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Testimony Of

The American Society of Civil Engineers

to the

U.S. House of Representatives

Committee on Energy and Commerce

Subcommittee on Energy

on

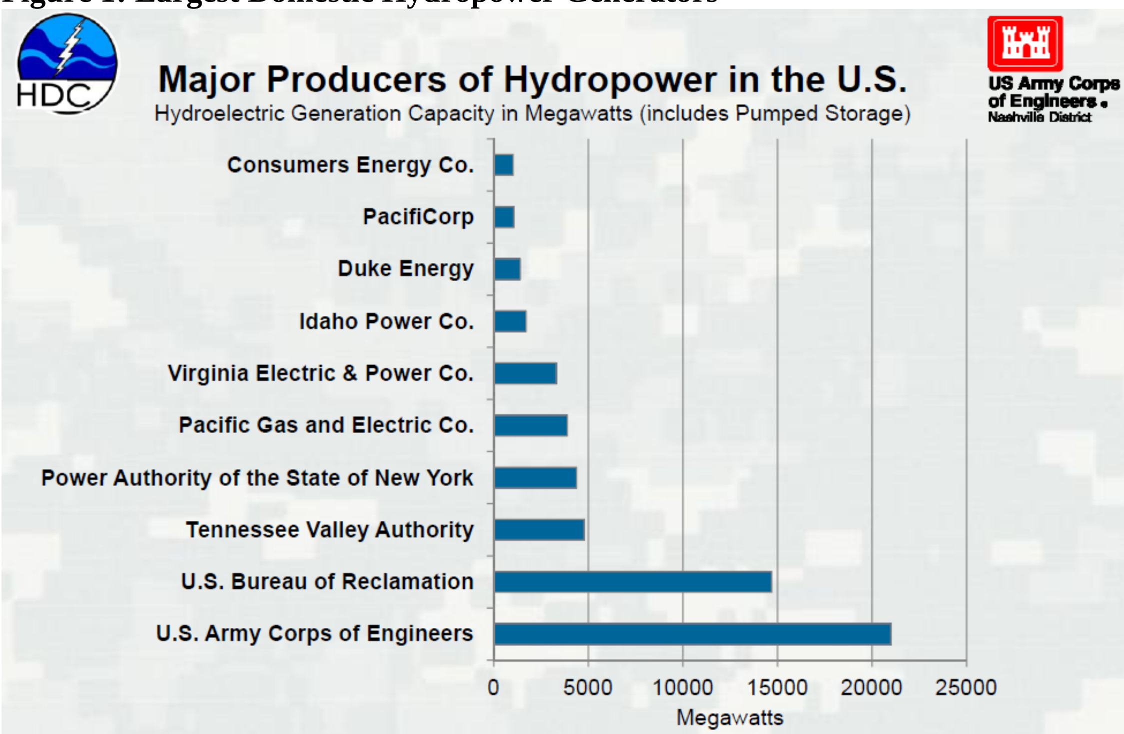
"Modernizing Energy Infrastructure: Challenges and Opportunities to Expanding Hydropower Generation"

March 15, 2017

1.0 CURRENT CONDITIONS

Hydroelectric generation in the United States is uniquely owned by a diverse group of investor-owned utilities, municipalities, cooperatives, government agencies, and private developers (see Figure 1 and Table 1 also). Privately owned infrastructure (over 1,500 installations) is regulated primarily by the Federal Energy Regulatory Commission (FERC) and other state-, local-, and tribal-based agencies. Federally owned hydroelectric generation is authorized/regulated by U.S. Congress, but must meet laws and evolving environmental regulations similar to those imposed by FERC and other federal agencies including the U.S. Army Corp of Engineers and U.S. Fish and Wildlife Service. Involvement of many agencies has greatly increased licensing/relicensing complexity.

Figure 1: Largest Domestic Hydropower Generators



Source: Hydroelectric Design Center, U.S. Army Corps of Engineers (USACE), 2013

In recent years, hydroelectric generation has produced roughly 7% of the total U.S. power generated, and the U.S. Energy Administration (EIA) anticipates this contribution will remain flat for coming years. Bolstered by tax credits and investment, the American Wind Energy Association disclosed on February 9, 2017 that wind energy has surpassed hydropower as the leading renewable energy source in the U.S. energy mix. The EIA in March, 2017 predicted continued growth in both wind and solar generation in 2017/2018 and beyond versus flat hydropower growth.

