qualify as small hydro, and are able to extract power from water without the need for a large dam or reservoir.

Types of Hydropower Projects

Hydro-Kinetics Projects:

Figure 1: Location of U.S. wave and tidal stream energy resources with the most electricity generation potential



Source: edited from Bedard, Roger. EPRI.

Figure 2: An oscillating water column wave energy converter

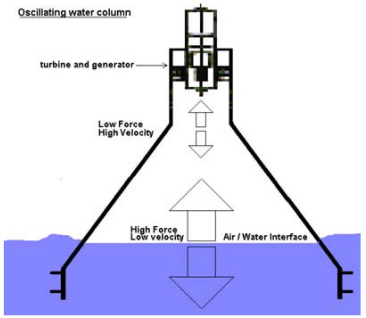


Figure 3: A point absorber wave energy converter

Figure 4: An attenuator wave energy convertor

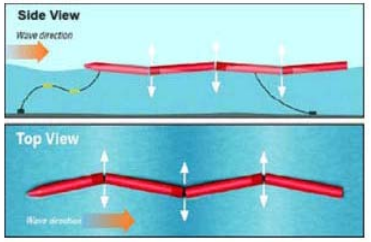


Figure 5: An overtopping wave energy converter

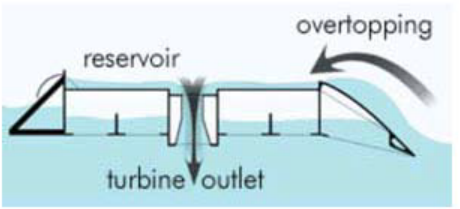
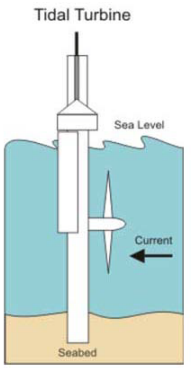


Figure 6: A horizontal axis hydrokinetic rotating device



Estimates suggest that **the amount of energy that could feasibly be captured from U.S. waves, tides and river currents is enough to power over 67 million homes.**

Source: Union of Concerned Scientists website

Current Hydropower Capacity Projects

Current FERC Licensed Projects:

52,800 MW

Current FERC Licensed Exemptions:

862 MW

Source: FERC E-Library 5-25-13

FERC License and Exemption Applications

Issued Preliminary Permits

60,574 MW

Pending Preliminary Permits

4,495 MW

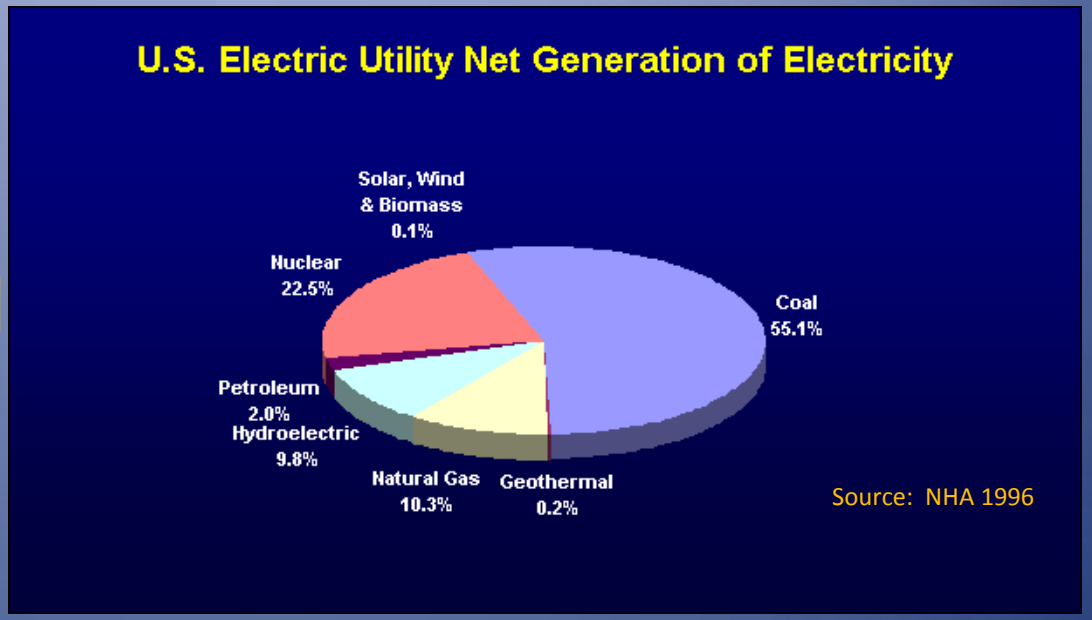
Pending Licenses, Re-Licenses and Exemptions

