Job Creation Opportunities in Hydropower

Final Report

Presented to
National Hydropower Association

Final

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Content of Report

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The U.S. hydropower industry could install 23,000 MW – 60,000 MW of new capacity by 2025 depending upon the national RES adopted, which will require nearly 230,000 – 700,000 jobs.

Key Findings

- The U.S. has the second largest installed capacity of hydropower in the world at ~100 GW (including pumped storage).
- Hydropower accounts for approximately 7% of overall domestic electricity production in the U.S. and ranks 10th worldwide in electricity production.
- Over 400+ GW of untapped hydropower resource potential (inland and ocean) exists within the U.S.
- The U.S. hydropower industry currently accounts for approximately 200,000 – 300,000* jobs.
- Developing these untapped hydropower resources could contribute significantly to the emerging green jobs market in the U.S.
- The U.S. hydropower industry could install 23,000 MW – 60,000 MW of new capacity by 2025 depending upon the national RES adopted, representing only 6% - 15% of the total untapped hydropower resource potential in the U.S.
- Total jobs (direct + indirect) required to meet these targets would be in the range of 230,000 – 700,000 jobs
- These total jobs estimates do not include induced jobs (e.g., service sector jobs such as retail, restaurants created by added dollars flowing into the market) that represent an additional upside potential from the growth of the hydropower industry.

* Assumes an average of 2-3 FTE/MW needed to operate, maintain and license compliance of existing 100,000 MW fleet

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Despite recently published reports and new studies that are underway, there is need for continued study of the U.S. hydro potential.

Research on U.S. Hydroelectric Potential	
Streams	DOE's 2006 and 2003 Idaho National Laboratory reports, as well as other studies, have been conducted in this area.
Constructed Waterways	DOE is currently examining the potential for developing hydro in constructed waterways in the U.S.
Tidal	• EPRI has estimated technical potential in 5 states and a more theoretical potential for Alaska. • Georgia Tech is working on an assessment of both available and effective tidal power densities in the U.S.
Wave	EPRI has estimated the theoretical potential for wave power in the U.S.
Ocean Current	An assessment of potential off the coast of the U.S. has not been undertaken. Potential off the coast of Florida has been estimated at 4 - 10 GW.
Ocean Thermal	No assessment of U.S. potential has been undertaken or is under way.
Ocean Salinity Gradient	No assessment of U.S. potential has been undertaken or is under way.

Key:

Existing research on U.S. potential, fairly comprehensive.	New research is underway/research exists, but further work is needed	No existing reports on U.S. potential.

A range of hydro development by 2025 based on *technical potential* was estimated based on the methodology summarized below.

NCI Methodology for Estimating Technical Potential

Key

Hydro potential reported in this study.

This study reports an estimated Technical Potential for Inland and Ocean hydro.

Based on the Technical Potential, NCI derived a range of hydro development by 2025. This range was then used in calculations of job creation potential.

Theoretical Potential

- Represents total energy available for capture, regardless of competing uses or protected areas.

Reduced due to environmental and other placement constraints

- Exclusions for areas that would likely not be developable due to sensitive environmental habitats or other constraints (i.e. competing land use, load/transmission proximity, site access). Does not include economic constraints.

Additional constraints

- Any additional constraints which affect the ultimate feasibility of development. Does not include economic constraints.

Technical Potential

- Represents the portion of the theoretical potential which could technically be developed. It does not take economic issues into consideration.

Range of hydro development by 2025

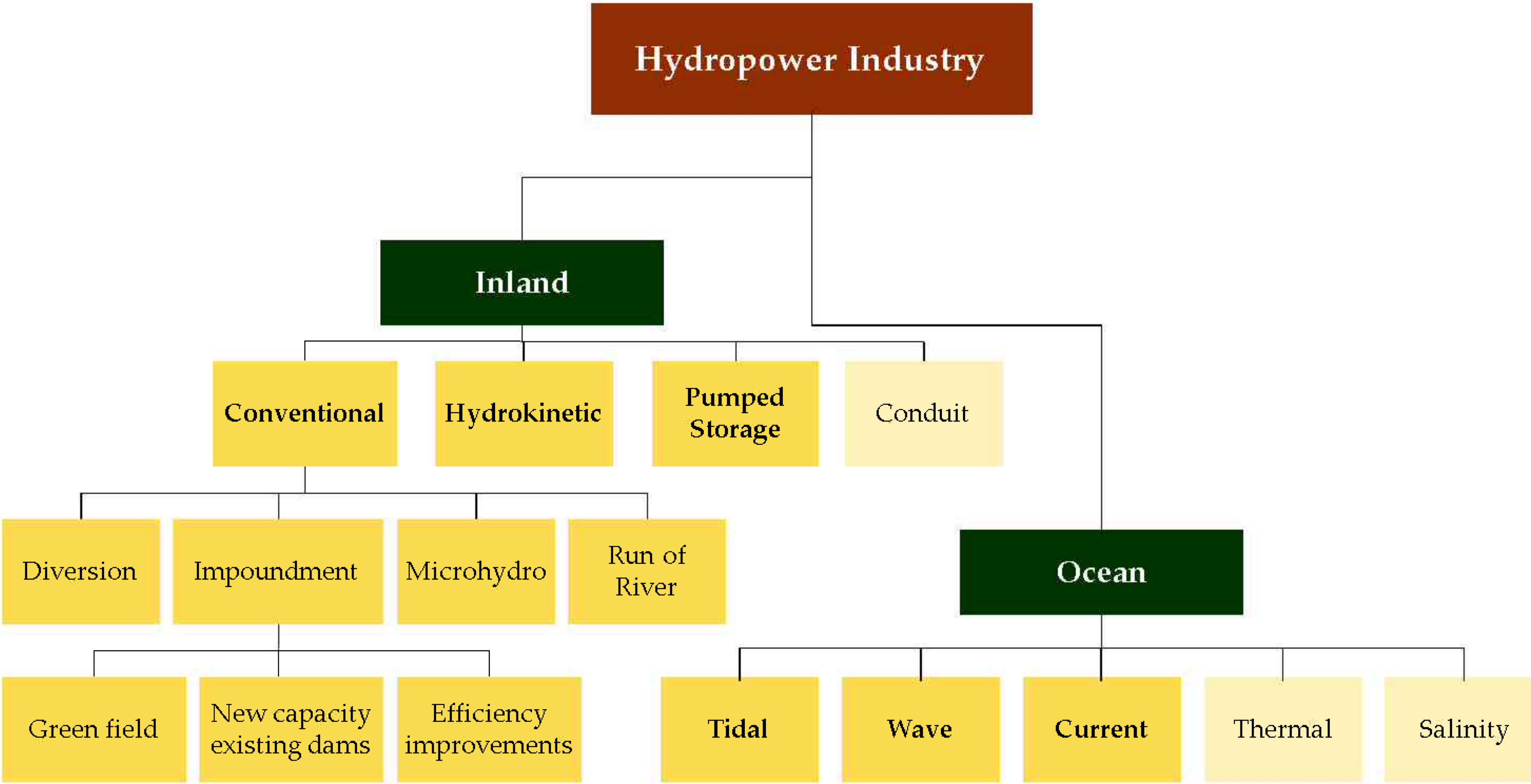
Navigant's upper limit for the 2025 technical potential was based on DOE inland reports, supplemented with information from other sources.

Comparison of Findings

	Navigant (NCI) Report	DOE Report
Theoretical Potential	• Not assessed in this report	• 600 GW
Reduced due to environmental and other placement constraints	• Not assessed in this report	• 300 GW (after removal of already developed potential and protected areas)
Additional constraints	• Not assessed in this report	• 200 GW (after site feasibility taken into account)
Technical Potential	• ~60 GW (plants<30MW at existing dams without hydro and green field) • ~15 GW (plants>30MW at existing dams without hydro and green field) • ~9 GW (capacity+efficiency upgrades) • See note: Pumped storage • 95 GW (Ocean – largely theoretical potential)	• 60 GW (plants<30MW) (after development criteria, i.e.working flow, taken into account) • Additional hydro potential examined by NCI was not assessed in the DOE report.

1. DOE numbers have been converted from MWa to MW based on a 50% capacity factor.
2. NCI did not estimate a pumped storage tech. potential, but did determined a range of possible development by 2025 later in the report.
3. *Feasibility Assessment of the Water Energy Resources of the US for New Low Power and Small Hydro Classes of Hydroelectric Plants* 2006, DOE-ID-11263 produced by Idaho National Labs for the U.S. Department of Energy.

Navigant Consulting has classified the hydropower industry into two categories and several subcategories shown below.

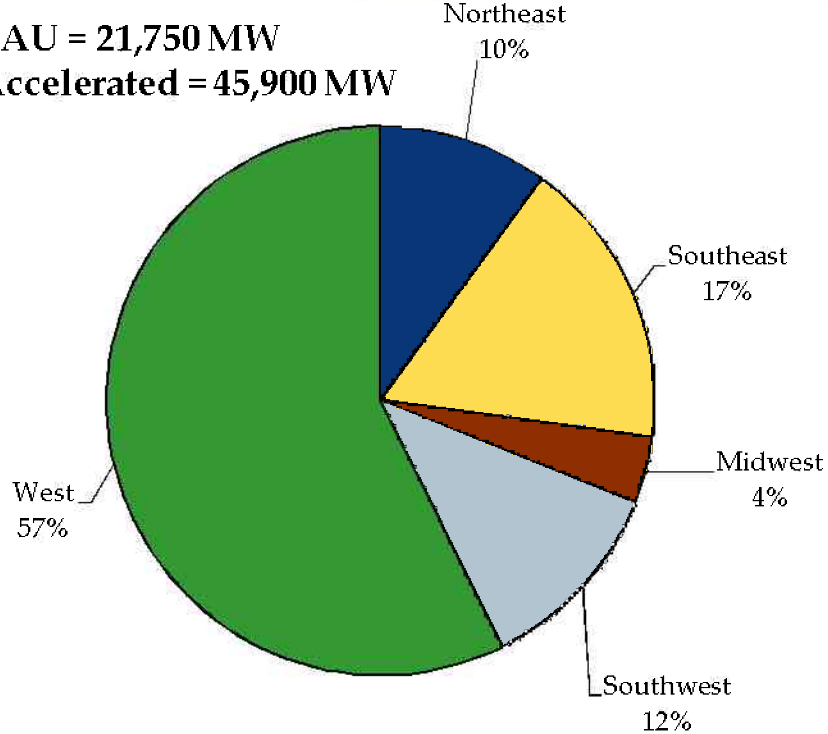


Note: Lighter colors indicate less mature technology not considered in this study

Forecasts by region were based on resource potential allocations by state.

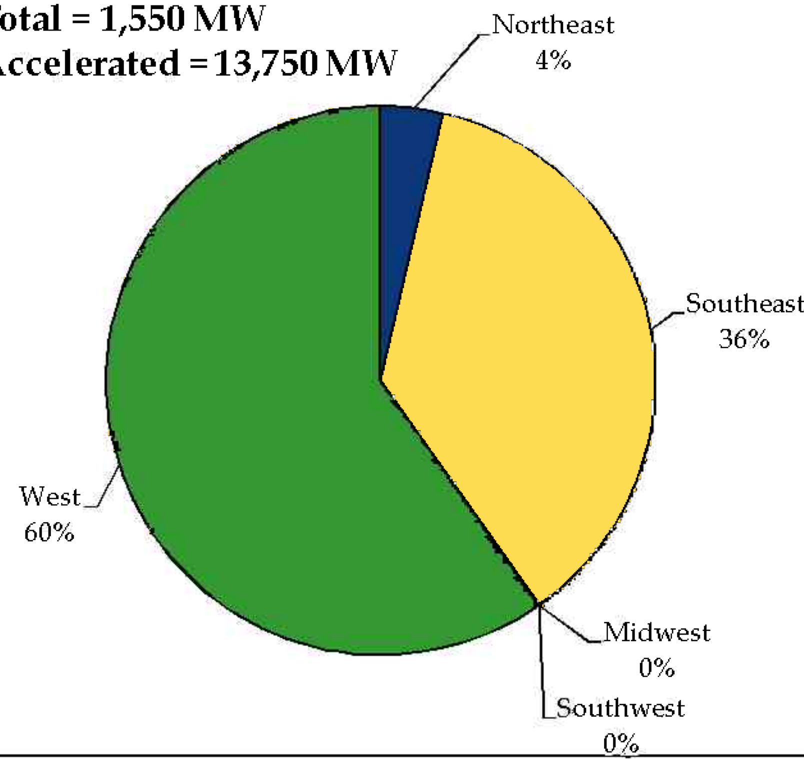
Inland Forecast Allocation 2025

BAU = 21,750 MW
Accelerated = 45,900 MW



Ocean Forecast Allocation 2025

Total = 1,550 MW
Accelerated = 13,750 MW



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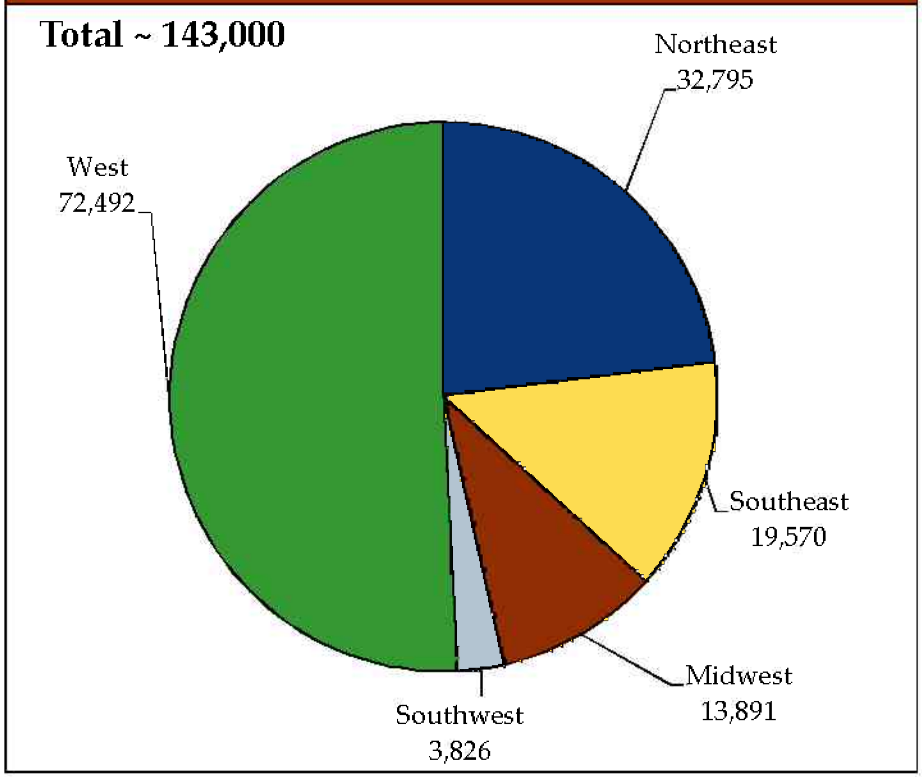
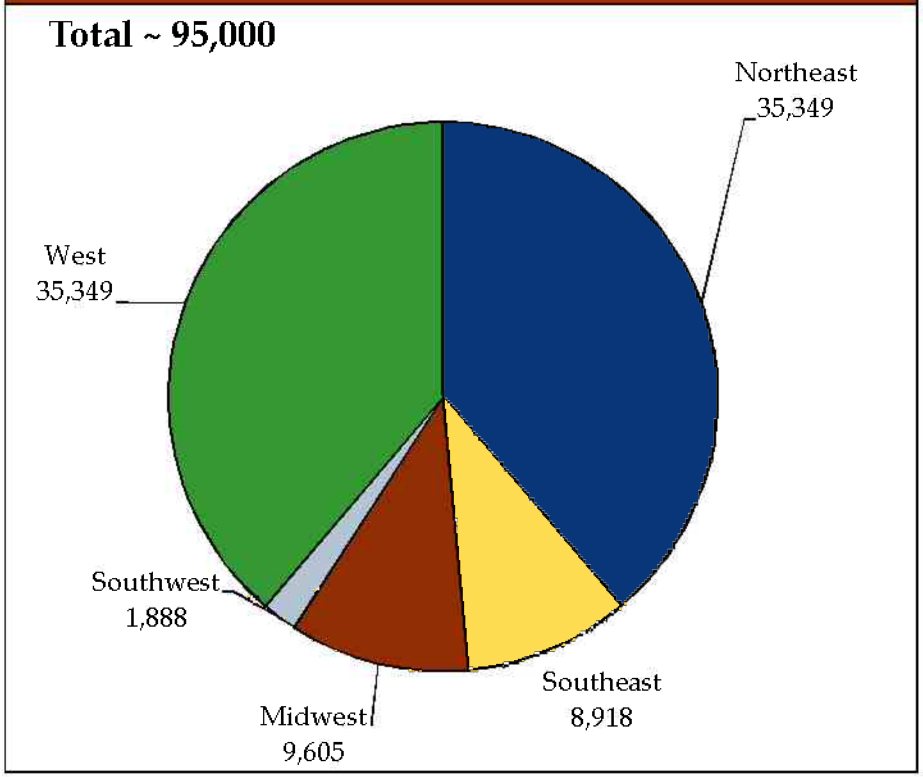
A total of ~238,000 jobs are estimated to be created in a BAU scenario with a low Renewable Energy Standard - RES (~10% by 2025).

Direct Jobs Allocation (Cumulative) BAU 2025



Indirect Jobs Allocation (Cumulative) BAU 2025



Note : Job estimates represent cumulative FTEs required over a 16 year period out to 2025

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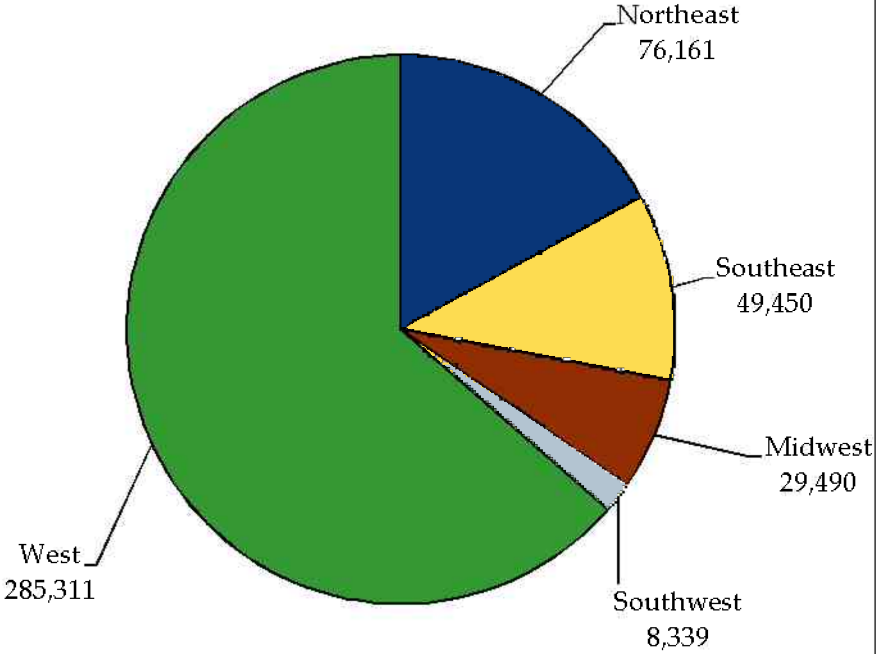
A total of ~700,000 jobs are estimated to be created in an accelerated scenario with a high RES (~25% by 2025).