The average age of the almost 87,000 publicly and privately owned dams in the National Inventory of Dams is 52 years and, by 2020, over 85% will be over 50 years old (a common design life). Approximately 3% of these dams were fitted with hydroelectric generating capability (the 97% balance represents an opportunity for hydropower, as dams create needed hydraulic head for desired generation). As of the end of 2015, the U.S. Department of Energy

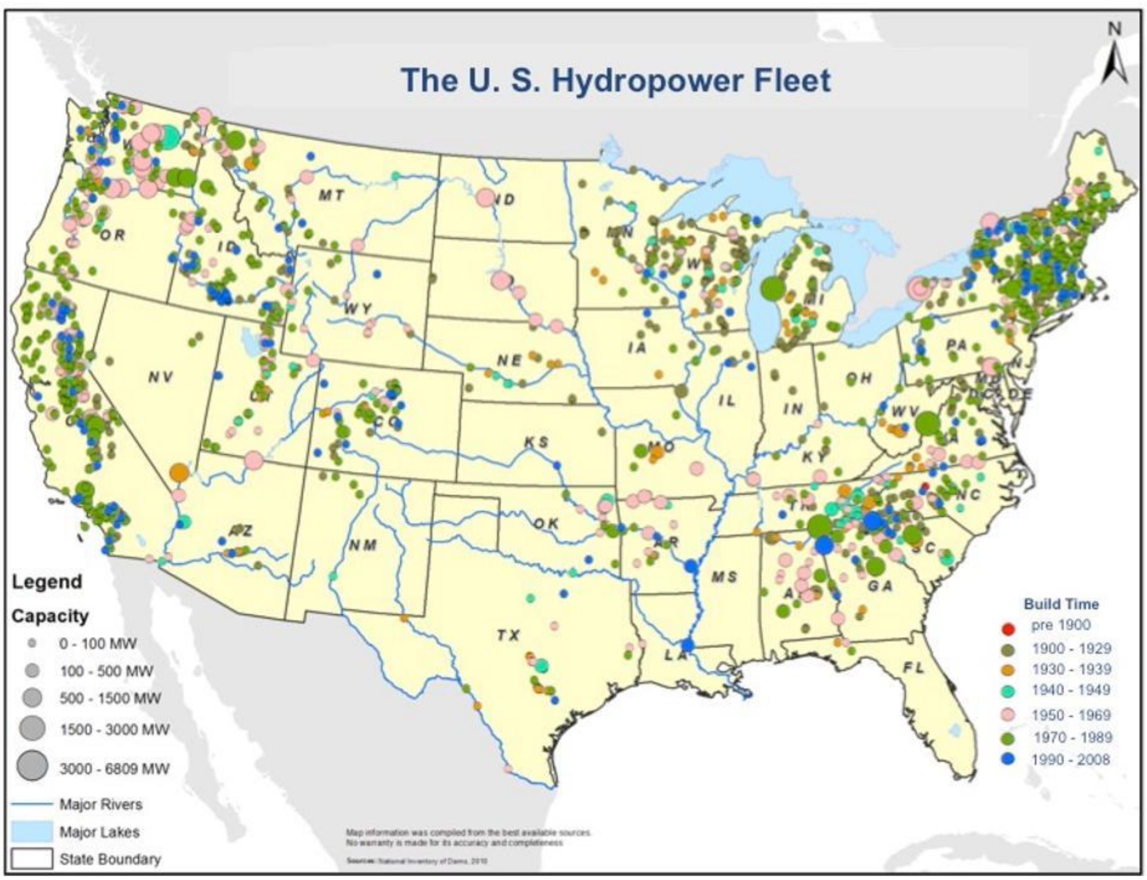
(DOE) reported there are 2,198 active conventional hydroelectric plants (representing 79.6 gigawatts, GW) and 42 pumped storage plants (representing 21.6 GW) for a total generating capacity of 101 GW with median age of over 55 years old. Table 1 illustrates approximate ownership class of 2,198 plants and 101 GW, based on FERC and Idaho National Laboratory reporting:

Table 1: Private vs. Public Hydropower Ownership

Ownership Class	Plant Ownership, Percent	MW Generation, Percent	Commentary
Utilities (privately owned)	31%	24%	Conventional and pumped storage hydro (PSH)
Non-utility Private Sector	38%	4%	Smaller, river-based units
Public Sector (Federal and Non-federal Public)	31%	72%	Larger units on major rivers (e.g., Columbia) and PSH

Information about individual FERC-licensed hydropower facilities is available at the FERC website; data on all domestic facilities is available from the Virtual Hydropower Prospector (http://en.openei.org/wiki/Virtual_Hydropower_Prospector), a Geographical Information System (GIS) based tool maintained by Idaho National Laboratory and shown in Figure 2.

Figure 2: U.S. Hydropower Fleet (Lower 48 States)



Courtesy of National Hydropower Association (NHA) and DOE/Oak Ridge National Laboratory

ASCE recognizes that economical, reliable, safe and environmentally acceptable energy production and development are critical to industrial and commercial expansion, economic growth, stability and national security. While hydropower typically has the ability to supply continuous (base load) power source on demand with minimal air pollution, the high initial capital costs, potential ecosystem disturbance, and reduced uncertainly during low water seasons/years does create uncertainty. For this reason, ASCE strongly encourages development of a national energy policy which balances investment in hydropower with other sources. As Congress continues to examine various fuel/resource contributions to the electricity market and private/public investment, we encourage extending the life of existing facilities and expanded use of new hydropower as further discussed herein.