14,274 MW

Source: FERC E-Library 5-25-13

Potential Development

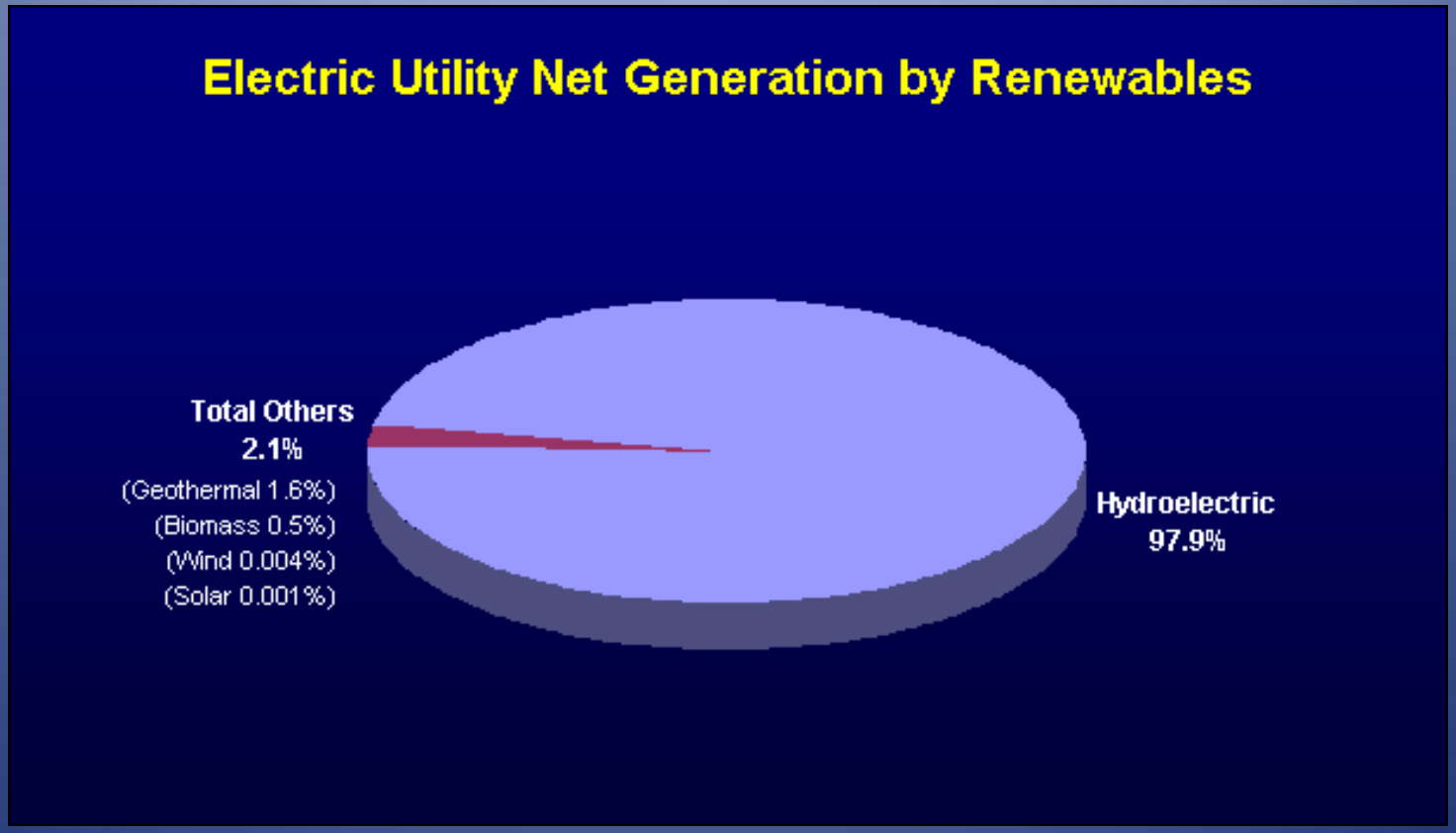
Only 3% of the existing 80,000 dams in the United States have hydropower generation



