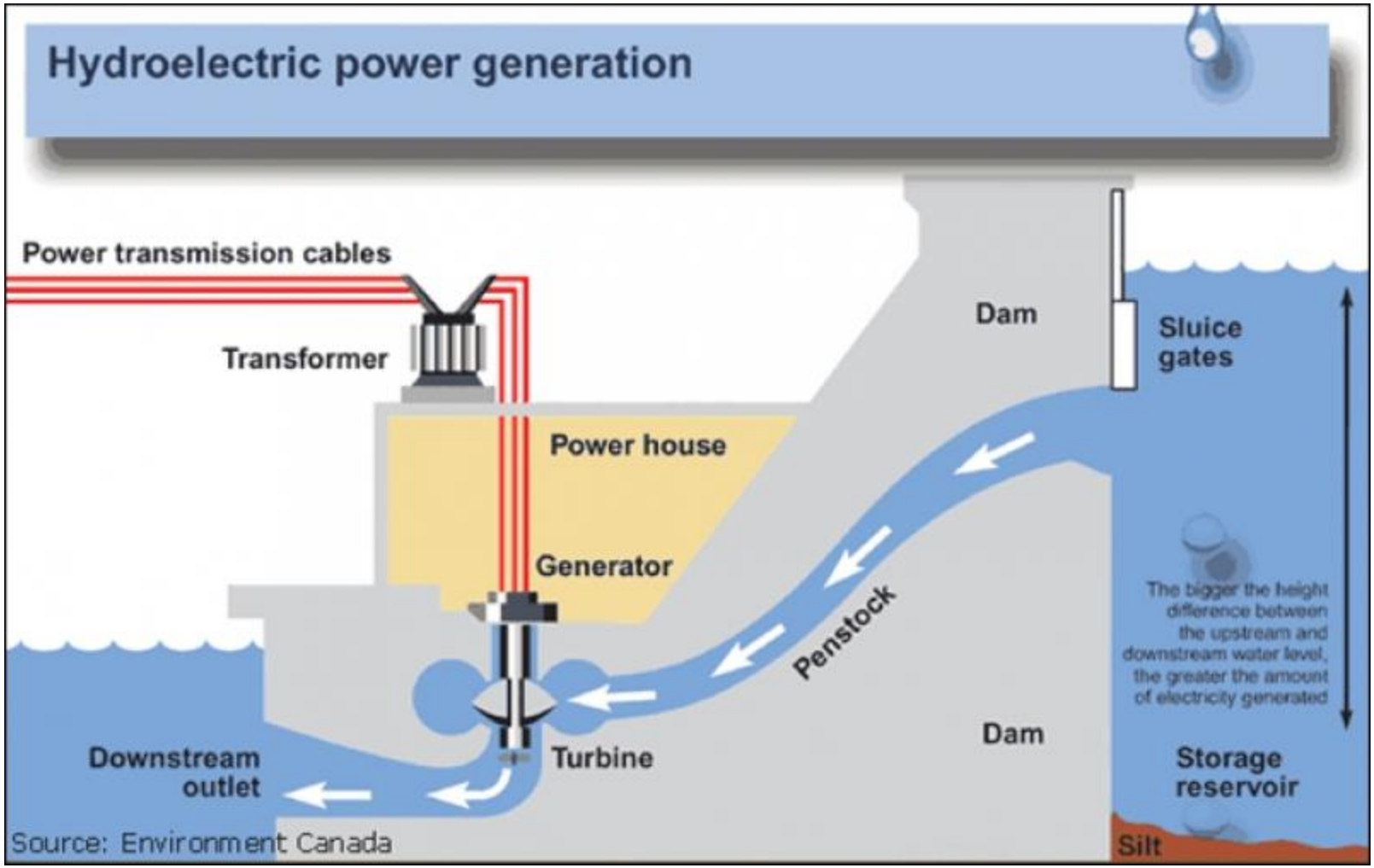
NARUC

Winter Committee Meetings

Committee On Water

Hydropower


Hydroelectric power generation
Power transmission cables
Transformer
Power house
Generator
Penstock
Turbine
Downstream outlet
Dam
Sluice gates
Dam
The bigger the height difference between the upstream and downstream water level, the greater the amount of electricity generated
Storage reservoir
Silt
Source: Environment Canada