2.0 HYDROPOWER EXPANSION – CHALLENGES AND OPPORTUNITIES

ASCE supports the expansion, and development of hydropower opportunities, from large-scale pumped storage (PSH) plants through low-head micro/hydrokinetic facilities, where found feasible. Clearly, such must be done in a manner that minimizes potential environmental impacts, maximizes safety, and balances the use of resources. Hydropower is among the most cost effective of all electricity sources given that it does not require a fuel source. Because its fuel is flowing water, and less frequently waves or pumped water discharged by gravity, it is viewed to be local, stable, and safe with no carbon emissions. To keep such safe and its environmental impacts reasonable, such facilities must be maintained and their design bases checked against changing climatic conditions. New projects must take advantage of biological technologies to avoid impacts to fish and other aquatic species.

Last year, the DOE released a new report looking at the future of hydropower through 2050. The report, *Hydropower Vision: A New Chapter for America's First Renewable Electricity Source*, found "that with continued technology advancements, innovative market mechanisms, and a focus on environmental sustainability, hydropower in the United States (U.S.) could grow from 101 gigawatts (GW) to nearly 150 GW of combined electricity generation and storage capacity by 2050." This would be comprised of 13 GW of conventional (upgrades of existing, adding hydro to unpowered dams/canals, limited new stream-based units) and 36 GW of pumped storage.

While there clearly is great potential and opportunity, there are also challenges. Two key DOE recommendations avoid many of these challenges: (1) upgrade performance of existing hydroelectric generation, and (2) utilize current non-power dams, canals, and conduits (e.g., irrigation) for new generation. In both cases, challenges such as land/impoundment procurement, complex environmental permits, and significant costs associated with dam and civil works construction are avoided. Both alternatives also enable investments which overcome aging of dam/civil works and improve overall safety; where possible, ASCE recommends these opportunities be prioritized particularly where reduced impacts to fish/aquatic life (for example, see low impact criteria proposed by Low Impact Hydropower Institute (http://lowimpacthydro.org/low-impact-criteria/)) and close proximity to existing transmission/distribution exist. Other goals including continued safe operations, keeping cost of generation low, and meeting licensing requirements are achievable (see *Regulatory Challenges* herein). Table 2 summarizes <u>key</u> challenges/opportunities for the existing hydroelectric fleet.

In 2016, American Municipal Power (AMP) successfully completed four run-of-river hydroelectric projects at four existing non-power USACE dams along the Ohio river adding over 300 MW of renewable energy to its diversify its portfolio. While admittedly not the least-cost generation to construct, the intrinsic benefits of requiring no fuel, emitting no airborne emissions and offering flexible base load generation were more compelling. Rye Development is also seeking to invest in nominally 265 MW of similar projects east of the Mississippi River at the present time. The AMP projects also were located close to existing distribution circuits, and clearly demonstrate the benefits of adding hydropower at existing dams.

Table 2: Existing Conventional and Pumped Storage Hydroelectric Generation

Challenges	Opportunities
Aging infrastructure (investments needed are competing with investment in other new sources or demand-side alternatives)	Expanded generation through new technologies (power uprate); unique flexibility to meet changing demands and backstop intermittent renewables
FERC-related relicensing (plan to reduce cycle to 2-year duration needs further improvements – workshop this month)	Continued reduction in environmental impacts (e.g., improved fish ladders, barriers)
Pressure to keep electricity rates low reduces maintenance spending	Low-cost renewable generation (original investment capitalized) with no harmful air emissions
Impoundments have been found to emit methane from microbes consuming organic matter in collected sediments	USACE, Bureau of Reclamation leadership on leasing existing dams for expanded hydroelectric use
	PSH storage offers invaluable grid support, as well as on-demand capacity/energy

The pace of developing and licensing new conventional hydroelectric projects in the USA has slowed in recent years, with one common citation being that all viable sites have already been developed. DOE statistics indicate that less than 1/3 of proposed new hydropower projects are new stream development (NSD) and over 50% of these reside in Alaska. However, opportunities do still exist beyond using existing non-power dams and a majority fit into one of the following categories:

- Hydrokinetic, micro, or small conventional configurations using new technology (commercial proofing, often led by the equipment manufacturer); typically less than 1 MW project size and limited in number
- Municipalities or commercial/industrial businesses with access to flowing water and with sustainability aspirations (e.g., renewable power goals or portfolio standard compliance); typically less than 30 MW in scale
- Utilities which have determined that a defined conventional hydroelectric project represents the best supply-side alternative via IRP (as a result of larger MW capacity projects with lower capital cost/kW generated and low life cycle cost).