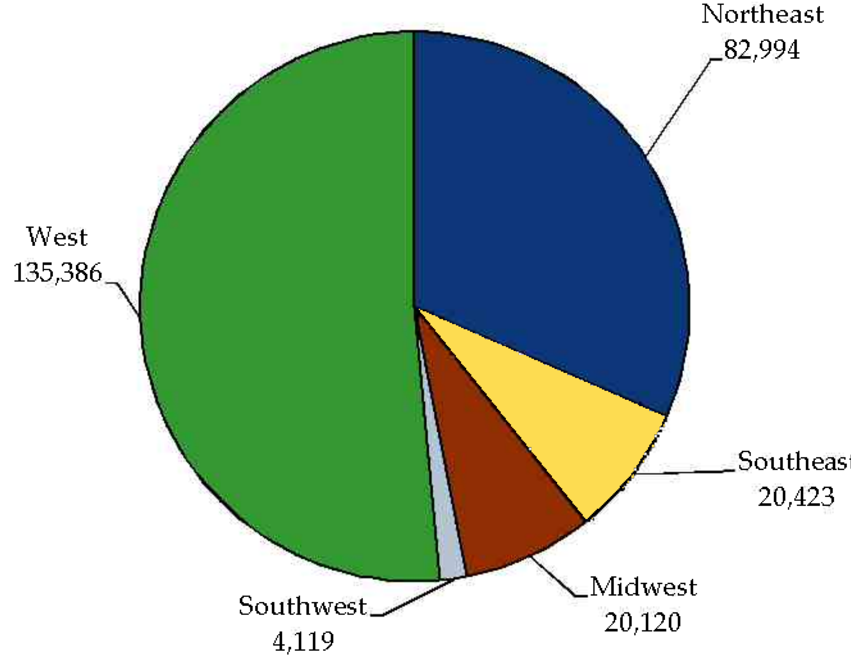
Direct Jobs Allocation (Cumulative) Accelerated 2025

Total ~ 443,000



Indirect Jobs Allocation (Cumulative) Accelerated 2025

Total ~ 265,000



Note : Job estimates represent cumulative FTEs required over a 16 year period out to 2025

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This study focused on estimating the direct and indirect jobs creation potential for the U.S. Hydropower Industry.

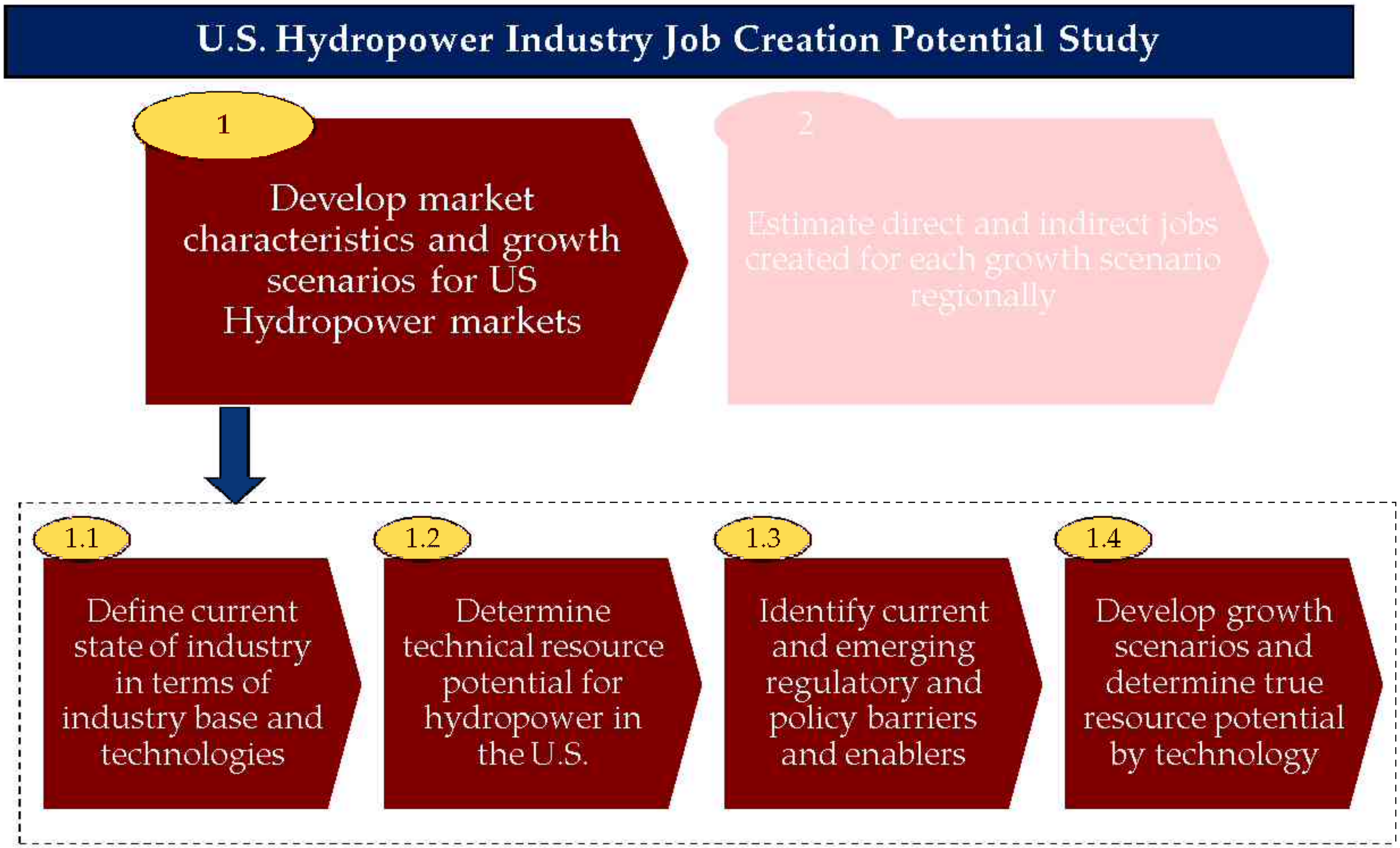
U.S. Hydropower Market Job Creation Potential Study

1. Develop market characteristics and growth scenarios for US Hydropower markets
2. Estimate direct and indirect jobs created for each growth scenario regionally

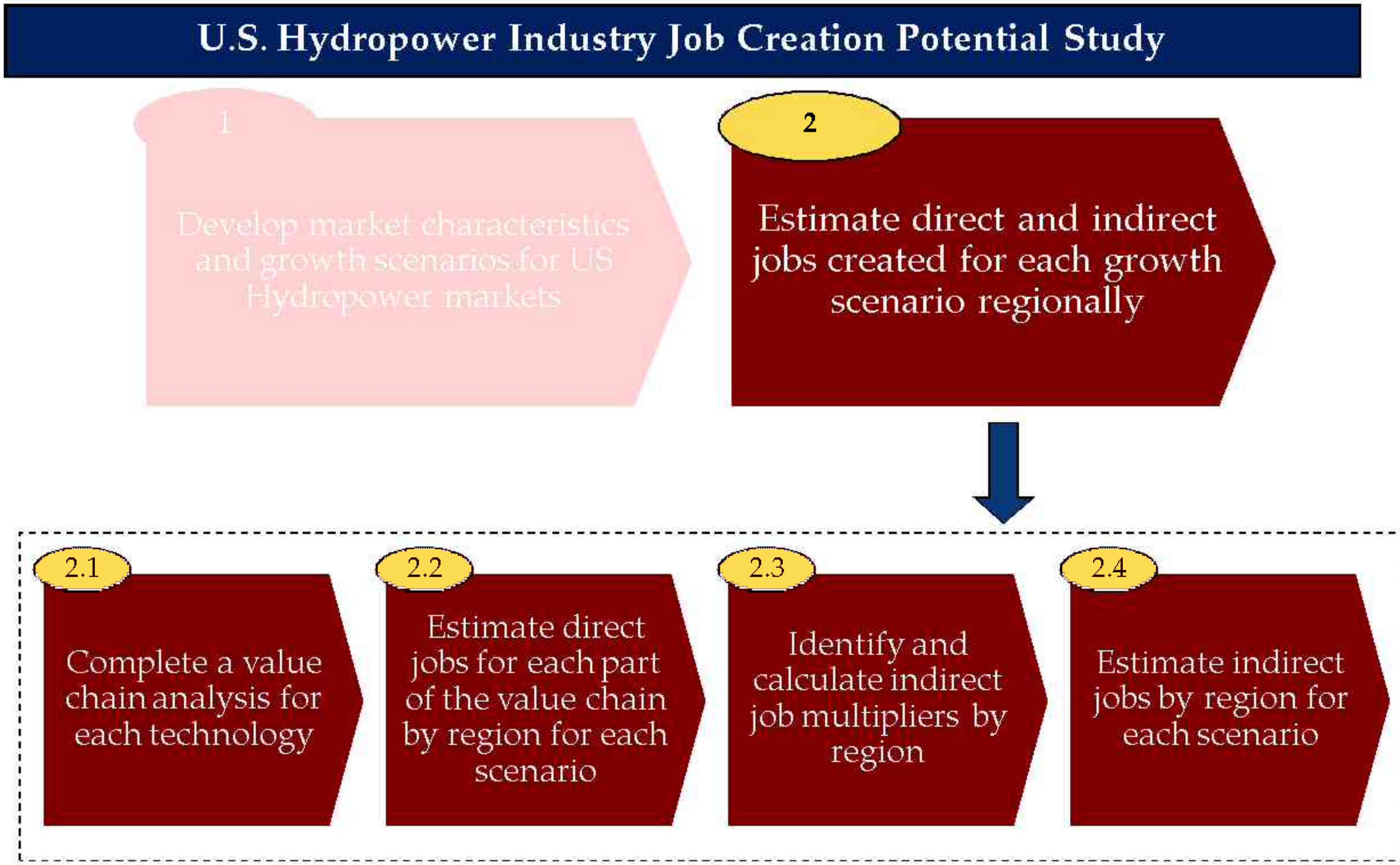
Key Deliverables

- **Task 1:** Theoretical and technical resource potential (under two growth scenarios) for various hydropower technologies in the US by region and state by 2025
- **Task 2:** Direct jobs in each part of the market value chain and indirect jobs created, by region for each for growth scenario

Task 1 focused on identifying the technical resource potential for various hydropower technologies in the U.S. by state and region.



Task 2 focused on estimating direct and indirect jobs created regionally for each growth scenario.



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Key U.S. hydropower industry characteristics have been summarized below.

Key U.S. Industry Characteristics
• The U.S. hydropower industry currently accounts for approximately 200,000 – 300,000* jobs. – The jobs span four specific value chain elements: 1) Project Development, 2) Manufacturing, 3) Project Deployment and 4) Operations and Maintenance. • The U.S. has the second largest installed capacity of hydropower in the world at ~100 GW (including pumped storage). • Hydropower accounts for approximately 7% of overall domestic electricity production in the U.S. and ranks 10th worldwide in electricity production. • Over 400+ GW of untapped hydropower resource potential (inland and ocean) exists within the U.S. • Developing these untapped hydropower resources could contribute significantly to the emerging green jobs market in the U.S.

* Assumes an average of 2-3 FTE/MW needed to operate, maintain and license compliance of existing 100,000 MW fleet

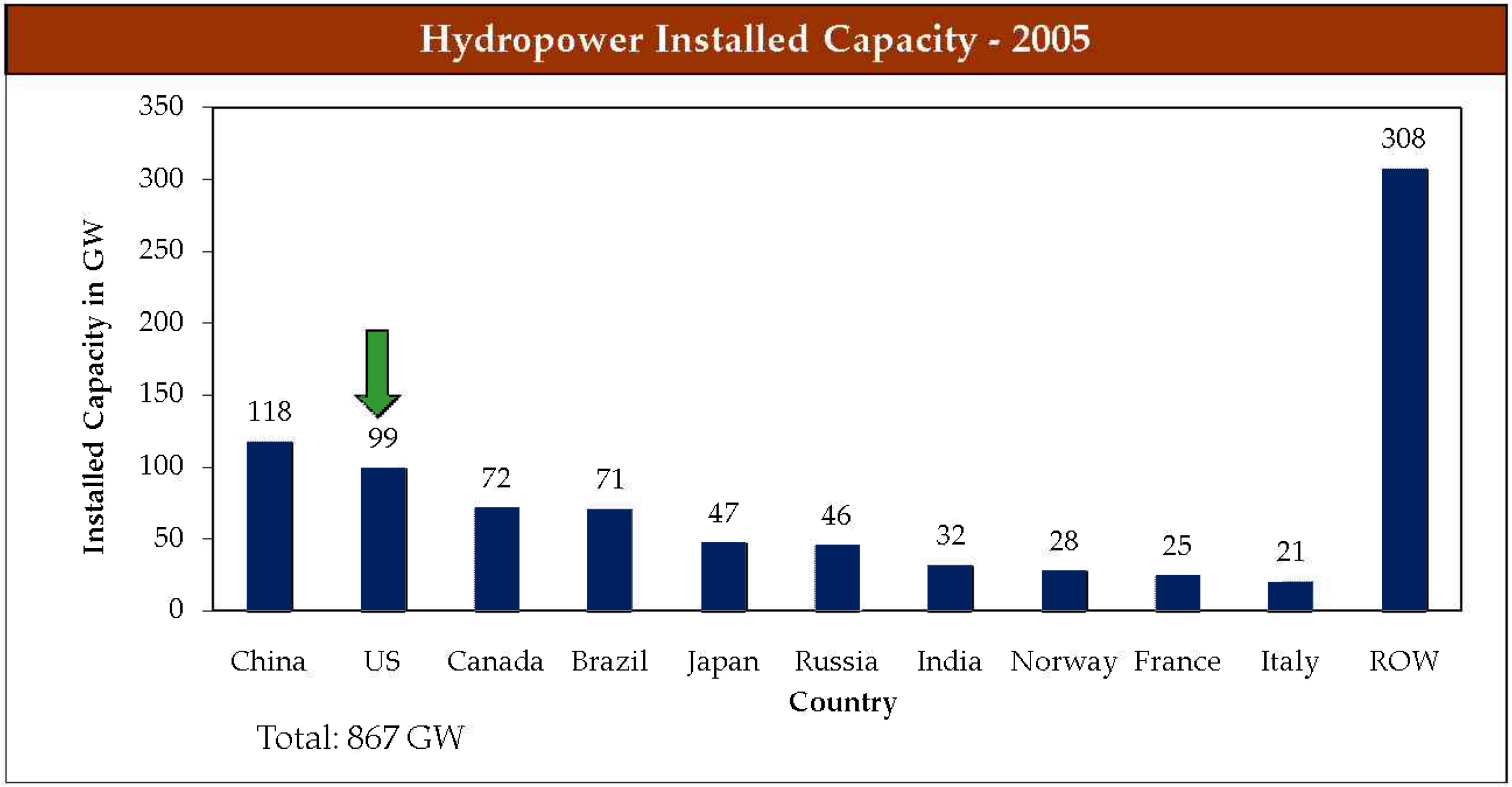
Inland hydropower is still the largest renewable energy resource deployed in the U.S. today.

Key U.S. Industry Characteristics

- NCI has classified the hydropower industry into two major categories: Inland and Ocean
- Inland hydropower
  - Technologies are the only systems currently deployed in the US and include: Impoundment, Diversion, Run of River, Hydrokinetic, Microhydro and Pumped Storage
  - Technical resource potential for the US is approximately 80 GW (upper limit by 2025), including efficiency upgrades and new capacity at existing facilities*.
- Ocean hydropower
  - Technologies include: Tidal, Wave, Current, Thermal and Salinity
  - Tidal barrage is the only mature ocean hydropower technology
  - Limited studies exist that have explored the potential of ocean hydropower technologies.
    - US wave potential has been estimated at 90 GW by EPRI
    - Tidal potential of ~300 MW for five states and ~3,800 MW in Alaska by EPRI.
    - An estimate of 750 MW of total technical potential off the Florida coast by 2020 has been developed based on Florida Atlantic University studies and in consultation with ocean current developers and experts. 4 to 10 GW of total theoretical potential is thought to exist off the coast of Florida.

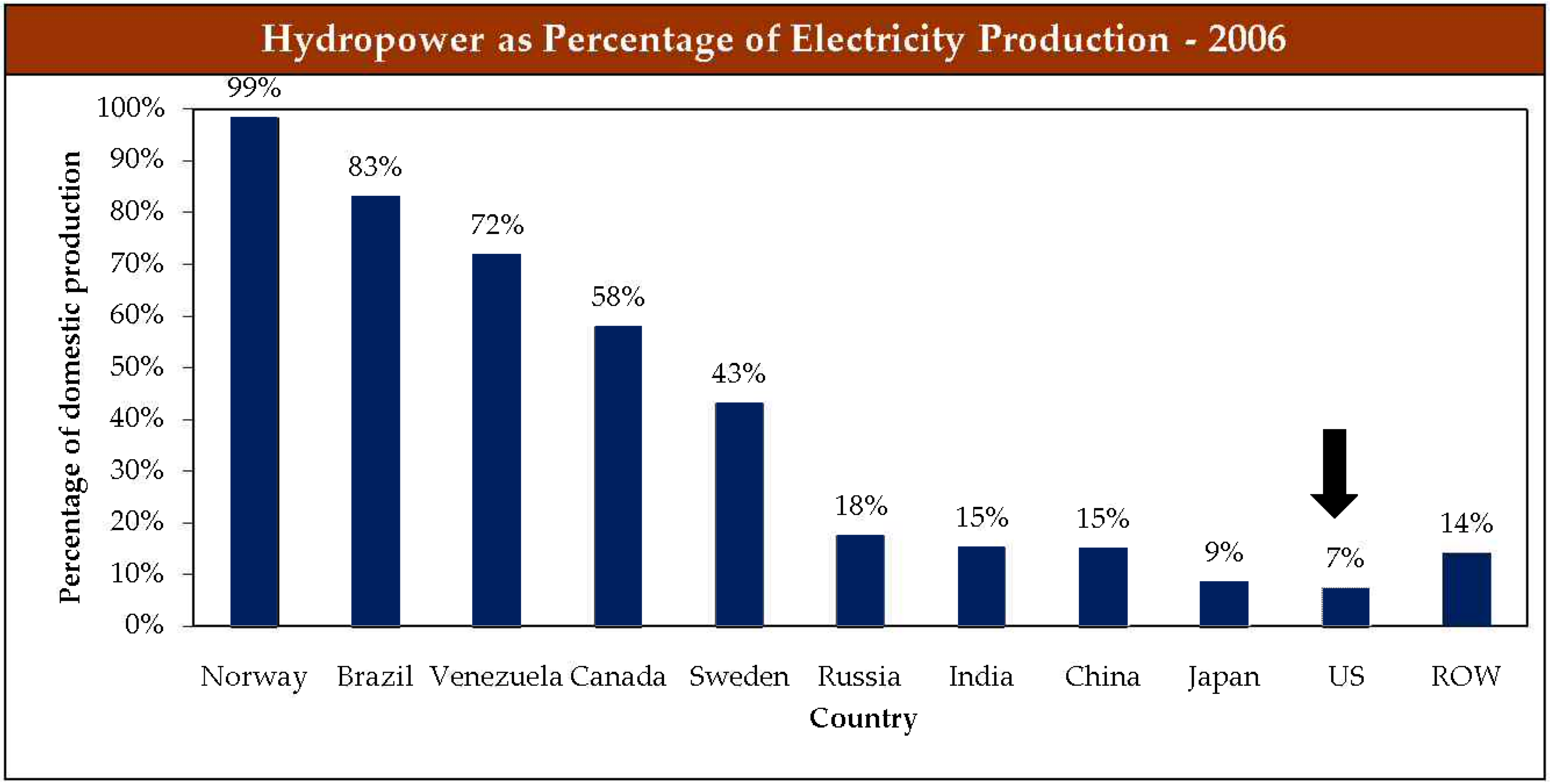
* Assumed for the purposes of this study based on available literature and does not include pumped storage or constructed waterway potential