Goal of US Department of Energy and NHA – Double Capacity in next 15 years

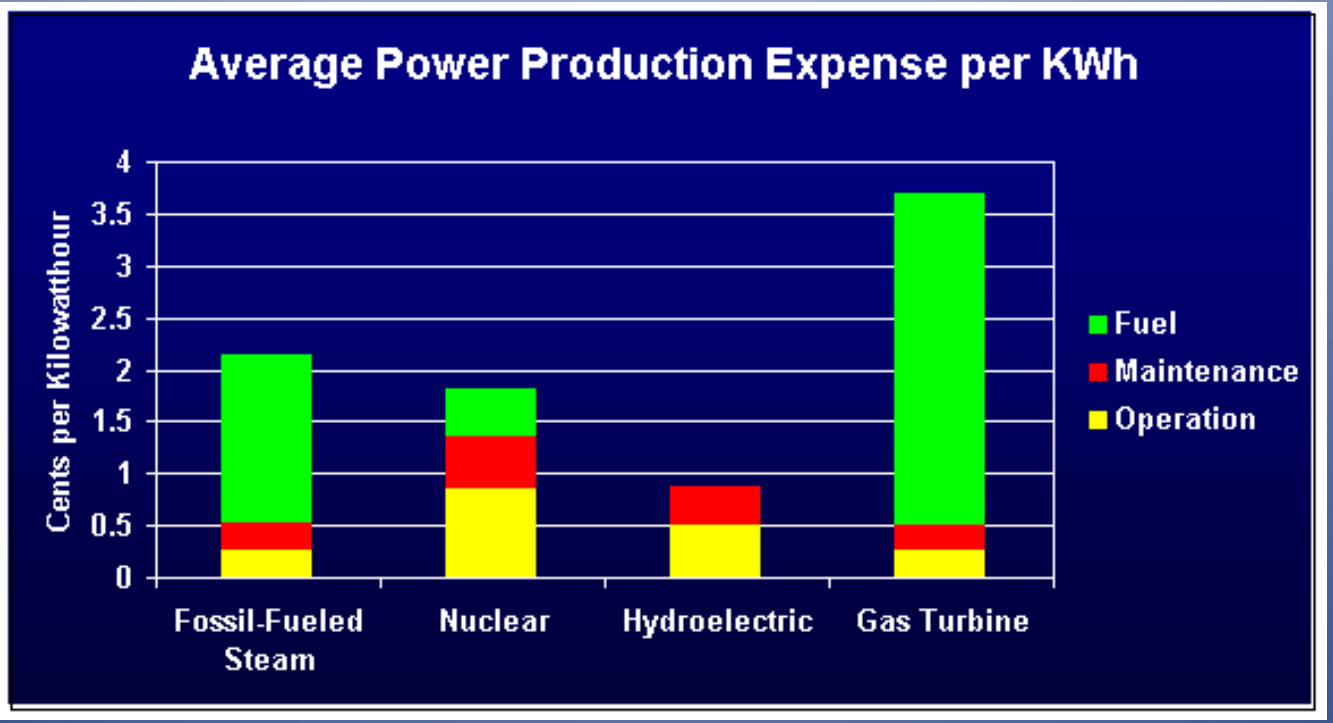
Source: NHA website 5-25-13

Current Renewable Generation



Source: NHA
1996

COST OF HYDROPOWER



Modern hydro turbines can convert as much as 90% of the available energy into electricity. The best fossil fuel plants are only about 50% efficient. (NHA)

In the U.S., hydropower is produced for an average of 0.85 cents per kilowatt-hour (kwh). This is about 50% the cost of nuclear, 40% the cost of fossil fuel, and 25% the cost of using natural gas. (Source: Wisconsin Energy Statistics, Wisconsin Energy Bureau, Department of Administration, 1994)