Notably in all three categories, these projects are competing with other renewables and gas-fired generation for advancement. Without tax credits, streamlining of permitting/approval, carbon tax, or other differentiator, investment in new hydroelectric projects is challenged as it is not the least cost of generation. An audit of 2015 to 2017 integrated resource plans of multiple utilities found little consideration of hydropower projects (except select utilities evaluated PSH, where a defined project is already in planning).

The following “concerns” inhibit investments:

- Long-term projection of relatively low natural gas prices and suitable volume available;
- Uncertainty in permitting/licensing, and long-lead time to develop projects, each of which challenges securing financing;
- Declining solar and wind equipment and overall project costs;
- Uncertainty over the impacts of climate change (e.g., floods, droughts, other) on future performance;
- Costs, lead time, and environmental impacts associated with construction of new dams with hydropower facilities (only select locations avoid these concerns)
- Market conditions; low prices currently paid for power by independent system operators and regional transmission owners favors other forms of generation to be constructed or demand-side management. An example is the Independent System Operator of New England (ISO-NE) and Commonwealth of Massachusetts procurement of low-cost hydropower from Canada along with new domestic wind construction.

A number of these concerns can be “stacked” together, which further challenges investment and moves focus to alternatives. Table 3 summarizes challenges/opportunities for new hydropower.

Table 3: New Dam-Based or Run-of-River (NSD) Hydroelectric Generation

Challenges	Opportunities
Limited sites with sufficient hydraulic head or headrace/tailrace properties remaining; concerns for future climate changes (e.g., floods)	Improved equipment increases output with lower aquatic impacts, including that for low head and variable flow rates (micro hydro)
Environmental impacts (to be balanced with generation opportunity)	Hydrokinetic (wave and tidal) systems gaining commercial acceptance
Licensing lead time and uncertain outcome, jeopardizes project financing	Focus on less-impactful hydropower addition at existing dam sites
Cost of generation higher than other sources (e.g., other renewables, gas-fired generation)	

Pumped storage (PSH) represents approximately 22,000 MW of capacity at present, and the DOE concluded that 36,000 more MW can be built by 2050. With current timelines running at least 8 years just to obtain all necessary approvals, permits, and licenses, improvements are clearly needed to make this happen. An important feature of PSH-based storage involves its ability to generate when intermittent renewables (wind, solar) are not available while also offering spinning reserve and reactive power support which increase the reliability and performance of the electrical transmission grid. Development of pumped storage capacity is a capital intensive infrastructure activity, requiring significant upfront investment and uncertain regulatory and licensing issues have limited use. The DOE *Hydropower Vision* report summarizes the enormous potential that properly sited PSH projects can offer.

While PSH benefits are significant, investment of private capital are challenged by uncertainty in project development (including licensing) and revenues from the electricity market. Elevated capital costs and constraints also affect potential federal PSH investments, although the U.S. Bureau of Reclamation (USBR) has actively engaged PSH enhancements at its existing hydropower facilities (reference USBR “Renewable Energy Update, Fiscal Year (FY) 2017, Q1”, TVA’s “2015 Integrated Resource Plan”, and Bonneville Power Authority (BPA) “2017-

2030 Hydro Asset Strategy" for the Federal Columbia River Power System). Public/private PSH development at federal hydropower facilities is encouraged by ASCE.

Table 4: New Pumped Hydroelectric (PHEV) Generation

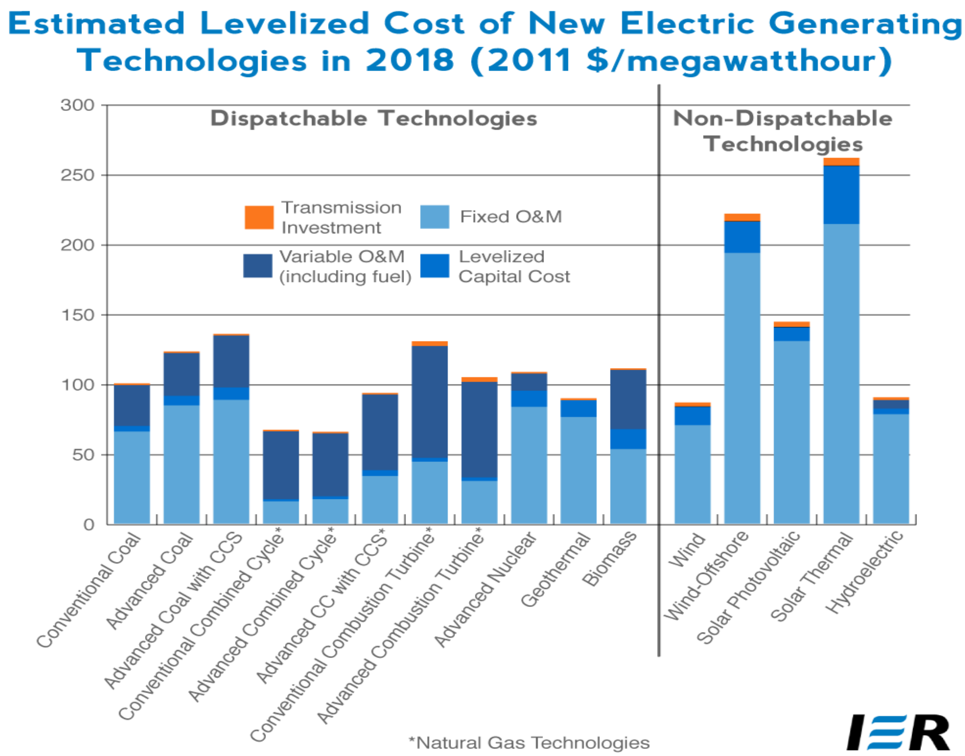
Challenges	Opportunities
Few opportune sites exist near population centers or industry (NIMBY); consider abandoned mine sites, federal hydropower sites, similar	Significant capacity, energy, and ancillary benefits to electric grid (e.g., Ludington) support continued development
Open loop PSH (connected to continuously flowing water) have elevated environmental impacts versus closed loop	If successful, FERC's streamlined permitting of closed loop PSH could stimulate greater interest particularly in western US
Markets (ISOs/RTOs) don't compensate owners for ancillary (storage) benefits	NHA reports that over 78% of the general public supports new hydroelectric and PSH projects
Significant lead time to plan, permit, obtain FERC license, finance, and build (risks to owner)	Pumping operation can be aligned with other renewables; generation can overcome intermittency
Elevated cost of generation due to elevated initial capital investment hurts inclusion in IRP	