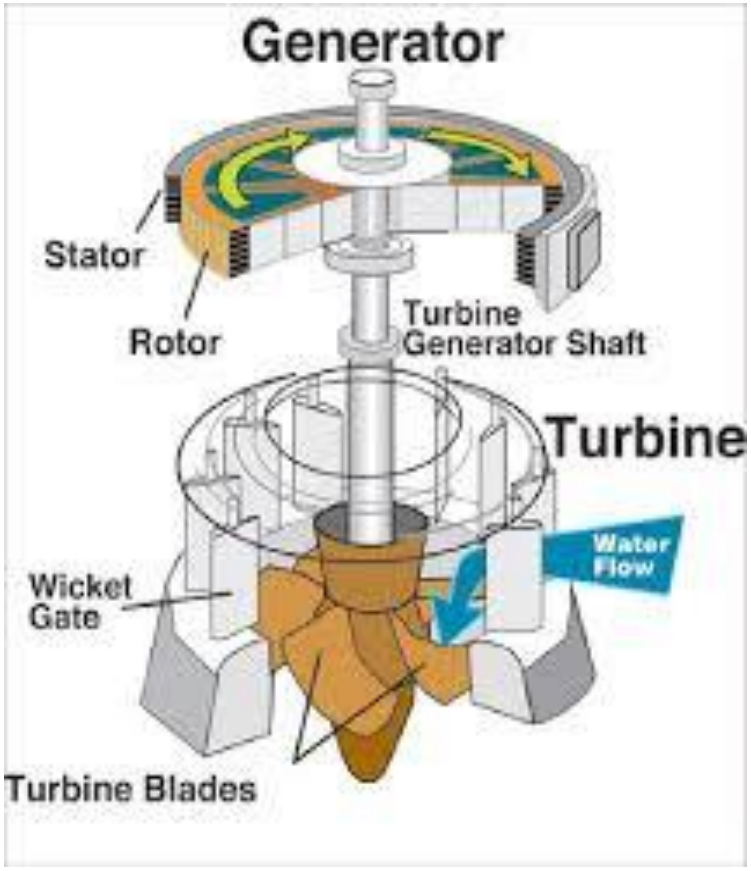
Types of **Hydropower** Projects

- Impoundment
- Diversion (run of river)
- Pumped Storage

Turbine Types

Impulse – high head, lower flow
-- Pelton

Reaction – higher flow, lower head
-- Bulb (turbine and generator)
-- Propeller
-- Francis