The U.S. hydropower installed capacity is the second largest in the world, but …



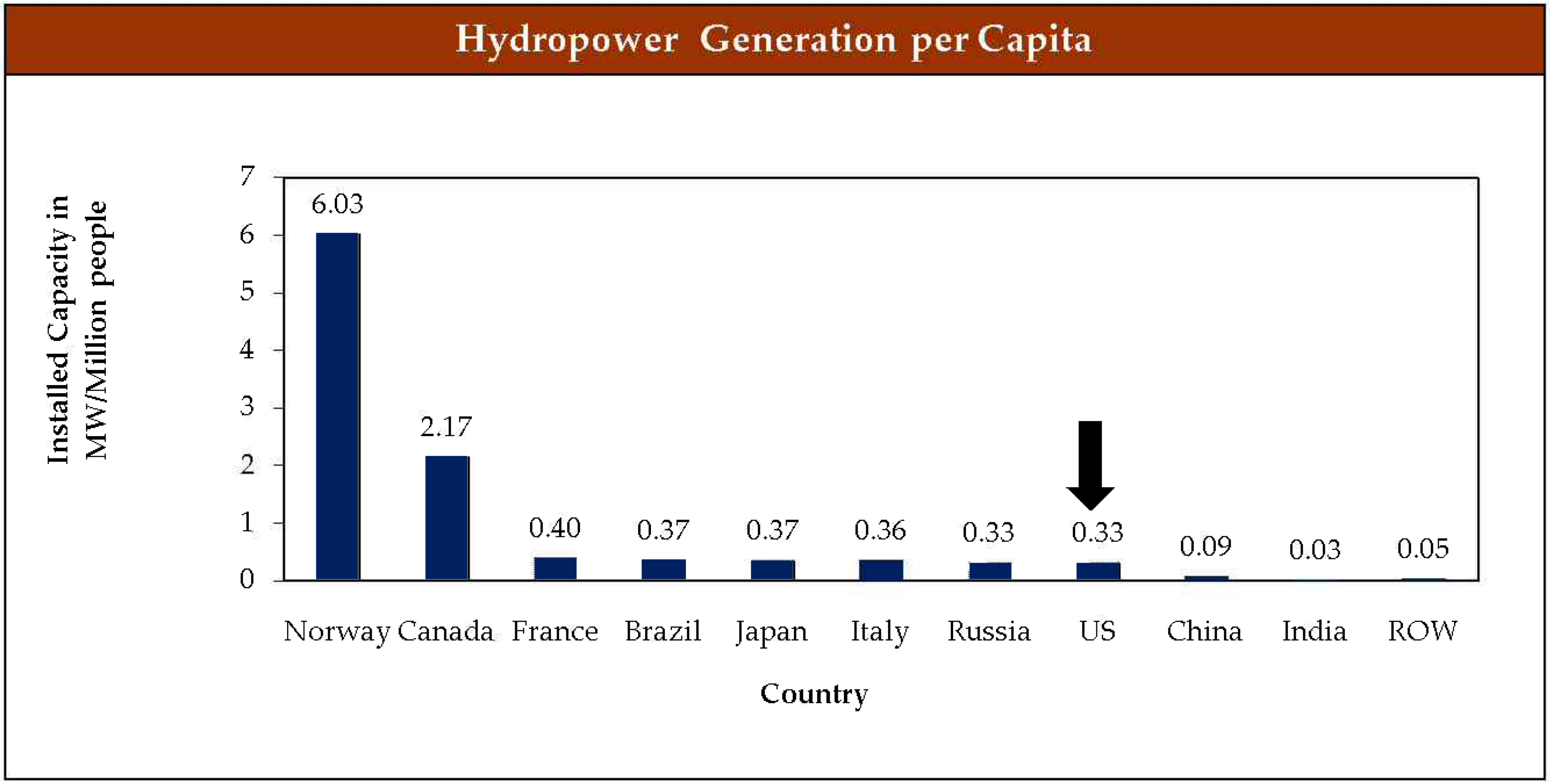
Source: IEA "Key World Energy Statistics" 2008

…. it ranks tenth in the percentage of hydropower as a part of total domestic electricity production (kWh).



Source: IEA "Key World Energy Statistics" 2008

….and ranks 8th in terms of installed MW per capita.



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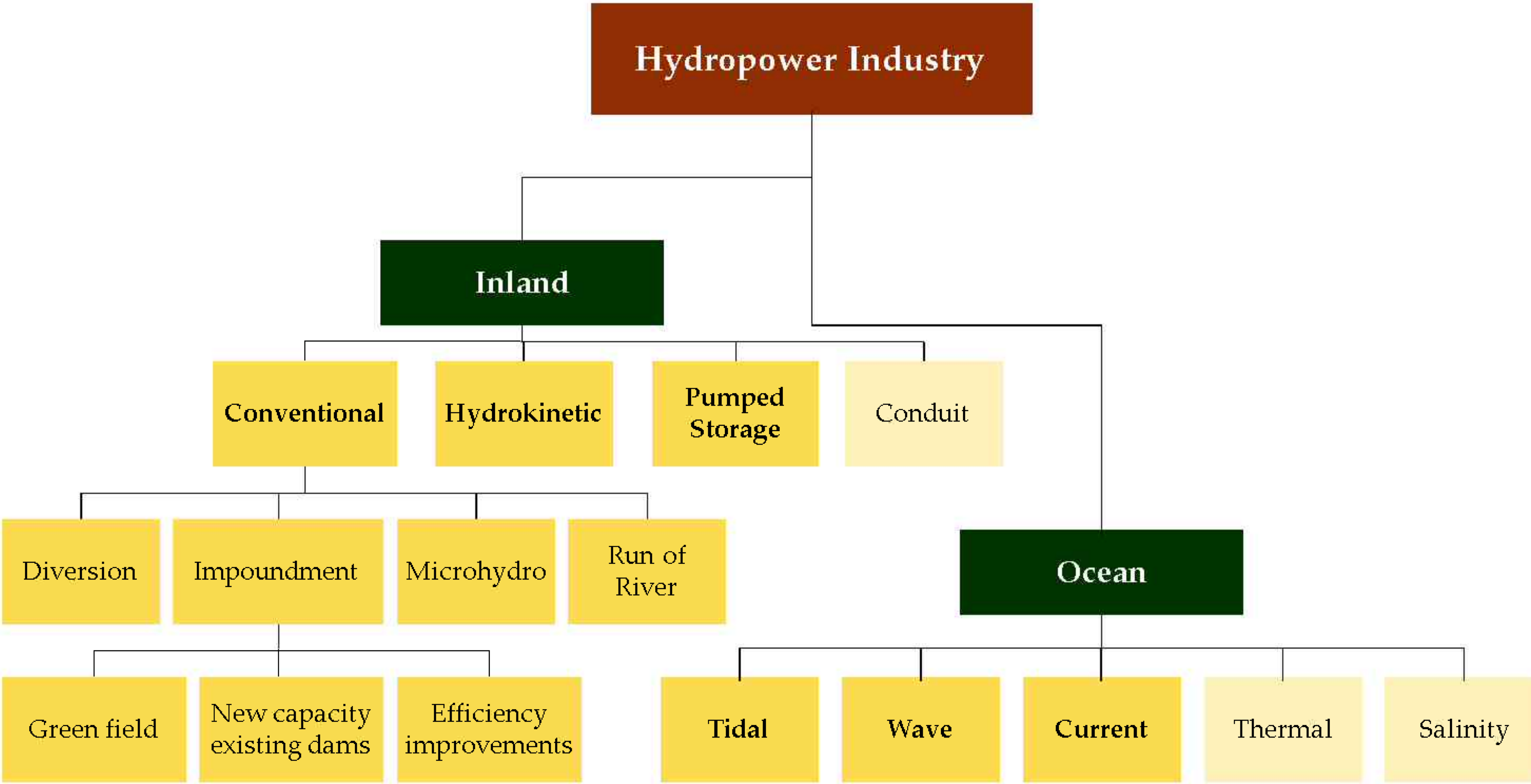
Navigant Consulting has classified the hydropower industry into two categories and several subcategories shown below.



Note: Lighter colors indicate less mature technology not considered in this study

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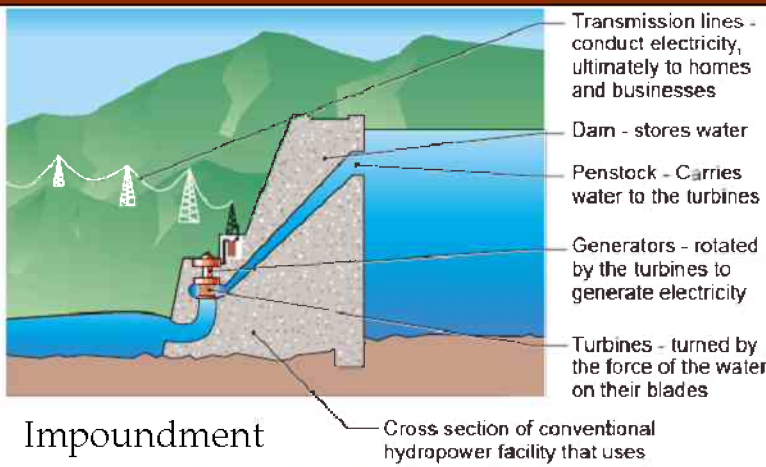
Project sizes are typically grouped as large, medium, small, low power, or microhydro by government agencies and developers.

Hydropower Project Size Ranges					
Size Category	**Micro-hydro**	**Low Power**	**Small**	**Medium**	**Large**
Installed MW Range	<0.1	>=0.1 and <1	>=1 and <=30	>30 and <=100	>100
Conventional					
Hydrokinetic					
Pumped Storage					
Ocean: Tidal					
Ocean: Current, Wave, and Thermal					

Sources: EPRI, DOE

There are four major categories of inland hydropower systems.

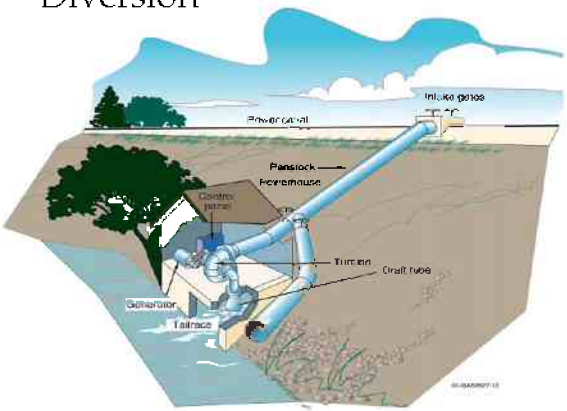
Inland Hydropower Systems Subcategories



Impoundment

Diversion

Run-of-river



Microhydro

Sources: Idaho National Labs

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Hydrokinetic projects generate electricity directly from the flow of water in inland waterways, ocean currents or tides.

- Conventional hydropower captures hydrostatic energy , which comes from potential energy due to the water's elevation[1].

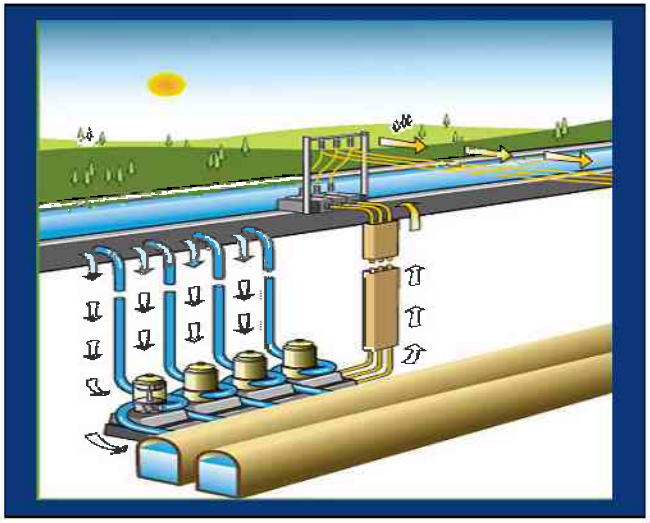
Technology	Description	Example
Horizontal Axis	Blades are perpendicular to axis Resembles a wind turbine	Verdant Power's East River pilot near Roosevelt Island, NY
Vertical Axis	Blades are in line with the axis Resembles an eggbeater	Darrieus Turbine
New technology	Oscillatory devices, venturi	Engineering Business's Stingray, Hydroventuri

- The U.S.'s first hydrokinetic power plant was approved by FERC in late 2008 and is partially installed today on the MS River in Minnesota.
- The turbines are located downstream of an existing hydro plant and are driven by the water exiting the dam.

1. Hydrokinetic and Wave Energy Technologies Workshop Program Proceedings. Idaho National Laboratories
2. Image source: Hydro Green Energy.

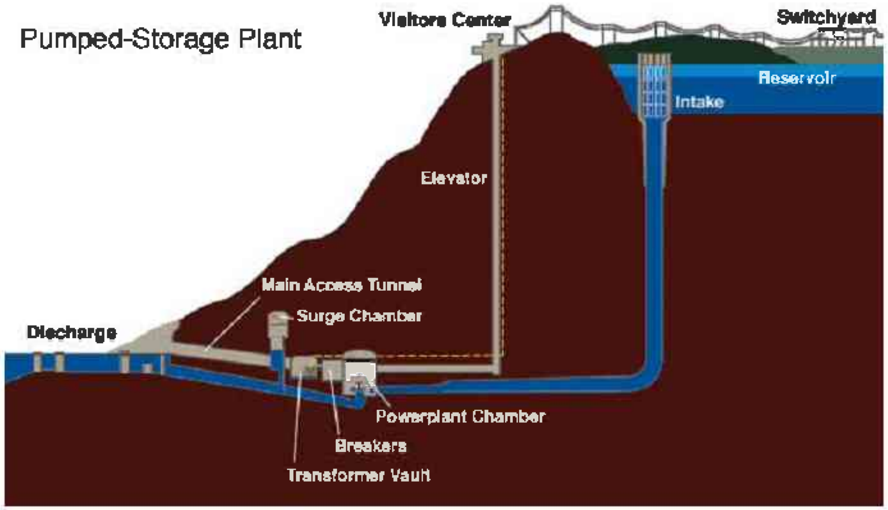
Pumped storage typically consists of two reservoirs with different elevations and is classified as a fifth subcategory in this study.

- Reservoirs are usually at least 100m apart.
- Water is pumped from the lower to upper reservoir during off-peak hours, and the flow is reversed during peak hours to generate electricity.
- Pumped hydro projects located by the ocean can use seawater instead of a lower reservoir.



Source: Riverbank Power

Diagram of Raccoon Mountain Pumped Storage, TN



Source: Tennessee Valley Authority

- A new pumped storage concept is to use a surface water body as an upper reservoir and install the powerhouse and lower reservoir deep underground.
- Deep cavernous rock with the capability of holding up to 1 billion gallons of water is required for the lower reservoir.

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There are two main types of hydro turbines: impulse and reaction. The height of standing water ("head") and flow dictate their applications.

Common Inland Hydropower Turbine Types and Subtypes		
Turbine Type	**Description**	**Subtype**
Reaction Turbine (low head projects)	Reaction turbines rely on moving water and water pressure to operate, and therefore must be fully submerged in water and fully encased to maintain pressure. The runner (the rotating part of the turbine) is placed directly in the water so that the water stream flows over the blades rather than striking each individually. This design is most suitable for sites with lower head and higher flows than those used with the impulse turbine.	Propeller Bulb turbine Straflo Tube turbine Kaplan Francis Kinetic
Impulse Turbine (high head projects)	Impulse turbines rely on a stream of moving water to hit each bucket on the runner (the rotating part of the turbine). There is no pressure change on the down side of the turbine, and the water flows out the bottom of the turbine after hitting the runner. This design is most suitable for sites with high head and low flow.	Pelton Crossflow

Source: EERE "Types of Hydropower Turbines"

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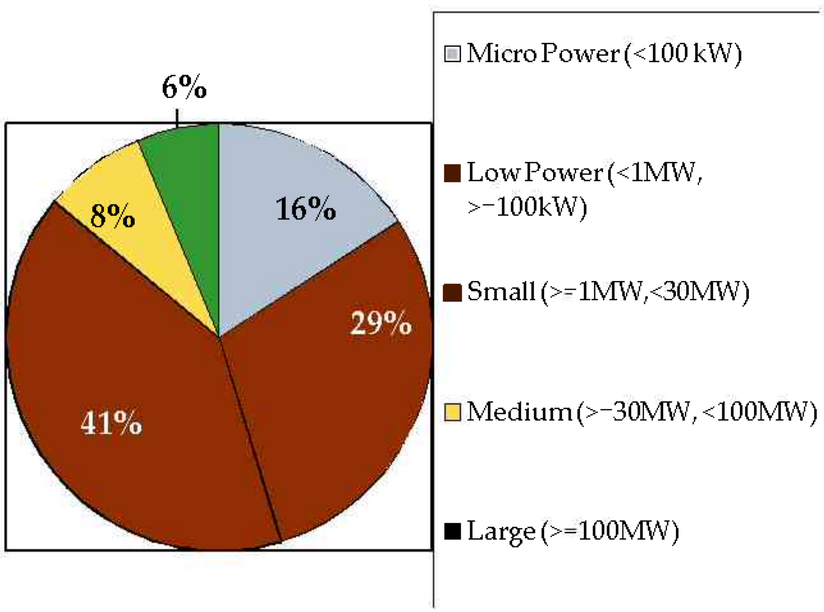
Based on Energy Velocity and INL data, large hydro (>100 MW) represents ~6% of the U.S.'s hydro plants and ~77% of installed capacity.

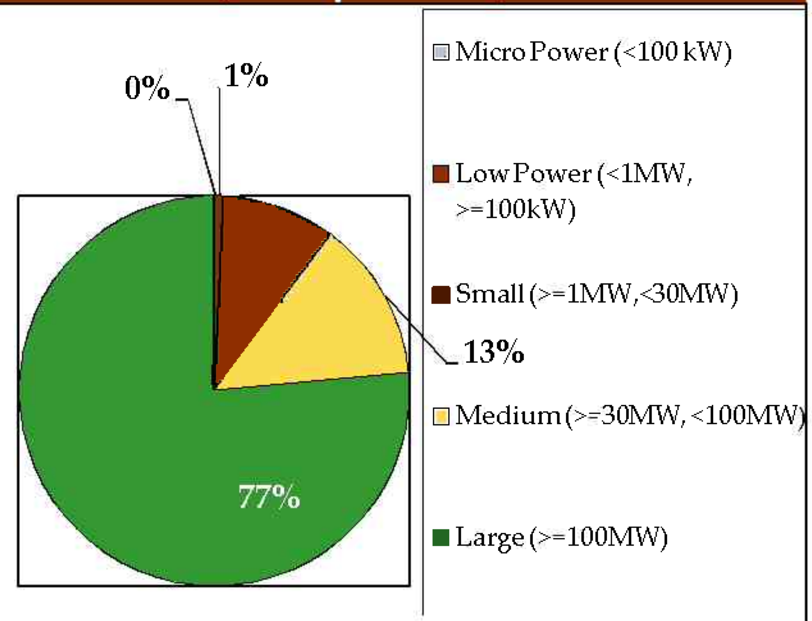
Number of Hydro Plants in the U.S.