2.1 Cost of Generation (COG) Challenges

Basic tenants in production and delivery of electric power include safety to the general public, low environmental impacts, high efficiency and waste avoidance, and low cost of service. Sustaining a balance of these tenants is difficult and best managed through flexible policies. The market-based system currently employed in much of the U.S. places a premium on low cost of service, perhaps without considering long-term sustainability. Minimizing the COG of hydropower requires controls over initial capital cost and ensuring that annual operating and maintenance (O&M) costs are similarly kept in check. An advantage many hydropower projects have over others is actual service lives are typically 50 years or greater), which generally yields a greater energy return on investment (ROI).

Figure 3 depicts estimated 2018 levelized COG for various supply-side generation systems. Hydropower COG is more expensive than gas-fired and wind-based generation under current market conditions where the long-term cost of natural gas is low/stable and tax credits exist for other renewable generation. Hydropower's advantage is that it is not exposed to fuel-related inflation.

Figure 3: Future Levelized COG



Source: The Institute for Energy Research (IER)

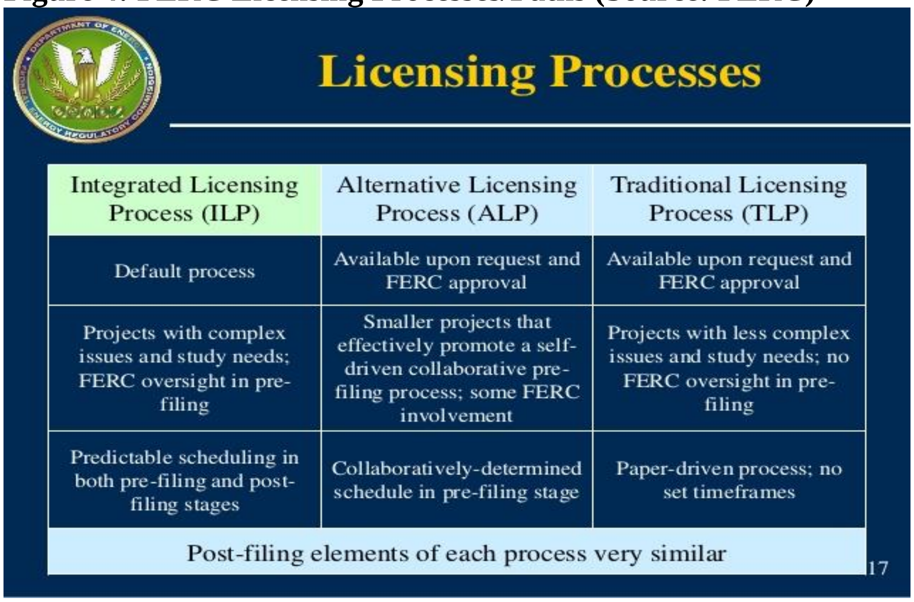
Integrated resource planning (IRP) is often focused on necessary near-term supply- and demand-side actions of a utility, developer, or public agency. Where shortfalls in capacity are found in IRP modeling, projects with certain costs/timelines are selected and this often disfavors hydropower alternatives. Policies such as avoidance of greenhouse gases impact selection and favor renewables but COG and transmission and distribution factors also come into play. In summary, short-term pressures to keep COG low often favor other forms of generation.