Examples of Hydropower installations

Smith Mountain

Niagara

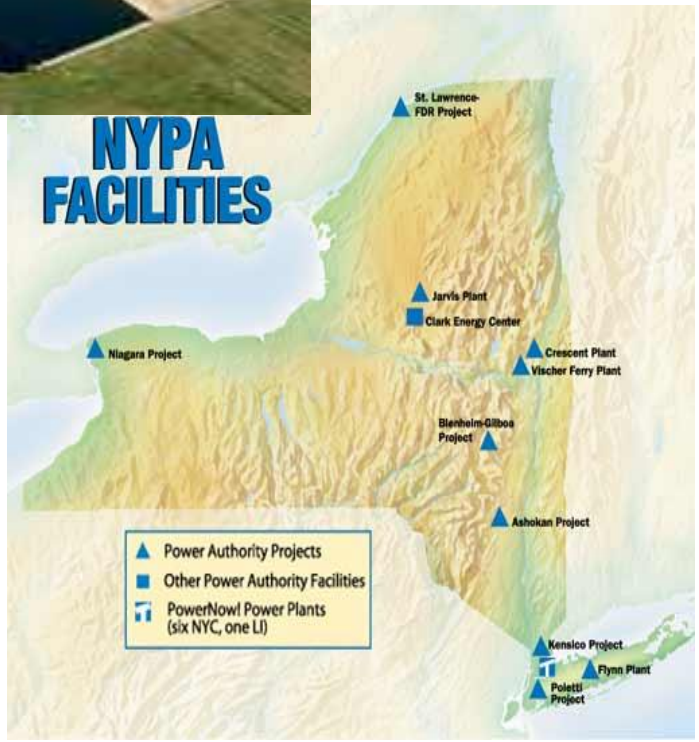
St. Lawrence

Blenheim Gilboa

Ashokan

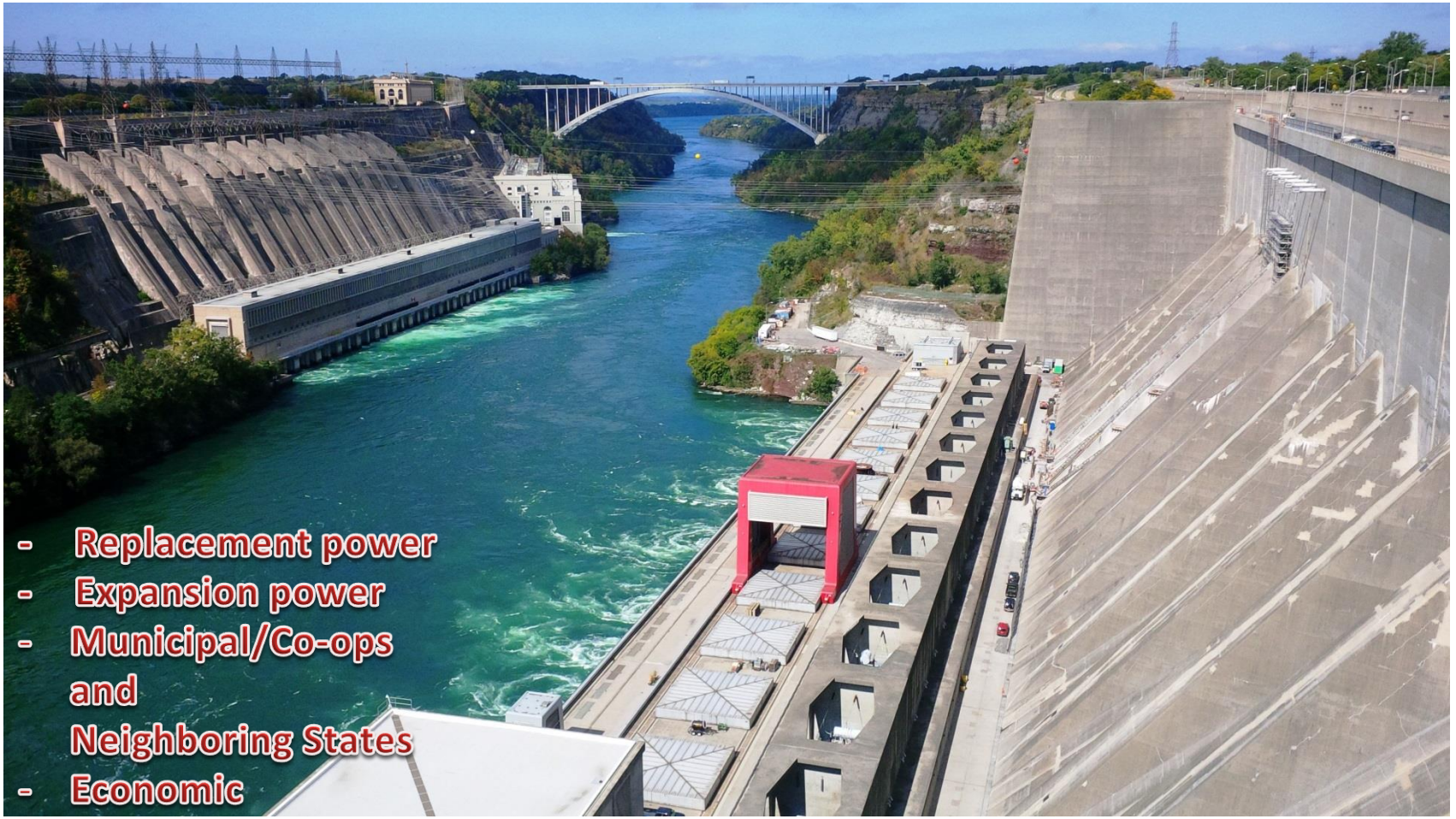
Small Hydro Applications

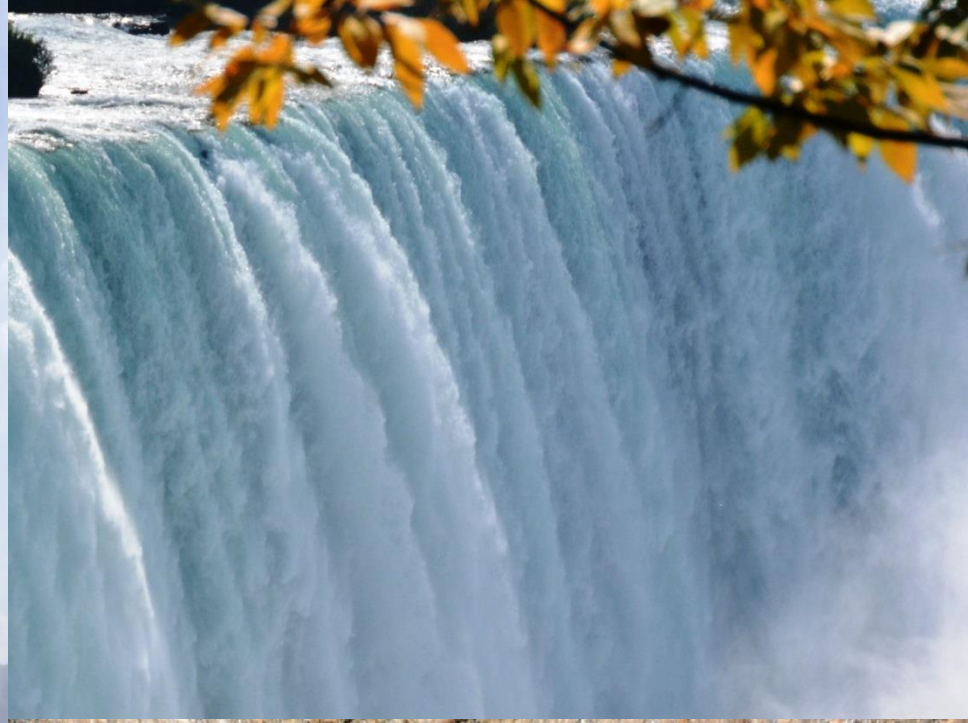
Water Systems



Locks

Power Contracts (NYS)






NIKOLA TESLA
INVENTOR
1856–1943
The St. George Serbian Orthodox Church, Niagara Falls,
in partnership with The Niagara Parks Commission,
have erected this monument to Nikola Tesla.
Physicist, inventor, electrical engineer. Tesla developed
the world's first hydroelectric power system
used here at Niagara Falls.

Hydropower

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National Association of Regulatory Utility Commissioners