Total: ~2,500 plants

(Does not include pumped storage)

U.S. Installed Hydropower Capacity (Nameplate MW)



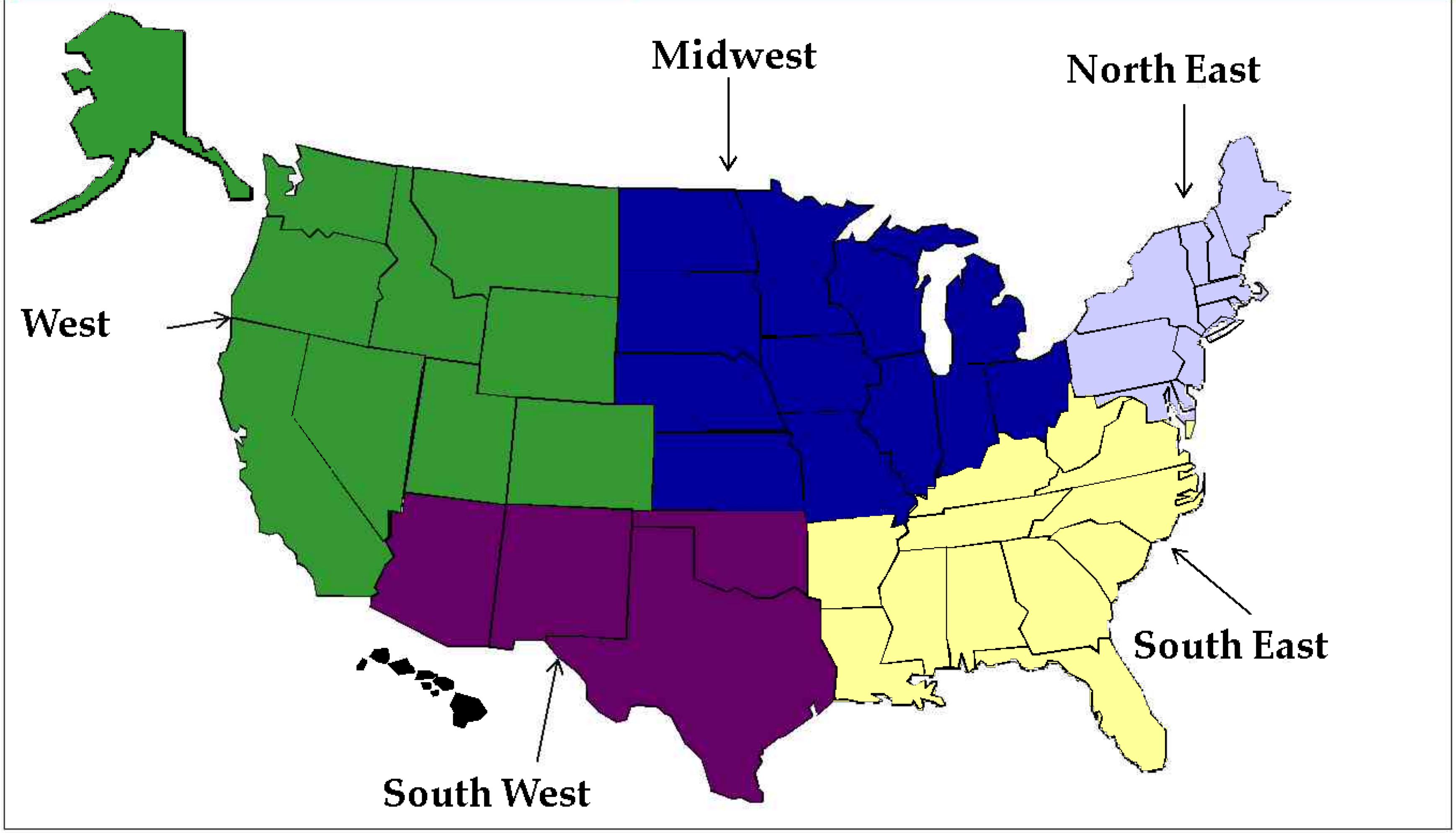
Total: ~78,000 MW

(Does not include pumped storage, ~ 20,000 MW)

Sources: Energy Velocity: 2009 data; Idaho National Lab, *Feasibility Assessment of the Water Energy Resources…"* January 2006.
Note: The above charts do not include an estimated 19,000 MW of pumped storage. No ocean or hydrokinetic (river in-stream or constructed waterway) plants are currently in operation in the U.S. aside from demo plants. Therefore, the above charts show data for conventional hydro.

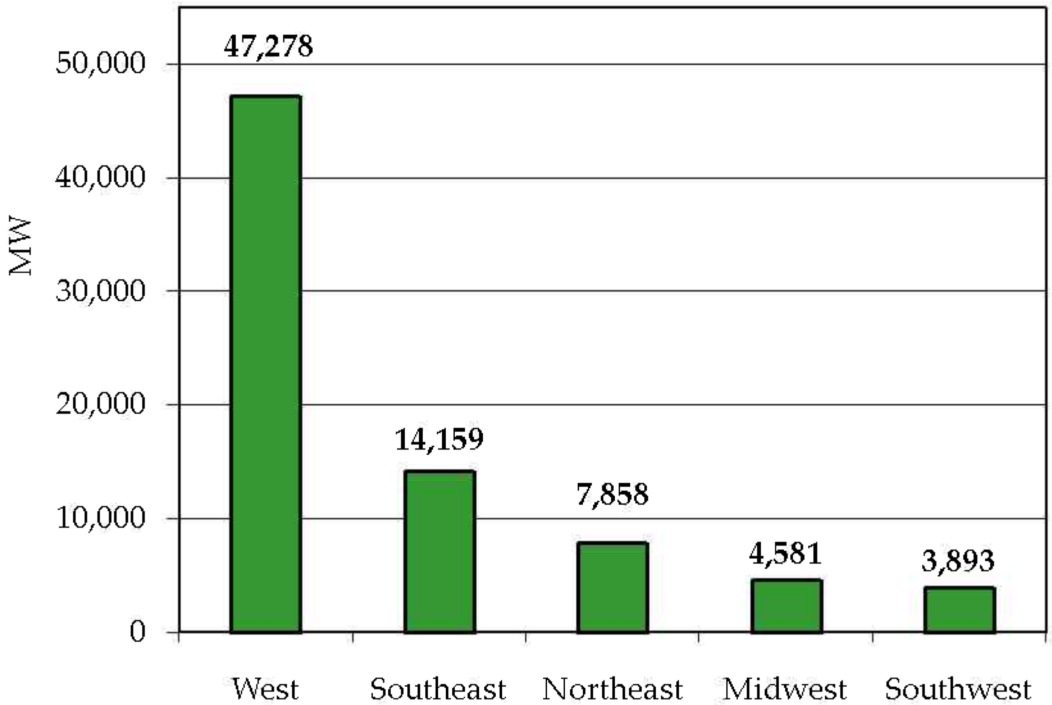
Our analysis focused on six major regions in the U.S.

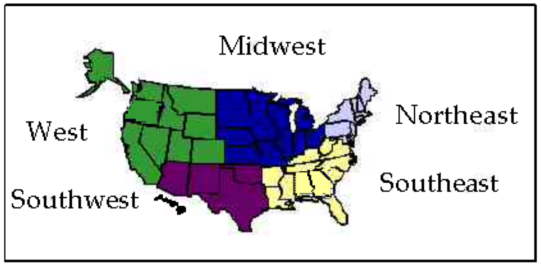
U.S. Regional Classification



The West has the largest installed base of conventional inland hydro.

U.S. Developed Inland Hydro Nameplate Power by Region (MW)





Total: ~78,000 MW

Source: Energy Velocity, 2009 data, Idaho National Lab, January 2006 data. Excludes pumped storage
Micro power: <100 kW; Low: >=100kW, <1MW; Small: >=1MW, <30MW; Medium: >=30MW, <100MW; Large: >=100MW

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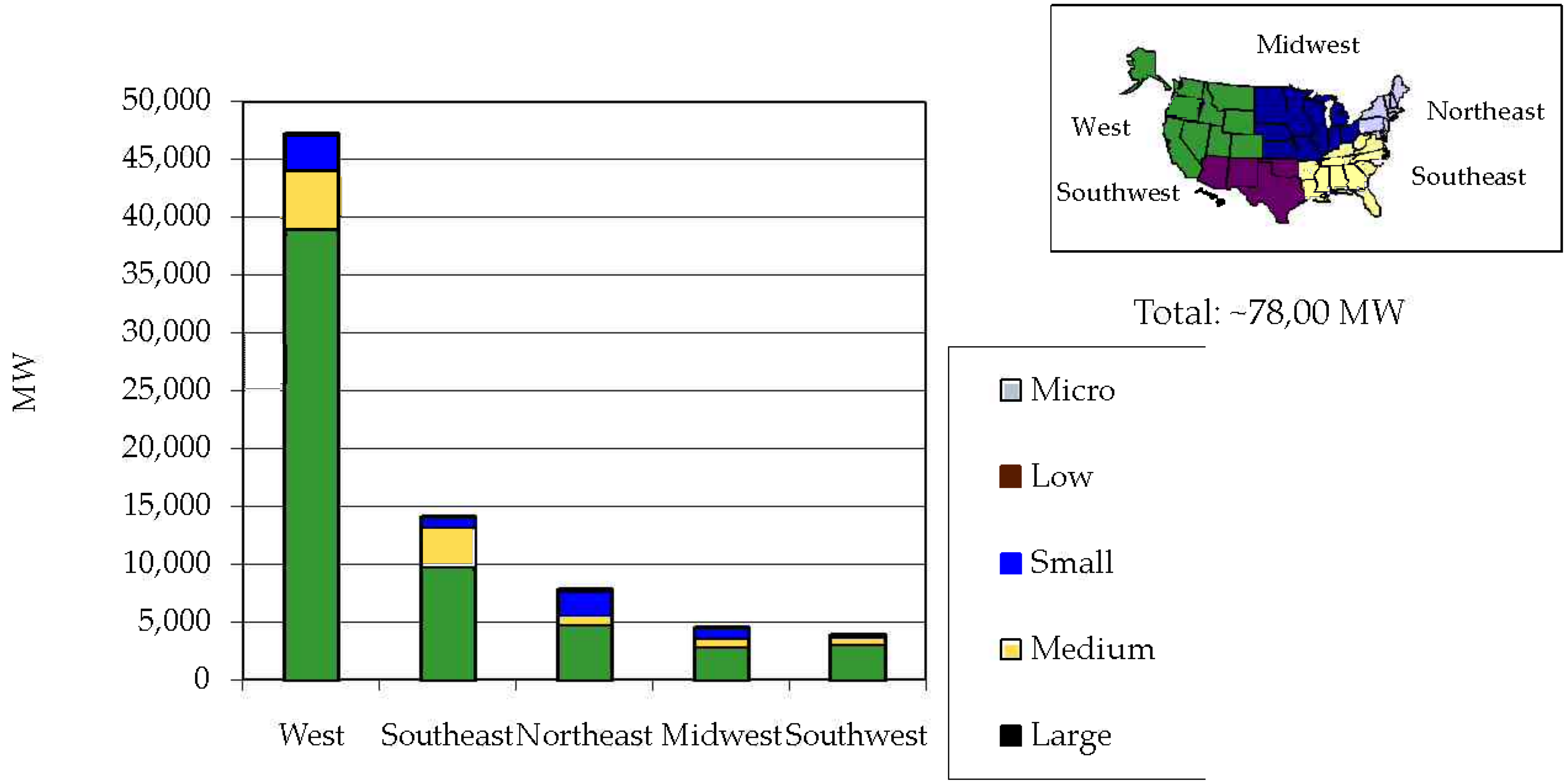
U.S. Developed Inland Hydro Nameplate Power by Region (MW)



Source: Energy Velocity, 2009 data, Idaho National Lab, January 2006 data. Excludes pumped storage
Micro power: <100 kW; Low: >=100kW, <1MW; Small: >=1MW, <30MW; Medium: >=30MW, <100MW; Large: >=100MW

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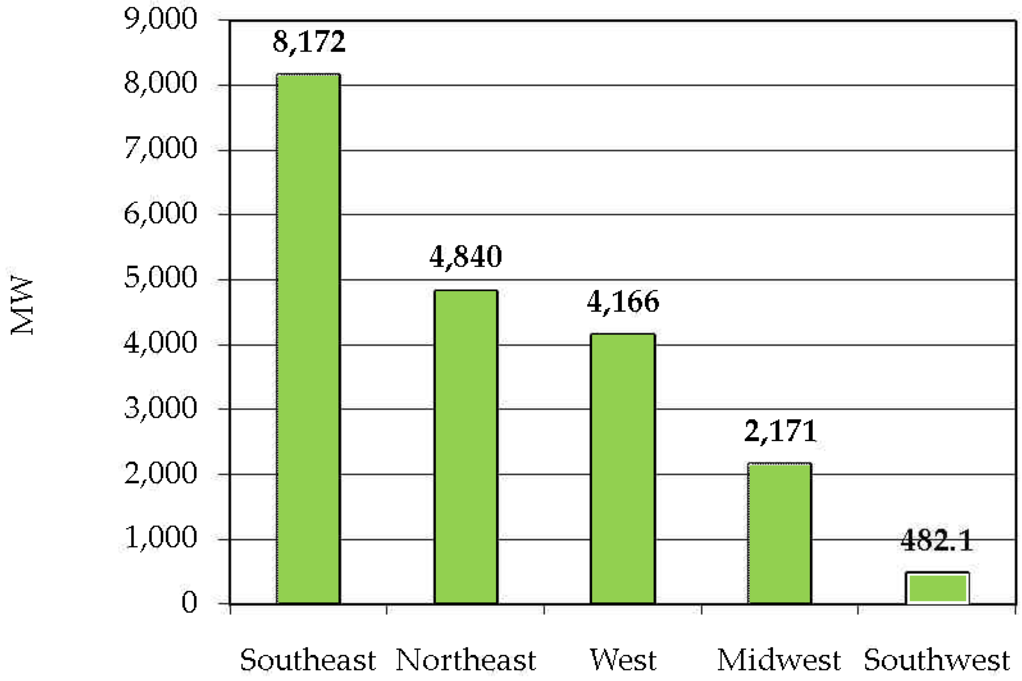
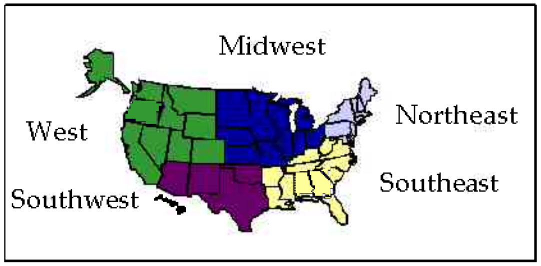
The Southeast has the largest installed base of pumped storage.

U.S. Developed Pumped Storage Nameplate Power by Region (MW)





Total: ~20,000 MW

Source: Energy Velocity, 2009 data.

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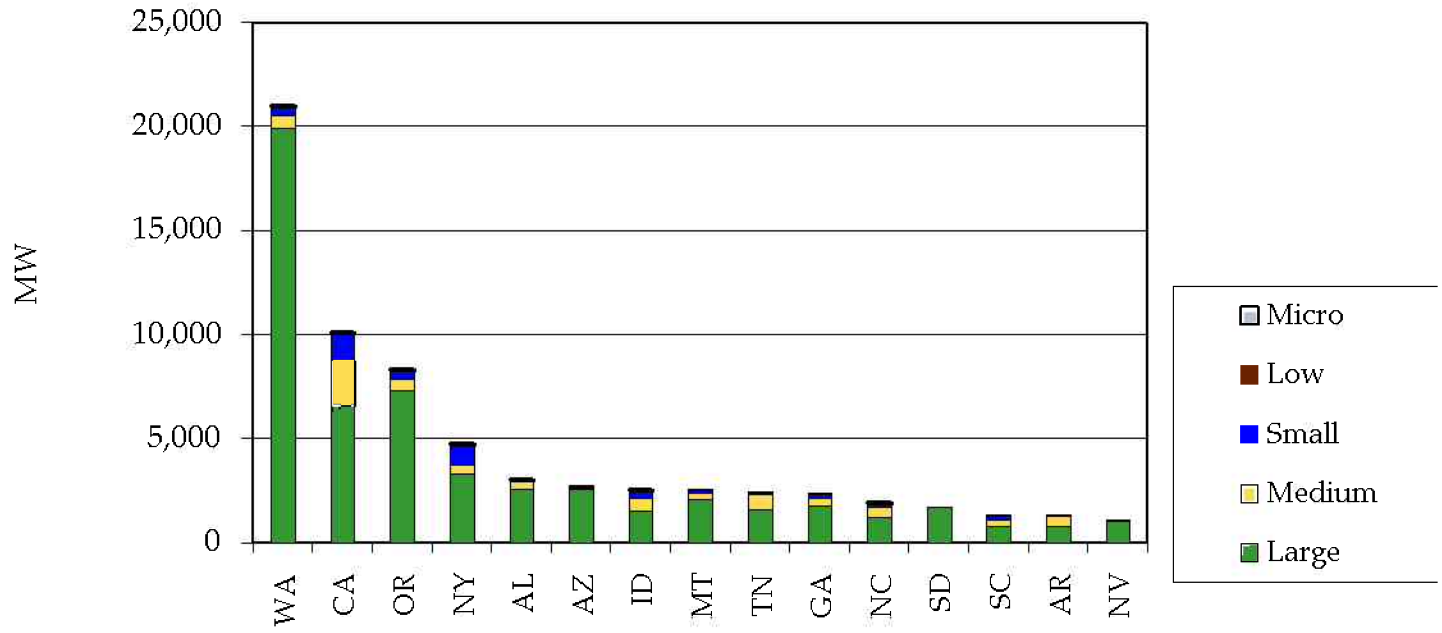
WA, CA, OR and NY are leading states in developed inland hydro.