2.2 Regulatory Challenges

ASCE also supports continued streamlining of the permitting/review process associated with new hydropower licenses. As a minimum, better definition of the process itself (parties with stature, decision-making authority) and the overall timeline needed to secure financing and enable integrated planning. The current licensing process is extremely complex, costly and time-consuming. Requirements tend to discourage hydro owners/developers from developing new hydropower at existing dams, and even those at low-impact small and low-head hydropower using open stream or conduit-based applications. The amendment process for increasing the capacity, efficiency and output of existing plants and relicensing projects at the end of their FERC operating license are similarly prohibitive.

On a positive front, memoranda of understanding (MOA) between the USACE, other Federal agencies, and marketers including the Southeastern Power Administration (SEPA) have yielded sustainable bases for rehabilitating and extending the life of federally owned hydropower and have opened the proverbial door for more public/private investments. In addition, integrated licensing (ILP) depicted in Figure 4 and conduit/small hydro exemptions have shown some promise in terms trying to establish more certainty, but additional effort is required.

Figure 4: FERC Licensing Processes/Paths (Source: FERC)


Licensing Processes

Integrated Licensing Process (ILP)	Alternative Licensing Process (ALP)	Traditional Licensing Process (TLP)
Default process	Available upon request and FERC approval	Available upon request and FERC approval
Projects with complex issues and study needs; FERC oversight in pre-filing	Smaller projects that effectively promote a self-driven collaborative pre-filing process; some FERC involvement	Projects with less complex issues and study needs; no FERC oversight in pre-filing
Predictable scheduling in both pre-filing and post-filing stages	Collaboratively-determined schedule in pre-filing stage	Paper-driven process; no set timeframes
Post-filing elements of each process very similar		

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An effort to make legislative improvements to new/existing hydropower regulation took place in calendar year 2016 (114th Congress) but the House and Senate were unable to agree on how to proceed. The Senate-passed Energy Policy Modernization Act (S. 2012) and the House amendment to that legislation (which included H.R. 8, the North American Energy Security and Infrastructure Act) contained said licensing reform provisions. Although understood that the hydropower provisions enjoyed broad bipartisan support, other provisions lumped into the same proposals addressing energy conservation, liquefied natural gas exports, and wildfire mitigation, met resistance. It is recommended that legislation solely addressing hydropower licensing improvements/regulations be pursued to increase hydropower deployment.

2.3 Aging Concerns

As existing hydropower facilities age beyond their design life, more frequent inspections, review of key design parameters (e.g., embankment pore pressures) and emergency action plans, and expanded use of technology can be used to preserve function/safety and avoid failures. As examples, drones and other remotely operated vehicles (ROVs) can be used to increase visual inspection frequency in areas where human access is challenged and remote sensing can monitor key parameters and sense changes (e.g., structural deflection/movement, water level/flow). Many licensees are already managing aging effectively but new technology can economically improve such. Aging is a greater concern in non-power dams inspected less frequently.

Photo courtesy of the Electric Power Research Institute (EPRI)

3.0 RECOMMENDATIONS

As Congress considers issues to help ensure existing hydropower dams are safe and that expanded use is contemplated, ASCE offers the following recommendations:

1. Fully fund dam safety programs and utilize alternative financing and "customer" investments. Our nation's dams provide power generation, flood control, water supply, irrigation, recreation, navigation, and environmental protection. Thousands of our nation's dams are in need of rehabilitation to meet current design and safety standards. Increased downstream development, aging, and climate changes all need to be considered to avoid future flooding, earthquakes, dam failures, or safety concerns. Whereas dams supporting hydroelectric facilities are regularly inspected as part of FERC licensing and safe performance has ensued, many other dams are less rigorously maintained.
2. Continued investment in economical, reliable, safe and environmentally acceptable hydropower is critical to industrial/commercial operations, economic growth, stability and national security. U.S. Department of Energy Hydropower Vision offers cohesive implementation guidance for industry expansion.
3. Technologies which enhance fish/habitat survival, maximize water use efficiency, and improve discharge water quality should be tapped to minimize environmental impact at existing dams and hydroelectric facilities. In addition, drones, GIS, and remote sensing should be used as low-cost supplements to license-mandated facility inspections.
4. Research such as select efforts to reduce capital cost, improve efficiency, and lower aquatic impacts (DOE's HydroNEXT initiative) are recommended, but must lead to industry improvements (examples include use of modularity to reduce initial cost).
5. Privatization of select federally owned dams should be studied, particularly in locales where local private owners or municipalities are in the best position to maintain them or where non-power dams can be enhanced with hydropower/hydrokinetic addition.
6. Legislation that purely focuses on improving hydropower licensing/regulation and adds certainty to permit/approval timelines is needed building upon the Hydropower Regulatory Efficiency Act of 2013 and streamline the previous FERC Hydropower Final Rule (Order No. 2002). Current permit/licensing challenges inhibit inclusion of potential hydroelectric projects in integrated resource planning.
7. A national energy policy that anticipates future energy needs, promotes development of clean/renewable energy supply such as hydropower, increases energy efficiency, and reduces dependency on foreign sources will enable prudent investment.