Hydropower Vision Briefing

February 14, 2017

Timothy J. Welch

Hydropower Program Manager

Water Power Technologies Office

U.S. Hydropower
At a Glance

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

101 GW

U.S. INSTALLED CAPACITY

Hydropower Generation and

Pumped Storage Hydropower

6.2%

U.S. ELECTRICITY GENERATION

2015

48%

U.S. RENEWABLE GENERATION

2015

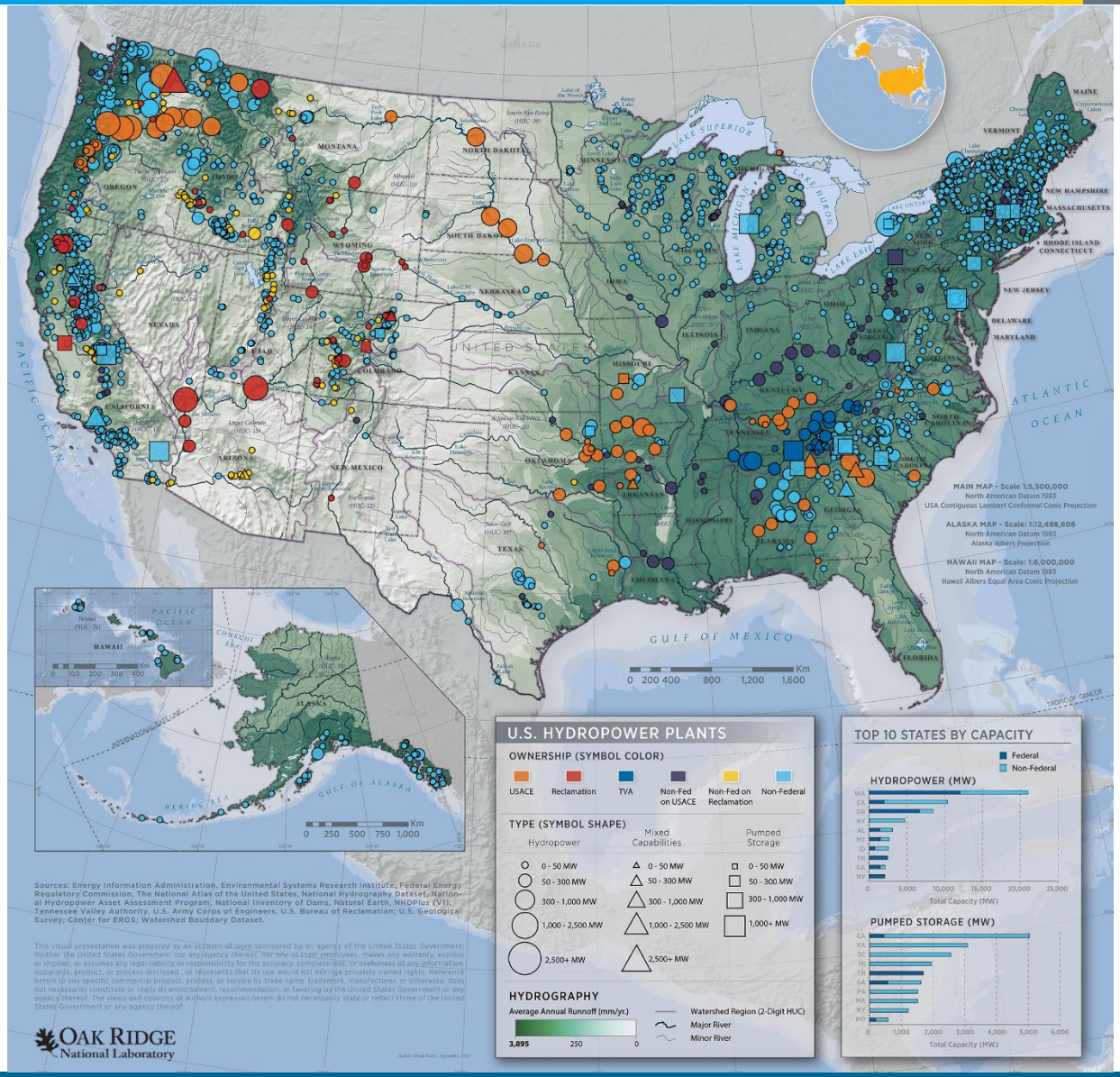
Provides

87,000

U.S. JOBS

U.S. Hydropower
Current State of the Industry

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

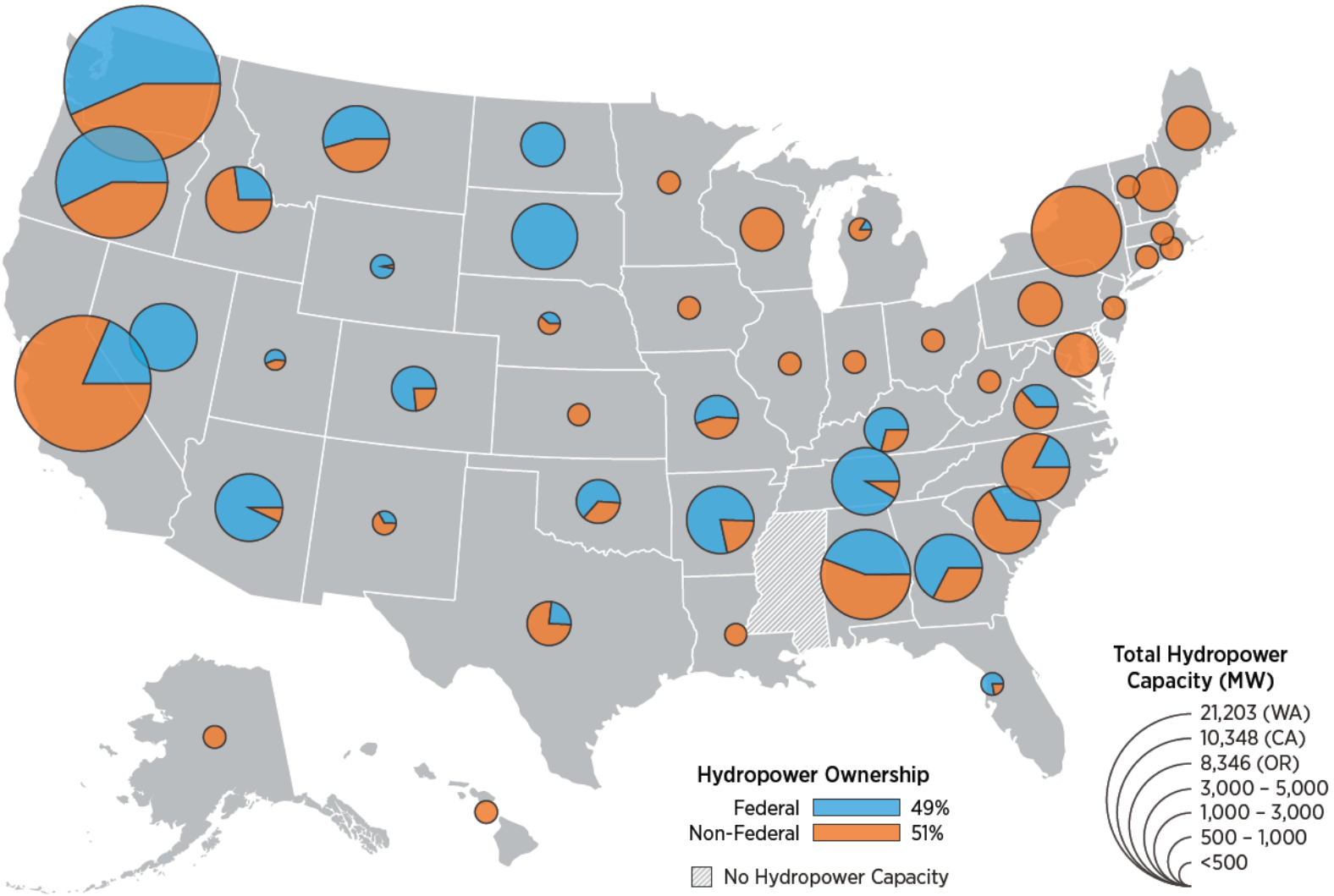


Hydropower is currently the largest renewable resource in the United States, providing energy storage and essential services to the electric grid.

While development has been slower in recent decades, nearly 1.5 GW of capacity were added in the last decade.

With innovation, nearly 50 GW of new hydropower and pumped storage hydropower (PSH) could be developed

U.S. Hydropower
Federal and Non-federal



Vision: Promote environmentally-sustainable hydropower and pumped storage growth through development of transformative technologies and approaches for generating clean, cost-effective hydroelectric energy, while ensuring energy security through a reliable grid, and enabling the integration of other renewables.