U.S. Developed Inland Hydro Nameplate Power by State (MW)

(States with >1,000 MW of potential)

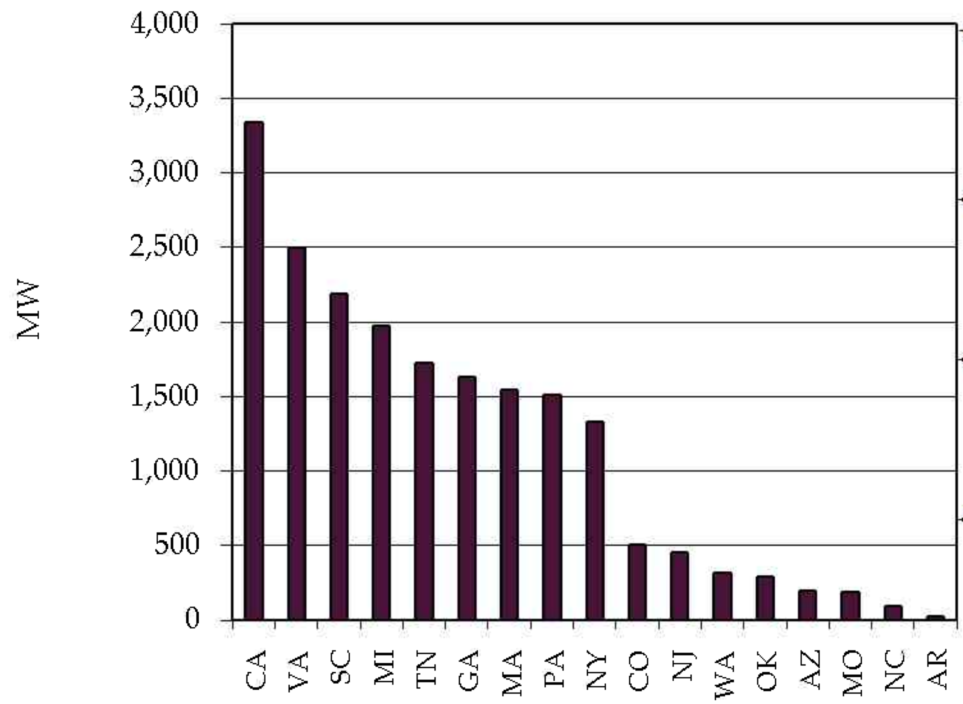


See Appendix for remaining 50 states.

Source: Energy Velocity, 2009 data, Idaho National Lab, January 2006 data. Excludes pumped storage
Micro power: <100 kW; Low: >=100kW, <1MW; Small: >=1MW, <30MW; Medium: >=30MW, <100MW; Large: >=100MW

CA, VA, SC and MI are leading states in developed pumped storage.

U.S. Developed Pumped Storage Nameplate Power by State (MW)



- U.S.-wide, total installed capacity of pumped storage is ~20 GW
- The average plant size is ~600 MW
- The youngest plant was constructed in 2002, but the majority of the plants were built in the '60s, '70s and '80s.
- **Technical Potential was not estimated given that feasibility can be considered to be limitless.**

Source: Energy Velocity, 2009 data.

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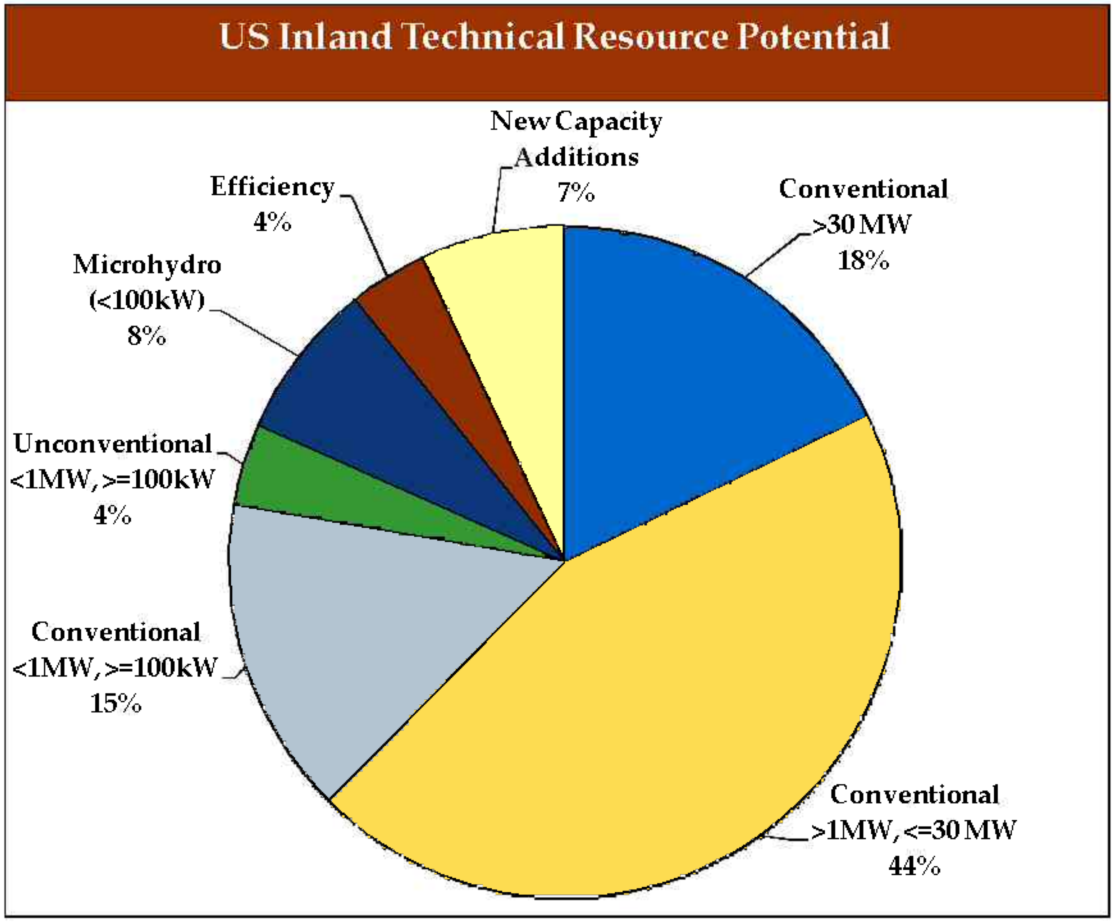
About ~84,000 MW of inland hydro technical potential exists across the U.S.



1. NCI defines total *technical* potential as the feasible sites selected by INL in its two studies: *Feasibility Assessment of the Water Energy Resources of the US for New Low Power and Small Hydro Classes of Hydroelectric Plants* 2006 and *Estimation of Economic Parameters of U.S. Hydropower Resources* 2003.
2. Annual mean power potential from INL's 2006 report was converted to nameplate potential by assuming a 50% plant capacity factor.

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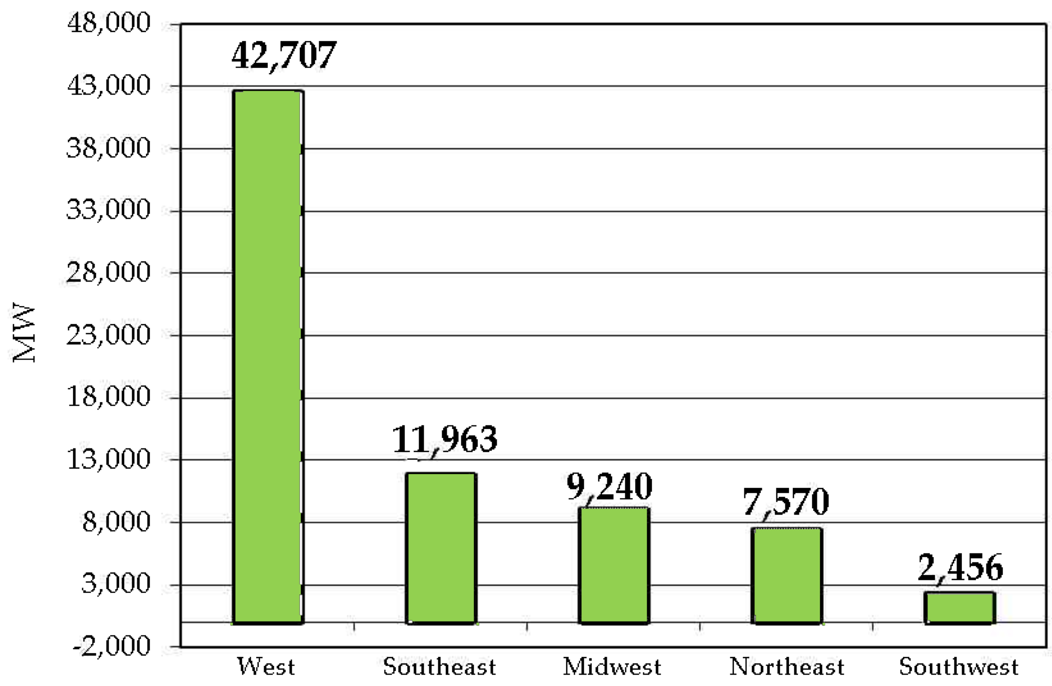
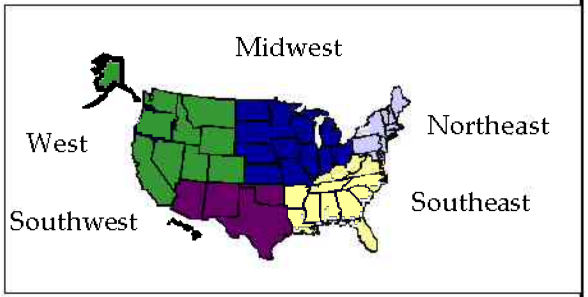
The West has the greatest untapped inland technical potential in the U.S.

U.S. Inland Technical Potential Nameplate Hydropower by Region (MW)





Total: ~74,000 MW
(excludes capacity additions and efficiency upgrades)

Source: INL *Feasibility Assessment of the Water Energy Resources of the US for New Low Power and Small Hydro Classes of Hydroelectric Plants* 2006 and *Estimation of Economic Parameters of U.S. Hydropower Resources* 2003: Excludes Capacity Additions and Efficiency Upgrades

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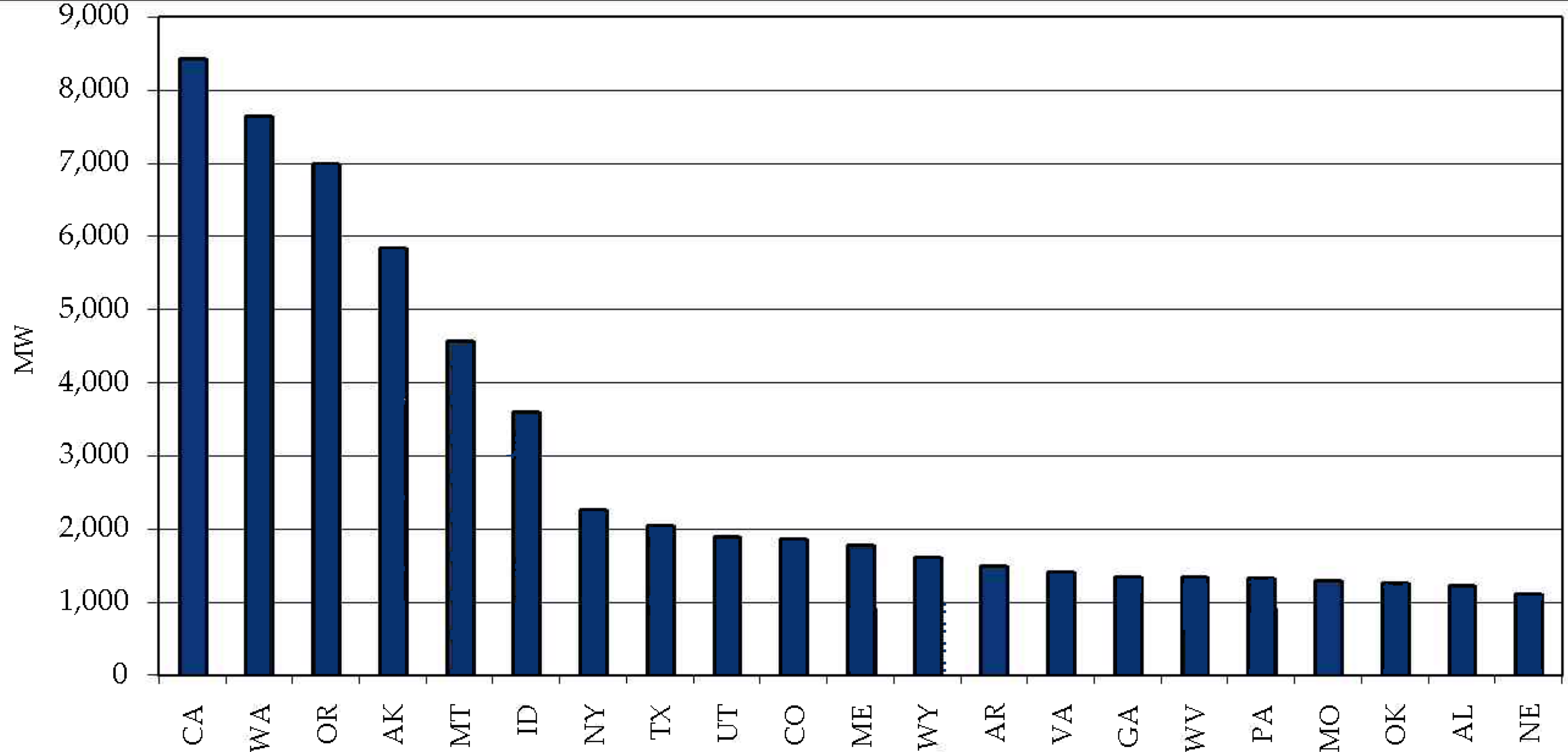
CA, WA, OR and AK have the greatest untapped inland hydro potential.

U.S. Inland Technical Potential Nameplate Hydropower by State (MW)

(States with >1,000 MW of potential)



See Appendix for remaining 50 states.

Source: INL *Feasibility Assessment of the Water Energy Resources of the US for New Low Power and Small Hydro Classes of Hydroelectric Plants* 2006 and *Estimation of Economic Parameters of U.S. Hydropower Resources* 2003. Excludes Capacity Additions and Efficiency Upgrades

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The large western states dominate each hydropower technology category in terms of technical potential available.

	Hydropower Technology	Technical Potential U.S.	Technical Potential by Region	Technical Potential by State
Conventional	Impoundment/ Diversion	~42,000 MW	• The West has ~27,000+ MW of technical potential, by far the most of any of the regions.	• Alaska, Washington and California have this highest technical potential.
Conventional	Microhydro	~6,000 MW	• The West and Midwest have the highest technical potential of ~2,500 and ~1,500 MW, respectively.	• California, Oregon and Idaho have the highest technical potential
Conventional	Run of River[1]	~23,000 MW	• The West and Southeast have the highest technical potential of ~15,000 and ~3,500 MW, respectively.	• Washington, Oregon and Arkansas have the highest technical potentials.
	Hydrokinetic[2]	~3,000 MW	• The West and Midwest have ~950 MW each of potential available.	• Montana, Washington and Texas have ~175 MW of technical potential each.
	Pumped Storage	Not estimated	Not estimated	Not estimated

1. NCI assumes that 50% of the small hydro (<30MW, >~1MW) potential estimated by INL (2006) would primarily fall under Run of River (ROR), the remainder would fall under diversion. Additionally, INL identified ROR sites >30 MW in its 2003 study: *Estimation of the Economic Parameters of U.S. Hydropower Resources.*
2. Technical Potential reported is the potential for "unconventional" technologies at low power sites identified by INL in its 2006 study. NCI considers this to be the maximum possible potential for hydrokinetic at sites <1MW, based on data existing, published research today.

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Installed costs can range broadly depending on the size and type of hydro project.

Costs and Growth Rates by Technology			
Hydropower Technology	**MW Range**	**Installed Cost ($/kW)**	**Discussion**
Conventional Hydro (impoundment)	50 (avg)	$1,000-$5,000	• Conventional hydro is a mature technology, costs are expected to decline moderately in the future as commodity costs decline. • The cost to upgrade at a site with an existing dam can be <$1,000/kW while small hydro can be as much as $4,800/kW. • Higher costs likely for green field sites which require significant civil works.
Microhydro	<0.1	$4,000-$6,000	• The installed cost for low-impact hydro systems is not expected to decline in the near term.
Run of River (diversion)	~10	$1,500 - $6,000	• Similar to conventional impoundment hydro, installed costs for run of river can vary widely.
Hydrokinetic			• **See Ocean Hydropower Cost section**
Pumped Storage	>500	$1,010 - $4,500	• Traditional pumped storage is a mature technology, and costs are not expected to decline going forward. • The new underground pumped hydro technology has been quoted at $2,000/kW and cost declines can be expected going forward, if the concept proves itself.

Source: INL 2003, Developer Interviews.

Ocean hydropower technologies are typically categorized as tidal, ocean thermal, ocean current, salinity gradient, or wave.

Ocean Hydropower Systems and Technology Subcategories		
Tidal	Barrage	•Ebb generation •Flood generation •Pumping •Two-basin scheme
	Tidal Instream Energy Conversion (TISEC)	•Horizontal axis •Vertical axis •Oscillating
Salinity Gradient	Reverse electro-dialysis	
	Pressure-retarded osmosis	
Ocean Thermal	Open Loop	
	Closed Loop	
	Hybrid	
Ocean Current	Horizontal axis	
	Vertical axis	
Wave	Onshore	•Oscillating water column •Tapered channel (Tapchan) •Pendulor device
	Offshore	•Point absorbers •Overtopping •Attenuators •Permanent magnet rack & pinion box/linear generators

Sources: EERE, INL Proceedings of the Hydrokinetic and Wave Energy Technologies Technical and Environmental Issues Workshop

Tidal barrage is the mature ocean hydropower technology with several others in the research and/or demonstration stage.

Ocean Hydropower Systems and Technology Subcategories

Tidal – Barrage
(La Rance, France 240 MW)

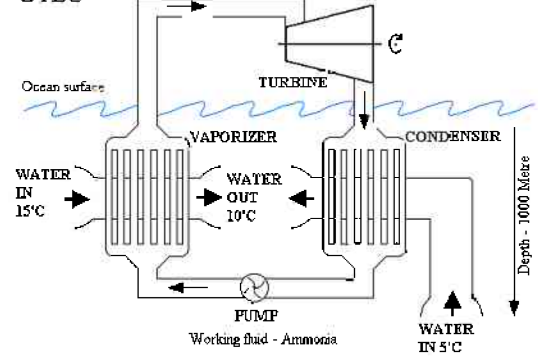
Tidal – TISEC
(Strangford Lough, Northern Ireland 1.2 MW)

Ocean Current –
Horizontal axis technologies

Wave – Attenuator
(Portugal, 3 - 0.75 MW units)

Wave – Overtopping
(Denmark)

OTEC



Ocean Thermal
Closed Loop Diagram

Image Sources: Wikipedia images released into public domain, U.S. Minerals Management Service.

Some studies exist that have examined the technical resource potential for wave and tidal energy technologies.

U.S. Ocean Hydropower Technical Potential by Technology	
Technology	**Technical Potential**
Wave	• 90 GW nameplate capacity (~30 GWa) as estimated by EPRI.[1]
Ocean Current	• Major U.S. ocean currents include the Florida Straits, Gulf Stream and California Current. The Florida Straits current is the largest U.S. ocean current resource.[2] • Off the coast of Florida, approximately 750 MW of technical potential may be developable by the year 2020, which represents a small fraction of estimated 4 to 10 GW of theoretical potential available in that region.[3]
Tidal In-Stream Energy Conversion (TISEC)	• An assessment of technical potential has not been undertaken. EPRI has conducted a TISEC study of 5 states, finding 300 MW of feasible technical potential, and an estimated 3,800 MW of theoretical potential in Alaska.

Sources:

1: *Assessment of Waterpower Potential and Development Needs. EPRI, Palo Alto, CA: 2007.* 1014762.