4.0 CITED REFERENCES

American Society of Civil Engineers (ASCE), 2017 Infrastructure Report Card (released on March 9, 2017), www.infrastructurereportcard.org

ASCE Public Policy Statements, www.asce.org/public_policy_statements/

U.S. Department of Energy, "Hydropower Vision", July 26, 2016

National Hydropower Association, Pumped Storage Development Council, "Challenges and Opportunities for New Pumped Storage Development", 2012

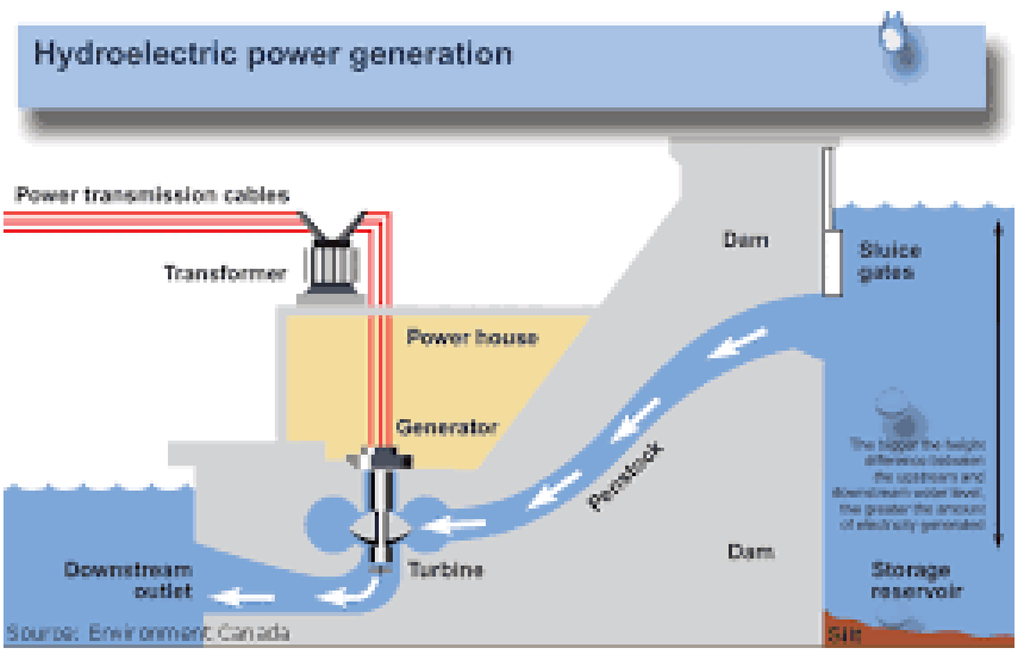
APPENDIX A - DEFINITIONS
The following terms were used herein:

Ancillary Service: services necessary to support the reliable transmission of electric power from seller (e.g., generator) to purchaser (e.g., consumer) in specific control areas of the interconnected transmission system. Examples include frequency regulation.

Capacity: the nameplate generation possible at a hydropower facility when design water flow and equipment are fully available, expressed in kilowatts (kW), megawatts (MW, or 1,000kW), or gigawatts (GW, or 1,000 MW).

Conventional hydropower: a combination of dam-based, canal/conduit, and run-of-river generating plant designs. These are typically divided into capacity classes: large (> 30 MW), small (between 1 and 30 MW), low power (between 100 kilowatts and 1 MW), and micro (< 100 kilowatts) generation.

Dam-based hydropower: a generating plant derives power from passage of water stored behind a dam placed in flowing water (impoundment or headrace) which creates hydraulic head, that can be focused through turbine generation with discharge into a flowing body of water or pond (tail race) downstream.



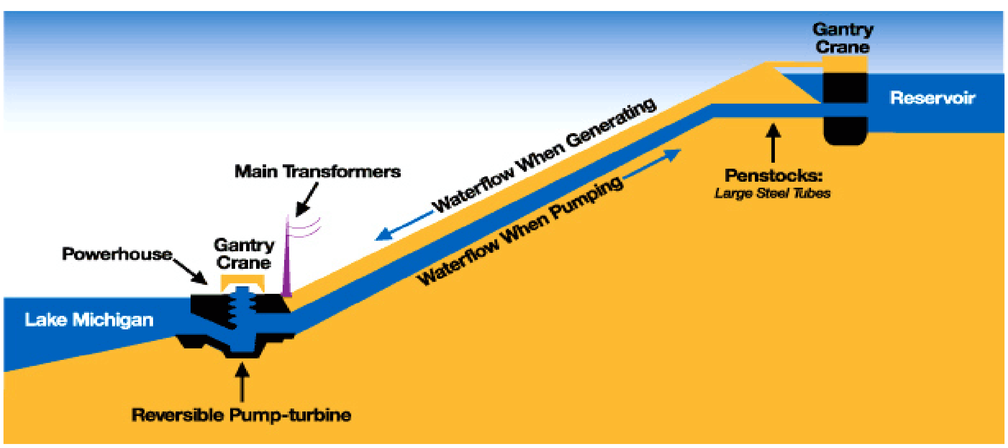
Graphic courtesy of U.S. Geological Service

Energy: actual generation produced by a hydropower facility over time (kW produced in one hour or kWh, typically aggregated over one year.