Our Role in Hydropower

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Funding and New Technology Development

- Develop critical technologies to support the current infrastructure and address market risks to **drive down development costs** for new hydropower.
- Evaluate **innovative pumped-storage hydropower** system designs that exhibit cost competitiveness with broader, more acceptable siting opportunities.

Market Acceleration and Deployment

- Address **environmental and regulatory barriers** that prevent significant amounts of new deployment.
- Assess and **quantify the value of hydropower** to the nation's electric grid and develop a **vibrant U.S. hydropower workforce**.

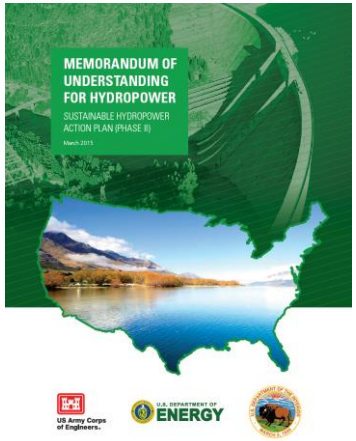
Stakeholder Coordination

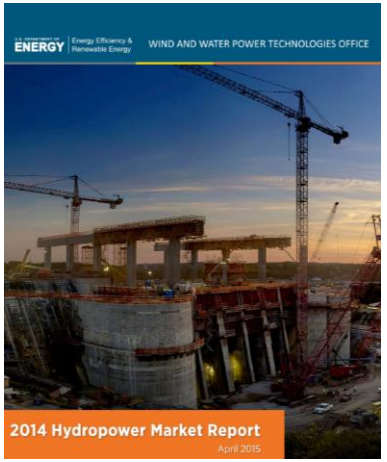
- Support **collaborative interagency efforts** with the U.S. Army Corps of Engineers and the Bureau of Reclamation.
- Coordinate with hydropower industry to investigate a framework for reliability and cost impacts of operational changes and technology deployments, and **optimize water use at existing hydropower plants**.

Hydropower Program
Recent Accomplishments

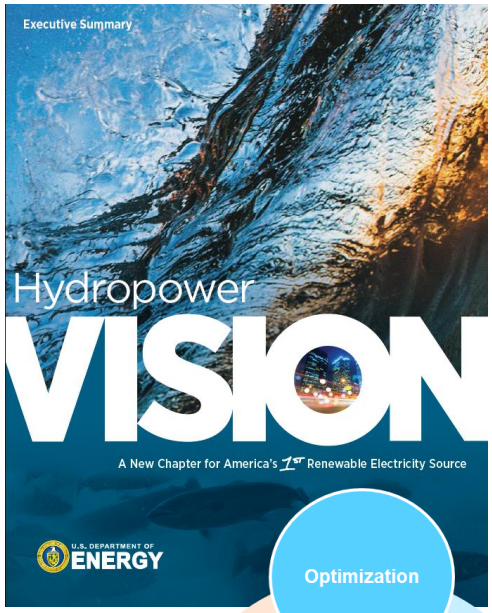
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

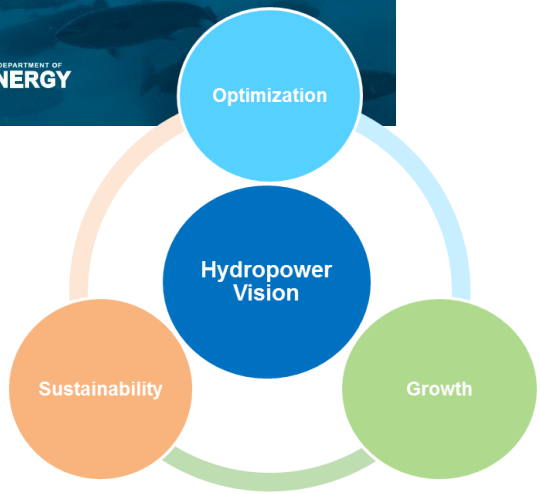
- **March 2015:** Renewed **Hydropower MOU** with Dept. of Interior and Corps of Engineers to support sustainable hydropower and federal facilities
- **April 2015:** Released the first-ever **Hydropower Market Report** to quantify the current size, scope, and variability of our nation's hydropower supplies
- **September 2015:** competitively awarded **$6.5 million** to seven organizations to advance the **manufacturing and installation of low-environmental-impact hydropower technologies**
- **July 2016:** facilitated an agreement between the Federal Energy Regulatory Commission and the Corps of Engineers, **to streamline hydropower project permitting**
- **July 2016:** Published a long-range national ***Hydropower Vision*** to establish the analytical basis for a new era of growth in sustainable domestic hydropower over the next half century.