2: MMS, Technology White Paper on Ocean Current Energy Potential on the Outer Continental Shelf, 2006

3: Florida Atlantic University, Center for Ocean Technology estimates 25 GW total ocean current energy off the FL coast, which , when constrained by capture efficiency of technology and areas excluded due to slow flow, results in 4 – 10 GW of theoretical installed potential, uncontrained by technical considerations such as siting, transmission, cost, or environmental exclusion. 750 MW estimate installable capacity by 2020 based on discussions with FAU ocean energy experts and ocean current developers.

4: Bedard, R., et al. North America Tidal In-Stream Energy Conversion Technology Feasibility Study, EPRI TP 009 – NA, June 11, 2006. Estimate of MW potential in Alaska was calculated based on estimated generation as reported by EPRI.

Limited commercial-scale cost data exists for ocean hydropower systems due to the lower technology maturity of most technologies.

Ocean Hydropower Systems Costs		
Technology	**Expected Commercial Cost ($/kW)**	**Notes**
Wave	Installed Cost (year 2020): ~$2,500/kW Annual Variable O&M: $25 to $46 per MWh	Based on EPRI report cost estimates for wave development and 2007 interviews with industry representatives, adjusted for inflation and forecast out to 2020 assuming a learning curve cost reduction of 10% to 20% each time production doubles.
Tidal In Stream Energy Conversion (TISEC)[1]	Installed Cost: ~ $3,000/kW ($1,000/kW – $4,000/kW) Annual Variable O&M$25/MWh variable O&M	O&M cost estimates are based on an estimated $1 M annual O&M cost for a 15 MW plant operating at 30% capacity factor.

Sources:
"Survey and Characterization, Tidal In Stream Energy Conversion (TISEC) Devices", EPRI, November 9, 2005;
Proceedings of the Hydrokinetic and Wave Energy Technologies Technical and Environmental Issues Workshop. Washington, DC. October 26-28, 2005.
Discussions with technology and project developers.

Below are four main policy and/or legislative efforts led by the Federal government that support hydropower development.

Incentive/ Legislation	Description	Eligible Hydro
Production Tax Credit (PTC) [OR - Optional ITC/Grant]	» 2.1 ¢/kWh (2008 tax year) for first 10 years of operation. PTC is indexed to inflation and is good through 12/31/2012 for wind, 12/31/2013 for others. » Credit value is 1.1 ¢/kWh for hydro technologies » Taxpayers eligible to take the PTC may instead opt to accept the Federal Investment Tax Credit (ITC) or a US Department of Treasury Grant, both typically equal to 30% of eligible costs.	Incremental and qualified conventional, ocean & hydrokinetic (>~150 kW)
Renewable Energy Production Incentive (REPI)	» Rough equivalent to the PTC but for public power entities » 2.1¢/kWh (2008 $) adjusted for inflation for the first 10 years of operation. The REPI is subject to annual appropriations such that it may not be fully funded from year to year. » EPAct 2005 reauthorized this program through 2026 (i.e., for projects installed through 2016)	Tidal, wave, ocean thermal
Clean Renewable Energy Bonds (CREBs)	» Tailored for not-for-profit utilities; generally has the same applicability as the PTC. » The federal government grants the bondholder a tax credit in lieu of the issuer paying interest to the bondholder » $800 MM in CREBs are authorized through December 31, 2009 under *The Energy Improvement and Extension Act of 2008*. H.R. 1 allocated an additional $1.6 B.	Qualified conventional hydro, hydrokinetic, tidal, wave, ocean thermal
Minerals Management Services (MMS)	» Issued a final rulemaking in 2008 regarding guidelines for development and use of resources in the outer continental shelf (OCS) of the U.S. This rulemaking may help address some barriers which have hindered development of this region.	Any development on the outer continental shelf.

Note: Hydro is not eligible for the Federal Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation.

Many states have incentives or policies that could enhance adoption of hydroelectric, hydrokinetic, and ocean energy technology.

Existing Hydro Incentives		
Enabler	**Description**	**Relevant States**
MA ocean energy development plan	MA's ocean plan may include pre-approved sites for renewable energy projects	MA
Property Tax Credit	Property tax exemption or credit for the value added by hydropower	AZ, CO, CT, IN, KA, KS, KY, MA, MT, NC, NJ, NV, VT
Loan Programs	Low-interest loans for hydropower development	HI, IA, ID, MA, MS, MT, NE, NC, OR, PA, RI, WI
Public Benefits Fund	Funding for investment or R&D support for renewable energy technology	CA, CO, CT, DC,DE, FL, IL, IA, ME, MA, MN, NJ, NM, NY, OH, OR, PA, RI, WI
Production tax Credit	A tax credit for every kWh generated from a renewable resource, provided by the state	FL, MD, OK
Production Based Incentive	A production-based incentive paid for every kWh generated from a renewable resource, provided by the state.	CA, MN
Industry Recruitment Support	Grants, loans and other financial incentives to attract manufacturers of renewable energy to the state.	HI, CO, MT, OR
Investment Tax Credit	Income Tax Credit for alternative energy investments, with hydro eligible	MT, OR, UT
Net Metering	State law requiring net metering, with hydro eligible	AZ, CO, HI, IA, MN, MO, MT, ND, NE, NV, OK, OR, UT, WA, WY
State Rebate Program	Dollar per Watt rebates for renewables, including hydro.	NV

Source: March 2009, Database of State Incentives for Renewable Energy (DSIRE)

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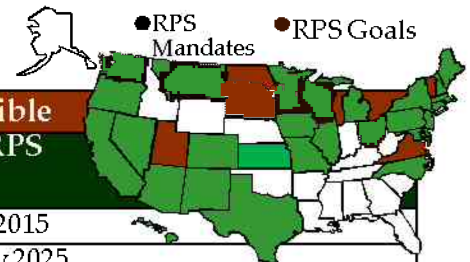
29 states and DC have RPS and 5 have goals. Hydro technologies qualify in all of these states.



State Renewable Portfolio Standards (RPS) for which Hydro is Eligible

State	Hydro Techs	Total RPS Target	State	Hydro Techs	Total RPS Target
AZ	CH^{10},CH^{EI}	15% by 2025	**ND**	CH, CH^{EI}	10% by 2015
CA	CH^{30}, CH^{EI},O	20% by 2010	**NH**	CH^{EI},CH^{*5}	23.8% by 2025
CO	$CH^{E,30}$,CH^{10}	20% by 2020 (IOUs), 10% munis and co-ops	**NJ**	CH^{*30}, O	22.5% by 2021
CT	ROR^{5} ,$ROR^{*E,5}$, O	27% by 2020	**NM**	CH	20% (IOUs), 10% (co-ops) by 2020
DC	CH^{*}, O	11% by 2022	**NV**	PH, CH^{30}	20% by 2015
DE	$CH^{30,ENV}$	20% by 2019	**NY**	CH, ROR, O	24% by 2013
HI	CH, O, OC	20% by 2020	**OH**	CH^{ENV}	12.5% by 2025
IA	CH	105 MW (2% by 1999)	**OR**	O, CH^{EI}	25% (large utilities), 5%-10% (small utilities) by 2025
IL	CH^{EI}	25% by 2025	**PA**	CH^{ENV}, CH^{EI}, CH^{*}	18% in 2020
KS	$CH^{10,}$ CH^{E}	20% peak demand by 2020	**RI**	CH^{30}, O	16% by 2020
MA	$CH^{ENV,EI}$,CH^{*5}, O	4% by 2009 (+1%/yr after) (tier 1); 3.6% tier 2	**SD**	CH	10% by 2015 goal
MD	CH^{30},CH^{*30},O, OC	20% by 2022	**TX**	O, CH^{O}	5,880 MW by 2015
ME	CH^{ENV},$CH^{100,E}$, O	10% add'l by 2017 class 1	**UT**	O, $CH^{EI,}$ $CH^{E,}$ CH	20% by 2025 goal
MI	CH^{E}, HK	10% by 2015	**VA**	CH, O	12% of 2007 sales by 2022
MN	CH^{100}	25% by 2025, (Xcel 30% by 2020)	**VT**	CH^{200}	Energy growth 2005-'12 met by RE; 20% by 2017
MO	CH^{10}	15% by 2021	**WA**	O, $CH^{EI,}$	15% by 2020
MT	$CH^{E,10}$	15% in 2015	**WI**	CH^{60}	10% by 2015
NC	CH^{10}	12.5% of 2020 sales by 2021 (IOUs), 10% of 2017 sales by 2018 (munis & co-ops)	n/a	n/a	n/a

O – Tidal Wave & Ocean Thermal, OC – Ocean Current, PH–Pumped Hydro, ROR–Run-of-river only, CH–Conventional Hydro (includes ROR) , HK=Hydrokinetic (no dams), ^{ENV}=State Environmental Standards, *Class/Tier2, ^{E}=Existing, ^{EI}–Incremental Efficiency Improvements to Existing, ^{5}–Under 5 MW, ^{10}–Under 10 MW, ^{30}–Under 30 MW, ^{60}–Under 60 MW, ^{100}=Under 100 MW, ^{200}=Under 200 MW, ^{O}=Unspecified "other hydro"

Source: July 2009, Database of State Incentives for Renewable Energy (DSIRE)

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Business as Usual (BAU) and *Accelerated* scenarios were developed. Forecasts for these scenarios were derived from literature reviews and industry interviews.

US Hydropower Market Growth Scenarios – Cumulative Capacity by 2025	
Scenario	**Description**
Business As Usual	Business as usual scenario assumes a 10% RES by 2025. It was also assumed that in this case, lower amounts of emerging technologies (hydrokinetic, ocean power etc.) would be installed.
Accelerated	Accelerated scenario assumes a 25% RES by 2025. It was assumed that in this case, larger amounts of emerging technologies (hydrokinetic, ocean power etc.) and pumped storage would be installed.

Business as Usual (BAU) represents a low RES (Renewable Electricity Standard) and *Accelerated* represents a high RES case.

U.S. Hydropower Market Growth Scenarios – Cumulative Capacity by 2025				
Category	**Technology**	**Realizable by 2025 (BAU)**	**Realizable By 2025 (Accelerated)**	**Projected Level of Development**
Inland	Efficiency Improvements + New Capacity	5,750 MW	8,900 MW	4,400 MW is current industry consensus commercial. Add 3% improvement to 45,000 MW of federal facilities for base case and 10% improvement in accelerated
	New facilities in existing dams without hydropower	5,000 MW	10,000 MW	Consistent with EPRI projections for 2025 used in normal case, >60% of resource potential deployed in accelerated case
	Greenfield Sites	500 MW	1,000 MW	Projecting accelerated case as twice business as usual case
	Inland Hydrokinetic	500 MW	2,000 MW	Projecting 2/3rds of full resource potential achieved in accelerated case
	Pumped Storage	10,000 MW	24,000 MW	Project 1/3rd of current queue deployed in BAU case, accelerated has >80% of all in queue projects (31 GW being approved).
	Total by 2025	**21,750 MW (7%)**	**45,900 MW (15%)**	
	% of Total Resource Available	**7%**	**15%**	300,000 MW total available inland

Sources: INL, EPRI and industry interviews.

Below are ocean *Business as Usual* and *Accelerated* potentials by 2025.

U.S. Hydropower Market Growth Scenarios – Cumulative Capacity by 2025				
Category	Technology	Realizable By 2025 (BAU)	Realizable By 2025 (Accelerated)	Projected Level of Development
Ocean	Wave	900 MW	9,000 MW	Project 1% of achievable capacity deployed after 2015 (normal) versus 10% of capacity for accelerated
	Ocean Current	250 MW	750 MW	Only assumed Florida potential with 1/3 of full potential realized in BAU and full capacity realized in accelerated
	Tidal In-Stream Energy Conversion (TISEC)	400 MW	4,000 MW	Project 10% of achievable capacity deployed after 2015 (normal)versus full capacity achieved for accelerated
	Total	**1,550 MW**	**13,750 MW**	Assumed after 2015 by 2025
Total Hydro	**Inland + Ocean**	**23,300 MW**	**59,650 MW**	
	% of Total Resource	**6%**	**15%**	300,000 MW Inland + 95,000 MW Ocean

Sources: INL and industry interviews.

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This analysis covered key parts of the value chain impacting jobs. Over 20+ interviews were conducted with companies representing several different parts of this value chain to estimate job numbers.

Hydropower Value Chain

Project Development
- Permitting
- Regulatory studies
- Licensing
- Design
- Scaled model testing
- Financing
- Insurance

Component Manufacturing
- Turbine
- Generator & Excitation
- Governor and Control System
- Other hydro mechanical components (valves, penstock etc.)
- Other electrical components (transformers, power electronics etc.)

Project Deployment
- Shoreline development
- Environmental instrumentation construction (e.g. fish bypass)
- Project Construction
- Project Commissioning
- Financing
- Insurance

Project Owner & Operator
- Routine O&M
- Minor equipment overhauls
- Major equipment overhauls

RECs & Offtakers

Note: Items in grey included in indirect jobs

In scope

Out of scope

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Navigant cross-checked cost basis job estimates with industry interviews. Below are typical full time equivalents (FTEs) per MW.

U.S. Hydropower Market Direct Jobs in FTE (Full Time Equivalents) – 2009		
Technology	**Average Project Size**	**Total FTE/MW (Average)**
Inland Hydrokinetic, Micro Hydro (<1 MW)	10 MW	6.00
Efficiency Improvements, New Capacity in existing facilities, modifications	10 MW	6.50
New Facilities in low head/low flow Existing Dams without Hydropower	10 MW	5.30
Green Field	50 MW	6.00
New Facilities in higher head / higher flow Existing Dams without Hydropower	50 MW	5.30
Green Field	100 MW	6.00
Pumped Storage	500 MW (interviews) 1,000 MW (cost basis)	5.10
Ocean – Wave, Tidal[1]	15 – 200 MW (literature) 50 MW (cost basis)	14.0

NOTE:

- FTE/MW represents typical value (non cumulative) required to execute a project of that size. Actual years taken to implement project will vary and this needs to be multiplied by years taken to get the cumulative man years estimate.
- Used interviews with 20+ industry stakeholders to arrive at a range of FTE/MW estimates
- Also used typical project costs to arrive at a cost based FTE/MW estimate that was used as the "average" value

Navigant Consulting's methodology for calculating indirect jobs is summarized below.

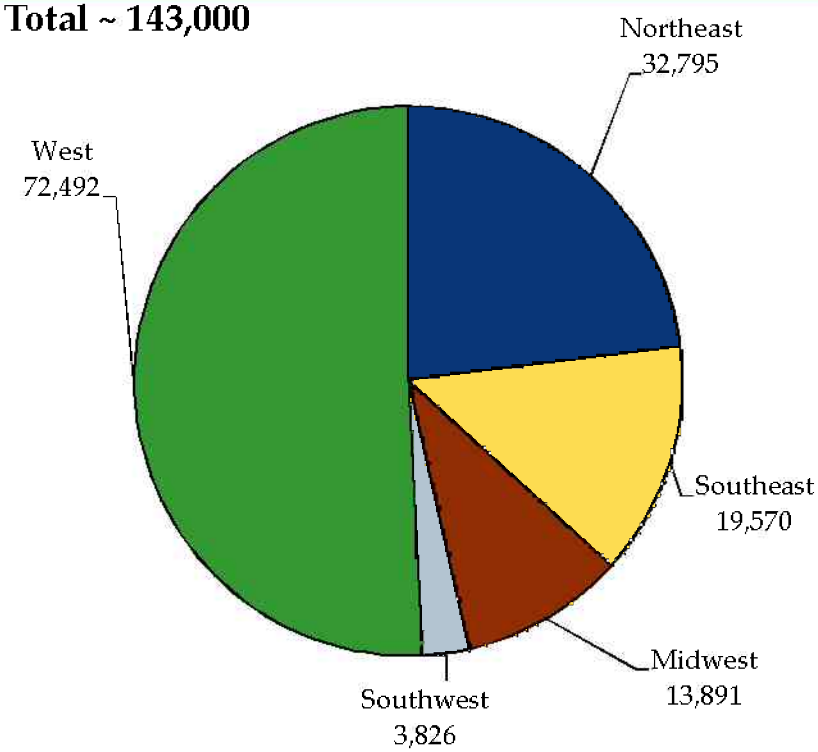
Indirect Jobs Analysis Methodology
• Used business as usual and accelerated forecasts out to 2025. • Used current distribution of technical resource potential available to estimate the MWs deployed by region.   – For example, the current resource potential suggests that 9,000 MW (~57%) of inland and ~1,200 MW (~59%) of ocean potential would be deployed in the West by 2025. • Assigned 80% of the manufacturing in the Northeast with 10% each in the Midwest and West • Assigned identical indirect (Type I) multipliers for both inland and ocean so total direct job numbers were added up by job classification (value chain, type) to calculate corresponding indirect jobs. • Obtained Type I multipliers by state from the US Bureau of Economic Analysis database.

Sources: Industry interviews, June 2009 and INL Report.

A total of ~238,000 jobs are estimated to be created in a BAU scenario with a low Renewable Energy Standard - RES (~10% by 2025).

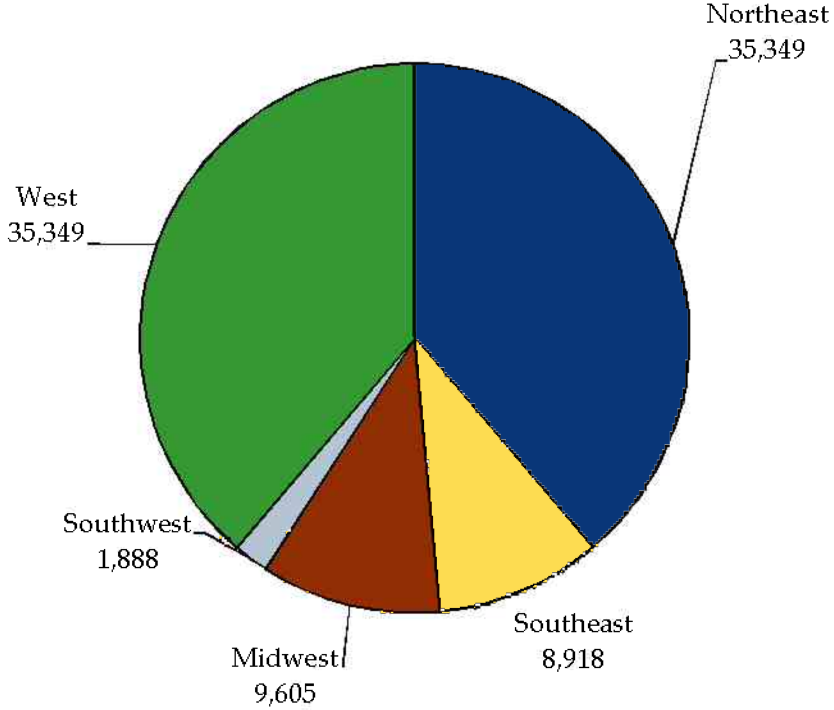
Direct Jobs Allocation (Cumulative)
BAU 2025

Total ~ 143,000



Indirect Jobs Allocation (Cumulative)
BAU 2025

Total ~ 95,000

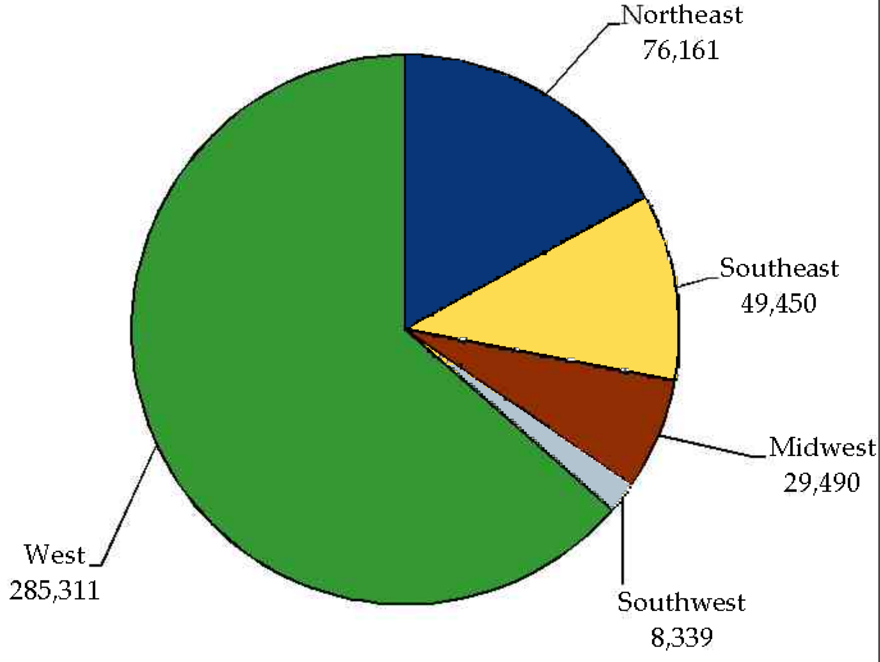


Note : Job estimates represent cumulative FTEs required over a 16 year period out to 2025

A total of ~700,000 jobs are estimated to be created in an accelerated scenario with a high RES (~25% by 2025).