Hydrokinetic power: a generating plant that harnesses the kinetic energy stored in the form of wave action, tidal motion, or water body flow typically using technologies that differ from conventional hydroelectric turbine generator sets. Hydrokinetic resources tend to be of the small or micro scale at present.

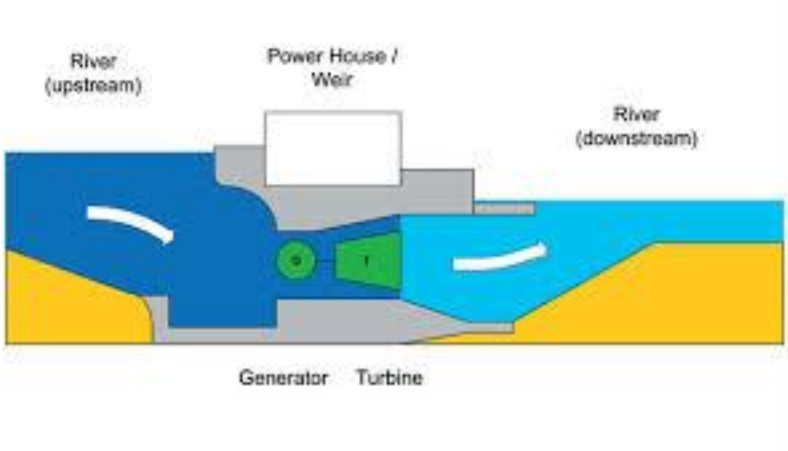

Photos courtesy of Ocean Leadership (tidal turbines)

Pumped storage hydropower (PSH): a generating plant that employs either combination pump/turbine generators or separate equipment to capture water during periods of low demand and cost from one water body and elevate such to a dedicated upper water body (storage) where, upon need for electricity it flows via gravity down through the turbine generator to the original body of water. An open loop involves a continuously flowing water body whereas a closed loop involves discrete water bodies (such as a lake and dedicated storage pond). The closed loop Ludington Plant in Michigan will soon possess over 2,000 MW of generating capacity.



Source: Consumers Energy Company

Run-of-River hydropower: a generating plant that derives its power directly from the flow of water passing through or over a turbine generator.



Graphic courtesy of Basic Mechanical Concepts

U.S. House of Representatives
Energy and Commerce Committee, Subcommittee on Energy
"Modernizing Energy Infrastructure: Challenges and Opportunities to Expanding Hydropower Generation"

EXECUTIVE SUMMARY – Testimony of the American Society of Civil Engineers (ASCE)

- ASCE's *2017 Report Card for Infrastructure* graded the nation's dams a "**D"** and energy infrastructure a **"D+"** in terms of capacity, condition, resilience, and funding. Public/private investment needed in all energy systems, including hydropower and associated transmission and distribution (T&D).

- Dam safety programs need full funding; our nation's dams provide power generation, flood control, water supply, irrigation, recreation, navigation, and environmental protection; over 85% will be 50 years old by 2020. Rehabilitation to meet safety, changing demands, and to protect downstream development should not be deferred.

- Prudent investment in hydropower reduces dependency on other sources, offers flexible and renewable generation with low air emissions, and supports economic growth and national security. U.S. DOE's Energy Hydropower Vision details opportunities for hydropower expansion.

- Technologies which enhance fish/habitat survival, maximize water use efficiency, and improve discharge water quality should be tapped to minimize environmental impact.

- Research to reduce capital cost, improve efficiency, and lower aquatic impacts (DOE's HydroNEXT initiative) recommended, but must lead to industry improvements.

- Few hydropower facilities have failed in the U.S., but age and climate change increase stresses. Continued updating of emergency action plans (EAPs) by licensees, coupled with inspections, updating design bases, and use of remote monitoring (e.g., drones, GIS, performance-based sensors) technology are encouraged.

- Privatization of select federally owned dams should be studied, particularly in locales where local private owners or municipalities are in the best position to maintain them or where non-power dams can be enhanced with hydropower or hydrokinetic addition.

- Legislation that purely focuses on improving hydropower licensing/regulation and adds certainty to permit/approval timelines is needed; current permit/licensing challenges inhibit inclusion of hydroelectric projects in integrated resource planning.

- A national energy policy that anticipates future energy needs, promotes development of clean/renewable energy supply such as hydropower, increases energy efficiency, and reduces dependency on foreign sources will enable prudent investment.