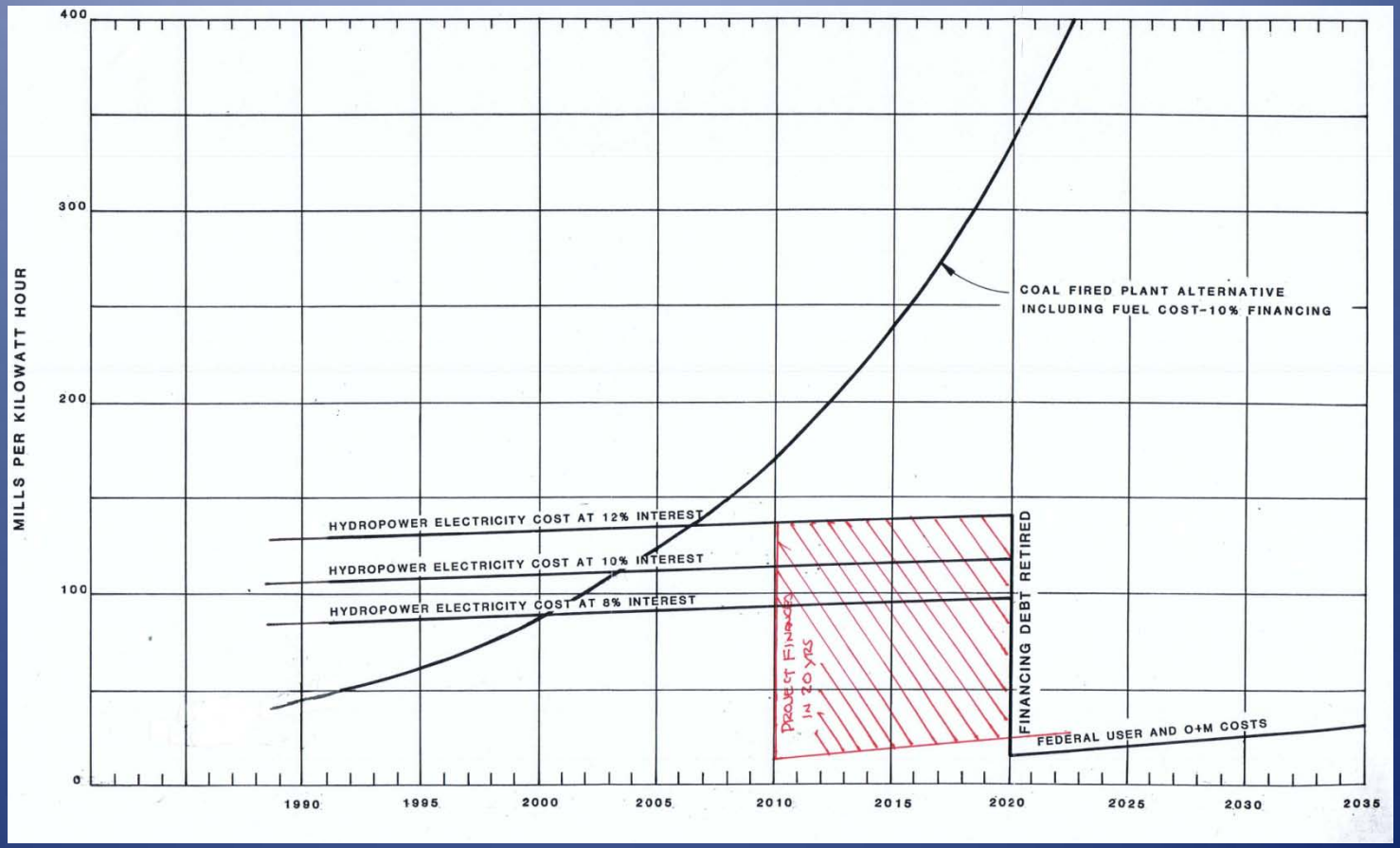
COST OF HYDROPOWER DEVELOPMENT

Today, the cost of developing hydropower at the existing dams ranges from approximately $1,100 to $4,000 per KW

To develop 65,000 MW will cost in the range of $162,500,000,000 or $162.5 B “that’s with a “B”

ECONOMICS OF HYDROPOWER DEVELOPMENT

L&D 13 Arkansas River was the last project in 1988 to receive Energy Tax Credits, Accelerated Depreciation and Investment Tax Credits. It was "internally" financed with a leveraged lease with GE Credit and then re-purchased in 2008+/-. In 2010 the Project was fully paid off (20 years vs. original 35 year financing)



(Source: BHPG Feasibility Study Report 1981)

BENEFITS TO US WITH HYDROPOWER DEVELOPMENT

A 2009 Navigant study indicates that installing 60,000 MW would result in 1.4 million cumulative jobs by 2025.

10,000 MW will come from converting non-powered dams, creating jobs across the country.

The remaining Potential will come from Pumped Storage, Ocean, Tidal and new “damless” Hydrokinetic technologies, and modernizing existing hydropower facilities.

HYDROPOWER SUMMARY

Available:

Hydropower is keeping the lights on in every region of the country. It is America's largest source of clean electricity, accounting for 65.9 percent of all renewable energy generation in the United States, and with the right policies, it has significant room to grow.

Reliable:

Hydropower has been a reliable source of power in the United States for over 100 years. That proven reliability benefits the national electric grid in a number of ways, from supporting other renewable energy sources to stabilizing the network to storing electricity for later use.

NHA
National Hydropower Association

HYDROPOWER SUMMARY

Affordable:

Hydropower is not only a low cost source of renewable electricity, it is among the most cost effective energy sources across the board. And since hydro taps the self-renewing power of our waterways, electricity from hydro is not subject to unpredictable price swings in the markets for energy commodities.

Sustainable:

Using hydropower – our leading source of renewable energy –avoids the emission of more than 225 million metric tons of carbon pollution in America each year.

NHA
National Hydropower Association

HYDROPOWER SUMMARY

Job Creation:

America's hydropower industry has the potential to create 1.4 million cumulative jobs by 2025, putting Americans to work building a 21st century clean energy infrastructure.

Other Benefits:

Hydropower facilities often do more than produce electricity, also providing vital benefits such as flood control, navigation, irrigation, water supply and a range of recreational opportunities.

NHA
National Hydropower Association

US Hydropower Projects

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