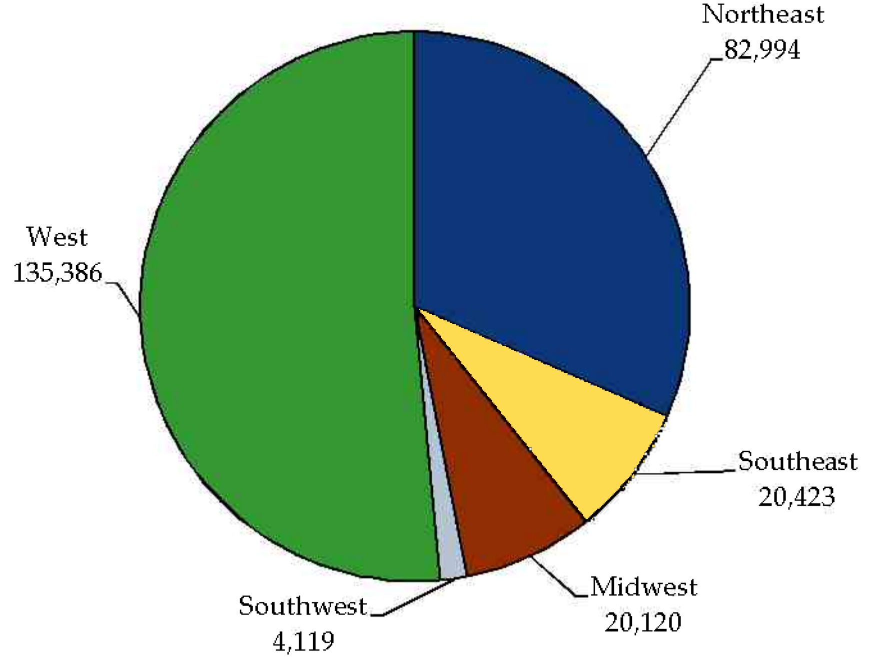
Direct Jobs Allocation (Cumulative) Accelerated 2025

Total ~ 443,000



Indirect Jobs Allocation (Cumulative) Accelerated 2025

Total ~ 265,000



Note : Job estimates represent cumulative FTEs required over a 16 year period out to 2025

The U.S. hydropower industry could install 23,000 MW – 60,000 MW of new capacity by 2025 depending upon the national RES adopted.

Conclusions
• The U.S. hydropower industry could install 23,000 MW – 60,000 MW of new capacity by 2025 depending upon the national RES adopted. – This additional capacity represents only 6% - 15% of the total untapped hydropower resource potential in the U.S. – Installing this additional capacity will require an estimated 140,000 – 440,000 cumulative direct jobs over a 16 year period. – These jobs will result in an additional estimated 95,000 – 265,000 indirect jobs over that same period. • Total jobs (direct + indirect) would therefore be in the range of 230,000 – 700,000 jobs • These total jobs estimates do not include induced jobs (e.g., service sector jobs such as retail, restaurants created by added dollars flowing into the market) that represent an additional upside potential from the growth of the hydropower industry.

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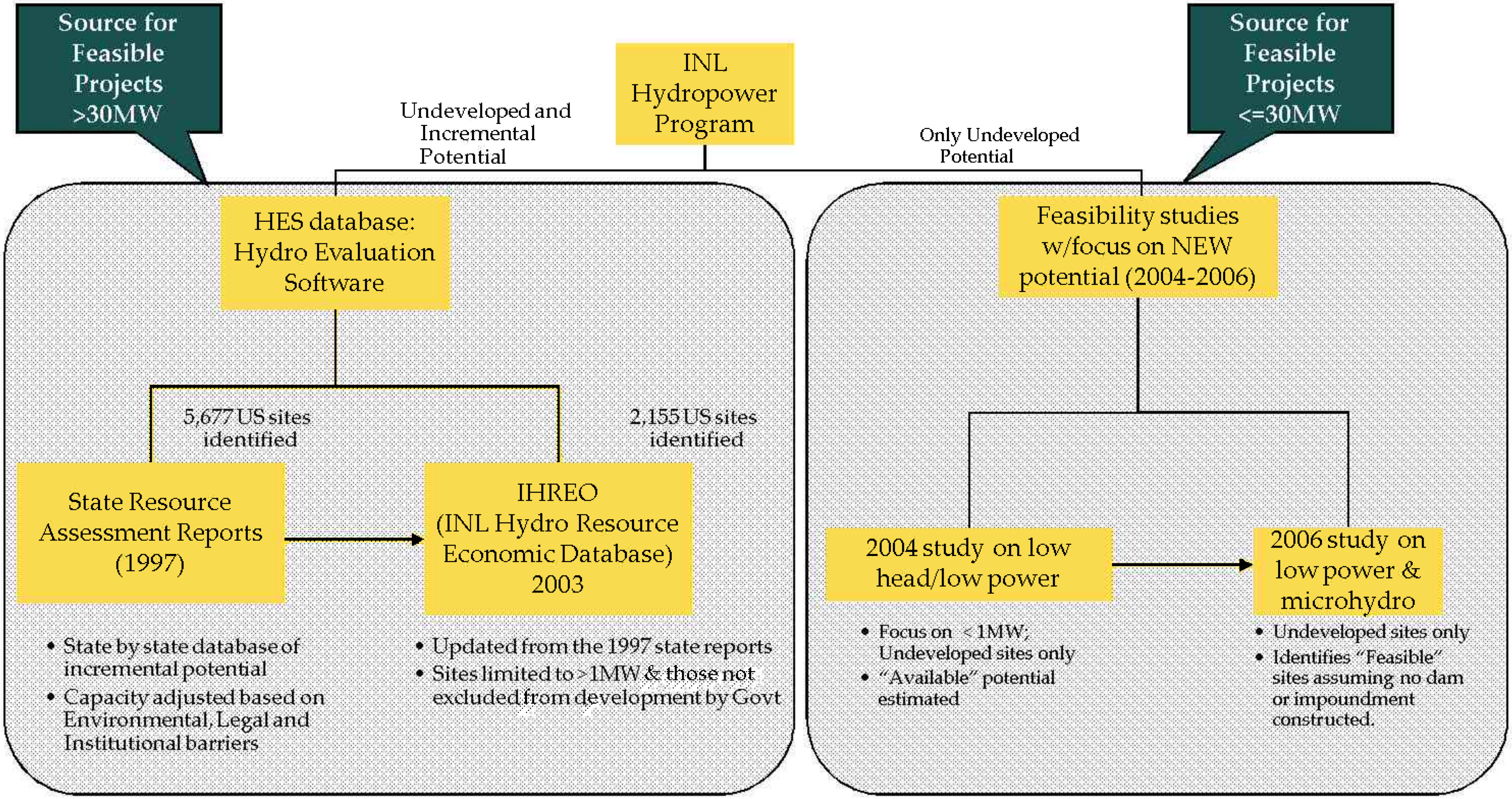
NCI relied upon studies from the INL's Hydropower Program to estimate the U.S.'s inland hydro potential.



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NCI used INL's 2003 and 2006 reports to estimate the technical potential across the U.S. for various project-size categories.

INL's 2003 report:

- Identifies 2,155 sites in the total U.S. with nameplate potential of 43,000 MW
- Criteria:
  - Only sites with ≥ 1 MW potential
  - Only sites not excluded from development by federal or state statutes or policies

INL's 2006 report:

- Identified 130,000 feasible sites across the U.S. with a total gross annual mean potential of 100,000 MWa (appx 200,000 MW nameplate capacity). The study applied further exclusions to these sites based on limits of working flow and penstock length, resulting in 30,000 MWa (appx 60,000 MW nameplate). Because this study aimed at identifying *technical*, not *theoretical*, potential, Navigant Consulting used the numbers constrained by working flow and penstock length as the basis for this report.
- Criteria:
  - Only small hydro (between 1 and 30 MW) and low power (<1MW) were considered at feasible sites.
  - Only developing NOT requiring a dam or reservoir was considered in this study.
  - Only natural streams considered, not constructed waterways, tidal or ocean resources.

Definitions (2003 Report):

Dam Status:

- **W** – Developed hydropower site with current power generation, but the total hydropower potential has not been fully developed. Only the undeveloped hydropower potential is included in this report.
- **WO** = Developed site without power generation. The site has some type of developed impoundment or diversion structure, but no developed hydropower generating capability.
- **U** – Undeveloped (greenfield) site with no impoundment or diversion structure.

Project Suitability Factor (Site Probability based on Environmental/Regulatory Assessments):

0.10 = Development prohibited or highly unlikely

0.25 = Major reduction in likelihood of development

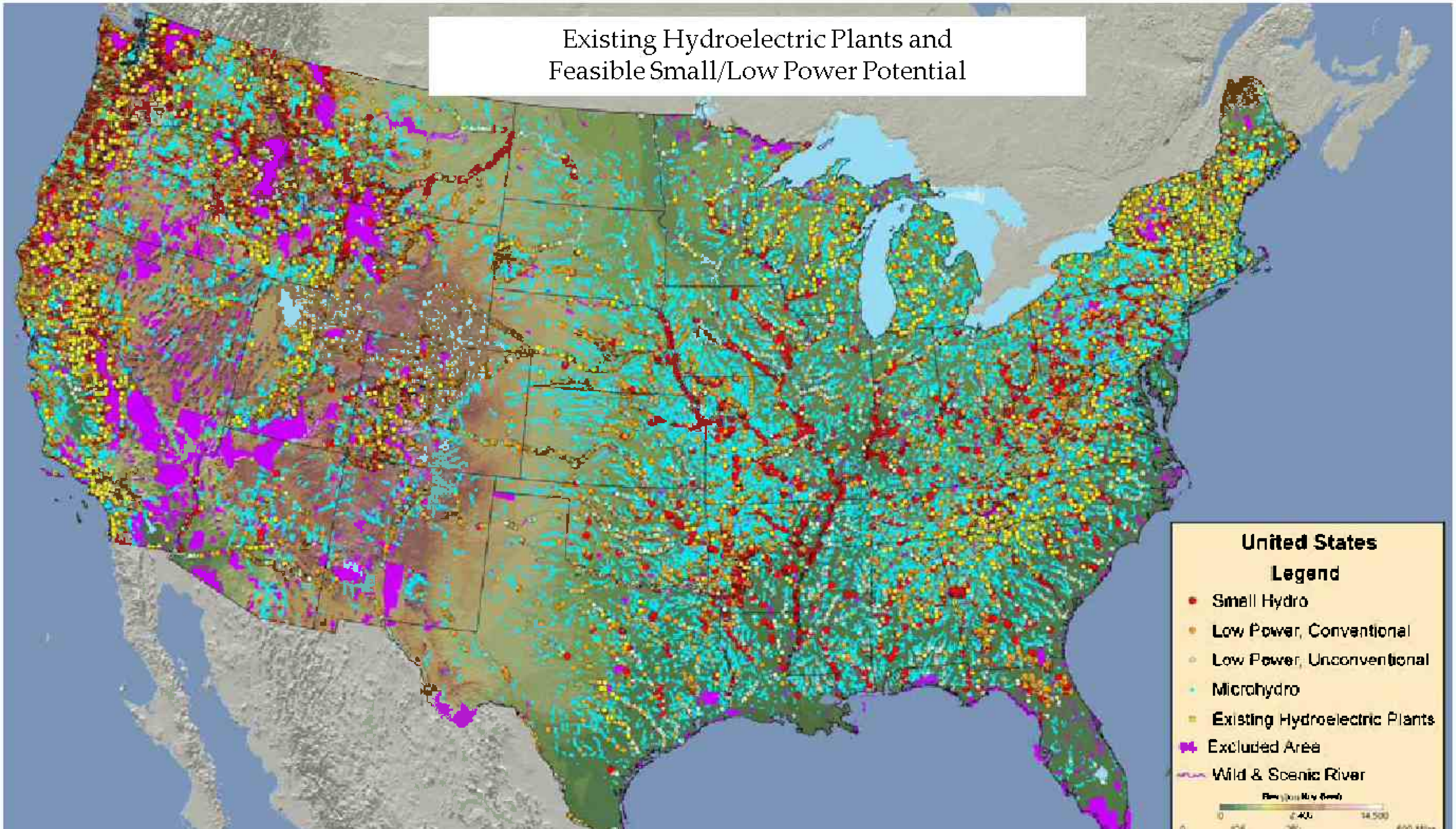
0.50 – Likelihood of development reduced by half

0.75 – Minor reduction in likelihood of development

0.90 = Least impediment to development

Source: Idaho National Lab

Existing U.S. hydro and potential small/low power inland hydro.



Source: Idaho National Lab

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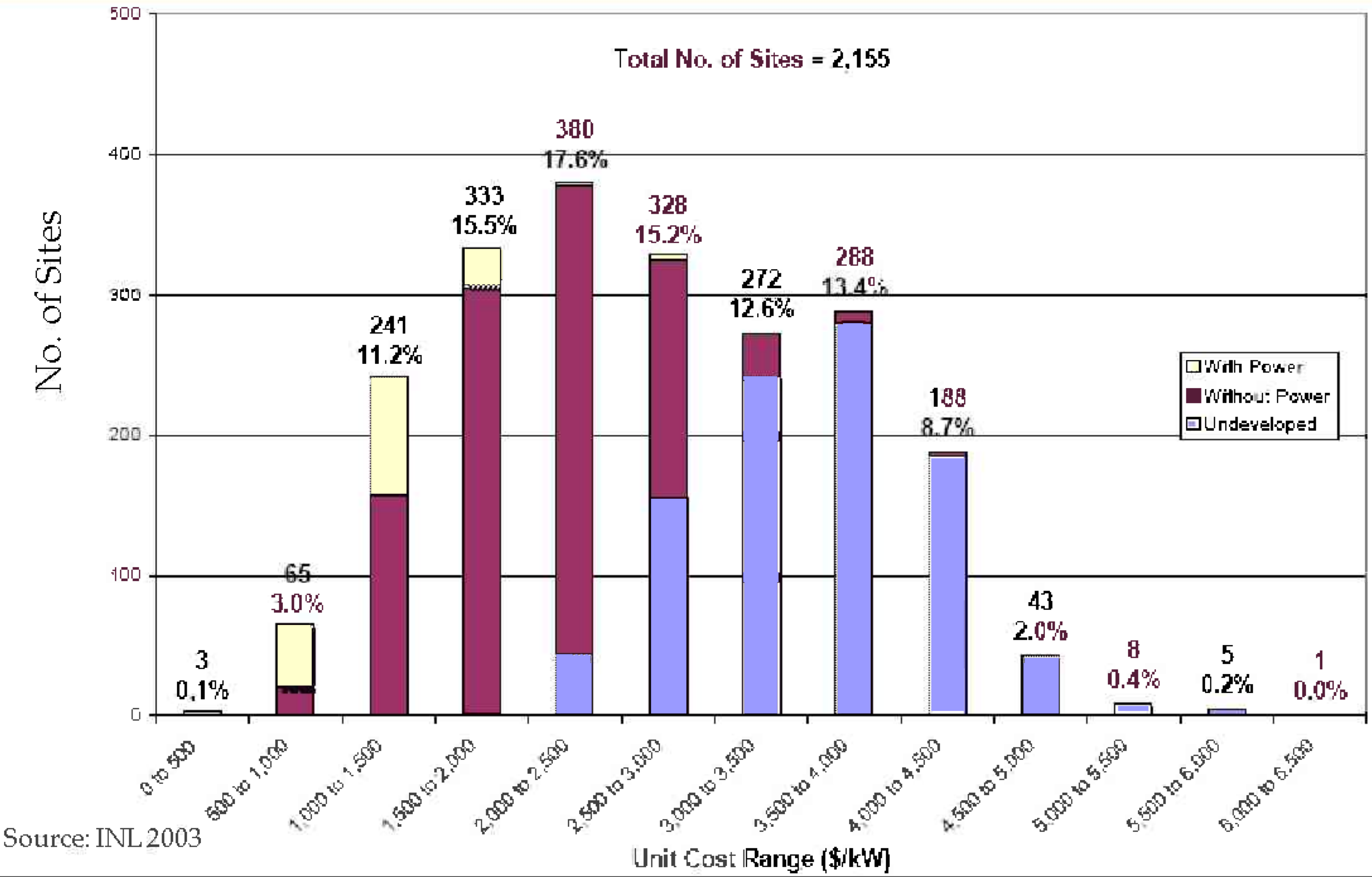
Inland hydro installed costs can range broadly depending on project characteristics. The chart below shows variation based on dam type.

Installed Costs of Inland Hydro for Various Dam Types in $/kW

(With Power, Without Power, and Undeveloped)



Source: INL 2003

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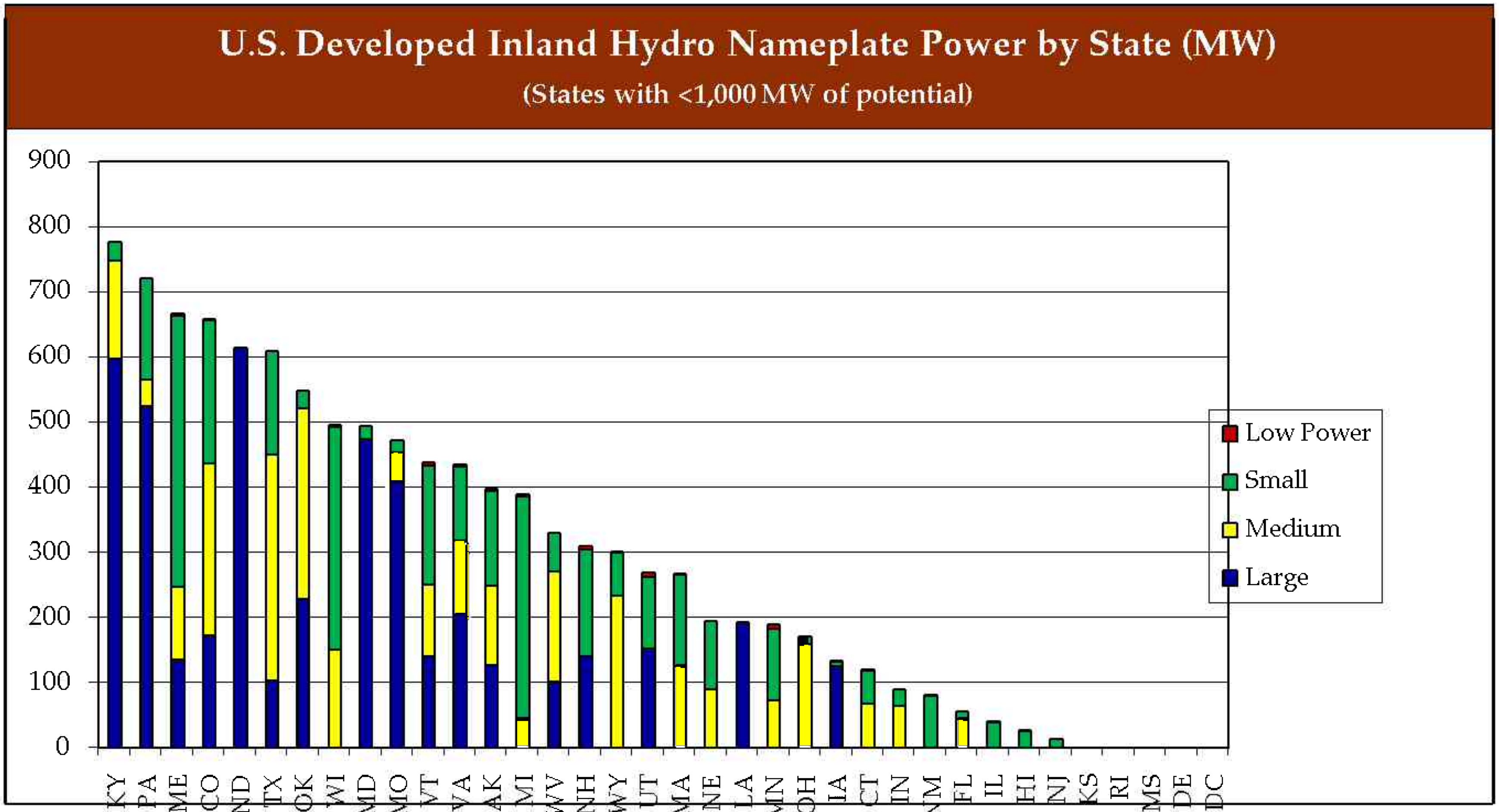
The chart below shows states with < 1,000 MW of developed inland hydro.



Source: Energy Velocity, 2009 data.
Low power: <1 MW; Small: >=1MW, <=30MW; Medium: >30MW, <=100MW; Large: >100MW

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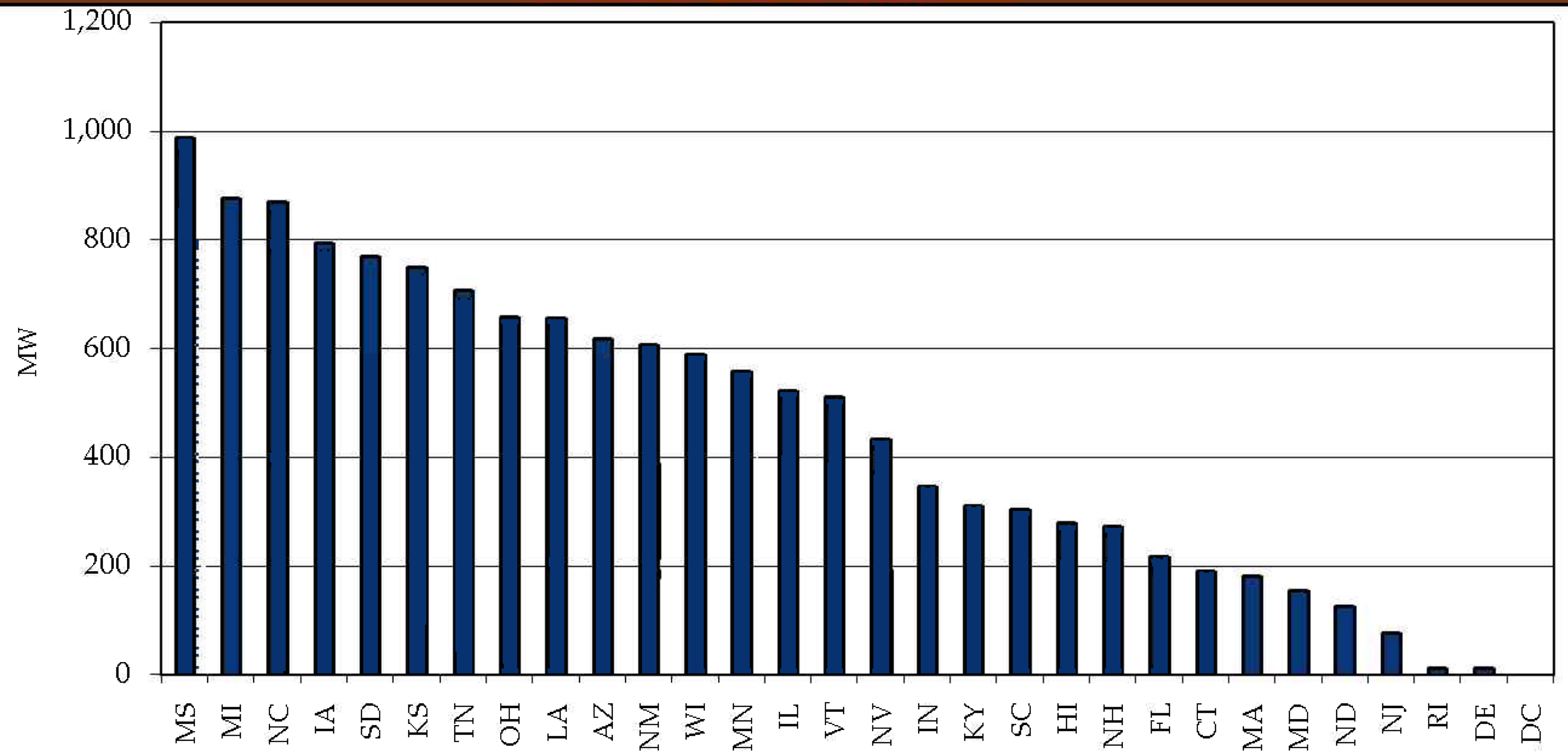
The chart below shows states with less than 1,000 MW of inland hydro technical potential.

U.S. Inland Technical Potential Nameplate Hydropower by State (MW)

(States with <1,000 MW of potential)



Source: INL *Feasibility Assessment of the Water Energy Resources of the US for New Low Power and Small Hydro Classes of Hydroelectric Plants* 2006 and *Estimation of Economic Parameters of U.S. Hydropower Resources* 2003. Excludes Capacity Additions and Efficiency Upgrades

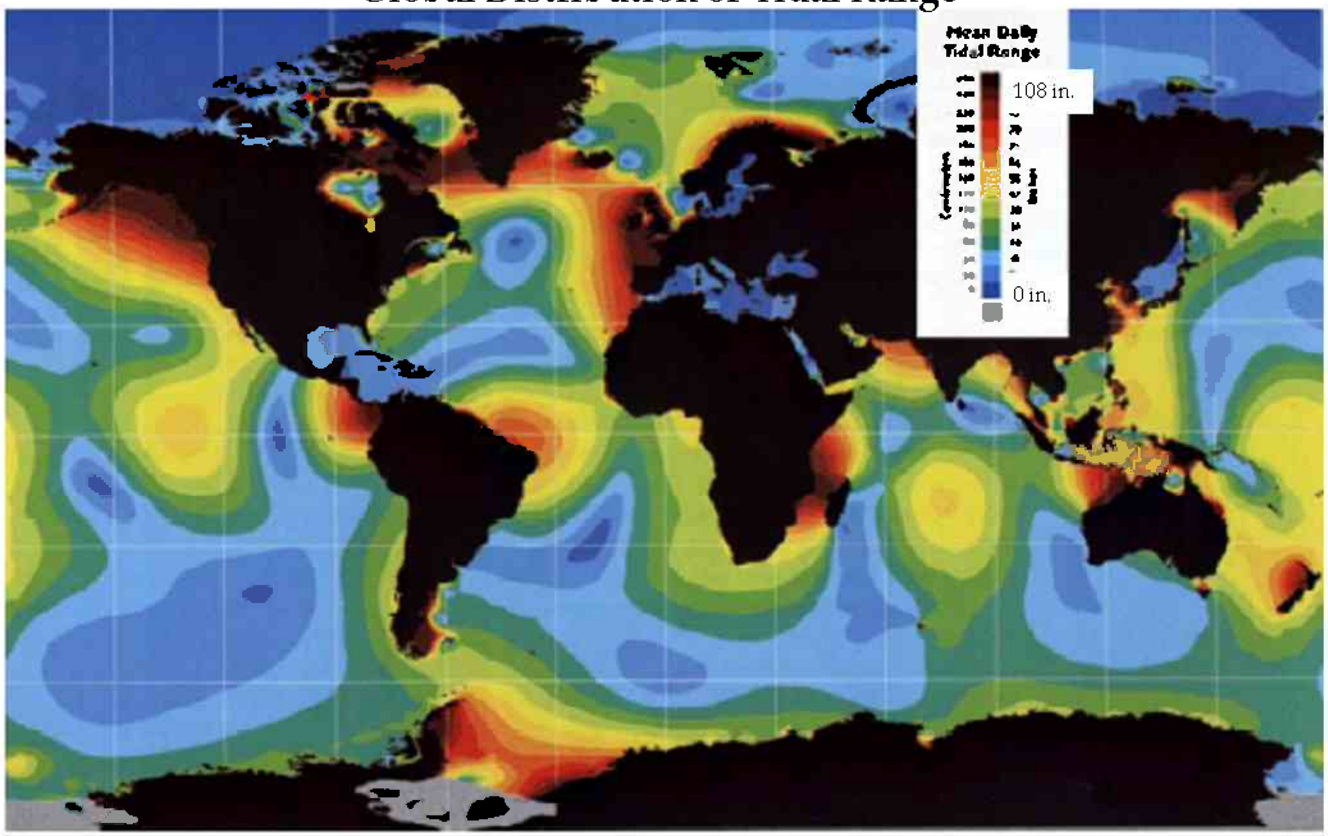
Though TISEC and Ocean Current energy both use hydrokinetic technology, design differs based on the different site characteristics.

Ocean Hydropower Systems and Technology Subcategories			
Technology	**Identifying Characteristics**		
	Resource Characteristics	**Flow Capture**	**Nameplate Capacity**
Tidal Instream Energy Conversion (TISEC)	• Uses tidal currents to generate electricity. These currents have an ebb and flow, with periods of no generation during tidal switch, typically when flow falls below 2 knots.	• Often designed to handle bi-directional flow of tides	• Typical nameplate capacities of 250 kW to 1 MW
Ocean Current	• Uses ocean currents, such as the Gulf Stream, Florida Current, or Florida Straits, to generate electricity. These currents are steady, with no dead periods.	• Designed to handle uni-directional flow • Designed to be more robust to withstand stronger currents	• Larger nameplate capacities of 1 MW to 2 MW per turbine

Limited work exists exploring U.S. tidal resource potential.

U.S. Technical Potential for Tidal (Tidal Barrage and TISEC)
An assessment of technical potential has not been undertaken. EPRI has conducted a TISEC study of 5 states, finding 300 MW of feasible technical potential, and an estimated 3,800 MW of theoretical potential in Alaska. [1]

Global Distribution of Tidal Range



Source: 1. Bedard, R., et al. North America Tidal In-Stream Energy Conversion Technology Feasibility Study, EPRI TP 009 – NA, June 11, 2006. Estimate of MW potential in Alaska was calculated based on estimated generation as reported by EPRI.

Navigant Consulting could not identify studies for U.S. ocean salinity or ocean thermal resource potential.

U.S. Technical Potential for Ocean Salinity and Ocean Thermal Energy
Ocean Salinity: An assessment of technical potential off the coast of the U.S. has not been undertaken.
Ocean Thermal: An assessment of technical potential off the coast of the U.S. has not been undertaken. However, areas potentially suitable for ocean thermal technology, where the difference between surface and deep water (1000 m) is approximately 20°C (36°F), include the coasts of FL, HI, the Gulf of Mexico, Puerto Rico and the Virgin Islands

Temperature Difference Between Surface Water and 1000 m Depth (°C)

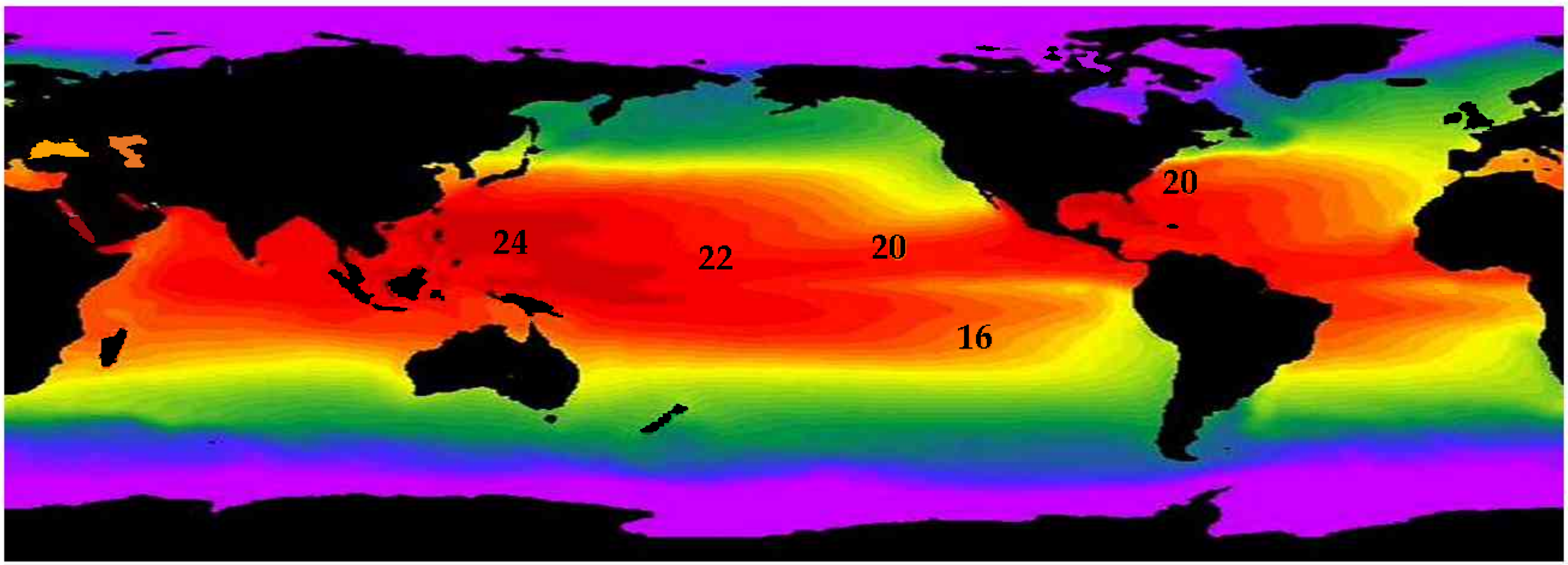


Image source: Florida Atlantic University, An Overview of Ocean Energy and the COET.

Navigant Consulting used a combination of data from ~20+ interviews, information from NCI's GKS Hydro and a final vetting with stakeholders to reach consensus on jobs per MW.

U.S. Hydropower Market Direct Jobs in FTE (Full Time Equivalents) – 2009						
Technology	**Project Size**	**FTE/MW (Development)**	**FTE/MW (Manufacturing)**	**FTE/MW (Deployment)**	**FTE/MW (O&M)**	**Totals**
Inland Hydrokinetic, Micro Hydro (<1 MW)	~5 MW average	3-6	~10	20-30	1-5	34-51
Efficiency Improvements, New Capacity in existing facilities, modifications	~10 MW average	1-3	2-4	~0.8-1.5	0.02-0.2	3.82-8.7
Efficiency Improvements, New Capacity in existing facilities, modifications	~50 MW and above	0.1-0.3	1-2	1-5	0.02-0.2	2.12-8
New Facilities in Existing Dams without Hydropower	~50 MW and above	0.2-0.5	1-2	4-8	0.06-0.21	5.26-10.71
Green Field	~50 MW and above	1-3	1-2	4-8	0.06-0.21	6.02-13.2
Pumped Storage	~500 MW	0.2-0.4	0.5-1	2-4	0.1-0.23	2.75-5.5
Ocean – Wave, Tidal[1]	15 – 200 MW	~0.3	~1	~5	~0.3	~6.6

1 - Project no. 502701, **CA-OE, *Co-ordination Action on Ocean Energy***, European Commission, Long term estimates
Sources: Industry interviews, June 2009 and Navigant *Generation Knowledge Services* model for O&M that is based on data from industry.

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Navigant Consulting's methodology for calculating jobs using a cost based approach is outlined below.

Indirect Jobs Analysis Methodology

- Used business as usual and accelerated forecasts out to 2025 for each technology space and an average project size to estimate total number of projects required to meet objectives.
- Estimated the typical number of total jobs needed to execute each project.
- Used the typical $/kW estimate for each technology type to estimate total dollars needed to deploy the resource by 2025.
- Multiplied the total number of jobs with an average annual FTE $/yr estimate (e.g. $75,000 per year for a full time equivalent) to estimate total labor dollars needed for resource deployment by 2025.
- Divided labor dollars by total project dollars and determined if the % of labor as a mix of total project costs was reasonable.
- Adjusted labor estimates for each project until this % estimate was reasonable (typical values are in the 60%-70% range).

Estimation using cost basis suggests lower end estimates from interviews and discussions are most appropriate.

U.S. Hydropower Market Direct Jobs in FTE (Full Time Equivalents) – 2009			
Technology	**Average Project Size**	**Total FTE/MW Average Interviews, Discussions**	**Total FTE/MW Average Cost Basis**
Inland Hydrokinetic, Micro Hydro (<1 MW)	10 MW	34-51*	6.00*
Efficiency Improvements, New Capacity in existing facilities, modifications	10 MW	3.82-8.7	6.50
New Facilities in Existing Dams without Hydropower	50 MW	5.26-10.71	5.30
Green Field	50 MW	6.02-13.2	6.00
Pumped Storage	500 MW (interviews) 1000 MW (cost basis)	2.75-5.5	5.10
Ocean – Wave, Tidal[1]	15 – 200 MW (literature) 50 MW (cost basis)	~6.6*	14.0*

NOTE: FTE/MW represents typical value (non cumulative) required to execute a project of that size. Actual years taken to implement project will vary and this needs to be multiplied by years taken to get the cumulative man years estimate.
* Large differences noted in these technology approaches due to relative immaturity of the technology approaches and limited data available (fewer companies currently involved in these spaces).

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