- *Hydropower Vision* is a bottom-up analysis applying **economic, technical, and sustainability criteria** to look at the potential for innovation and growth in hydropower generation and storage through **2050**.
- *Hydropower Vision* established in collaboration with key stakeholders (**300 experts from over 150 organizations**), representing Government, NGO's, Researchers and Industry.
- **Includes a detailed roadmap** developed with 5 critical action areas and a set of 64 detailed actions needed to support scenarios.





***Hydropower Vision: A New Chapter for America's First Renewable Electricity Source* released July 26, 2016**

Hydropower Vision: Report Objectives

The Hydropower Vision Report:

1. Documents the **state of the industry**, including benefits realized to date;
2. Presents **modeled reference scenarios** and related sensitivity ranges to analyze the **long-term economic competitiveness** of hydropower and the feasibility of growth through 2030 and 2050;
3. Evaluates **costs and benefits** to the nation that could be realized through the range of potential scenarios;
4. Recommends a **roadmap of actions** to attain sustainable growth, addressing a range of needs from technology optimization to environmental stewardship.

The Vision Report expressly does not:

- Establish DOE goals for industry growth;
- Encumber or obligate DOE or other agencies; nor
- Recommend policy.

Vision Pillars

The *Hydropower Vision* report is grounded on three equally important foundational pillars arrived at through extensive stakeholder input.

Optimization

Optimize the value and the power generation contribution of the **existing hydropower fleet**.

Growth

Explore the feasibility of **credible long-term deployment** scenarios for responsible hydropower growth.

Sustainability

Ensure that hydropower's contributions toward meeting the nation's energy needs are consistent with **environmental stewardship and responsible water use management**.

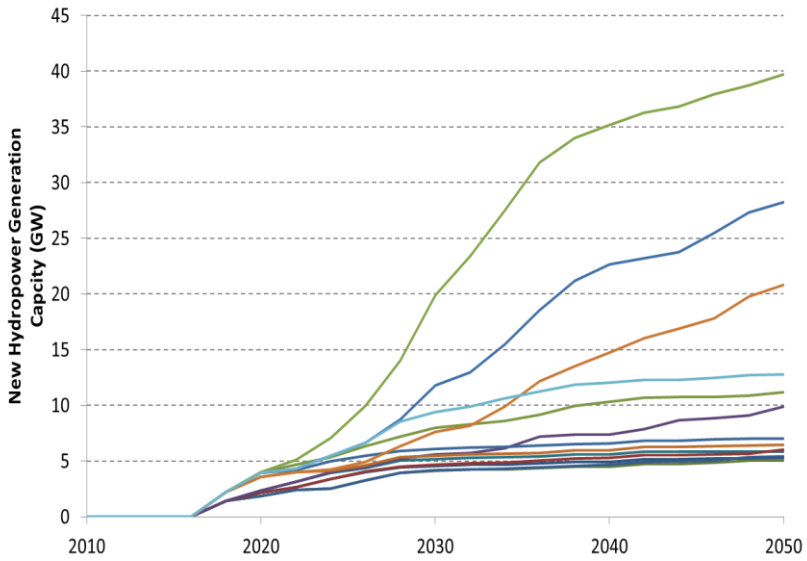
Modeling Hydropower's Contribution and Future Potential

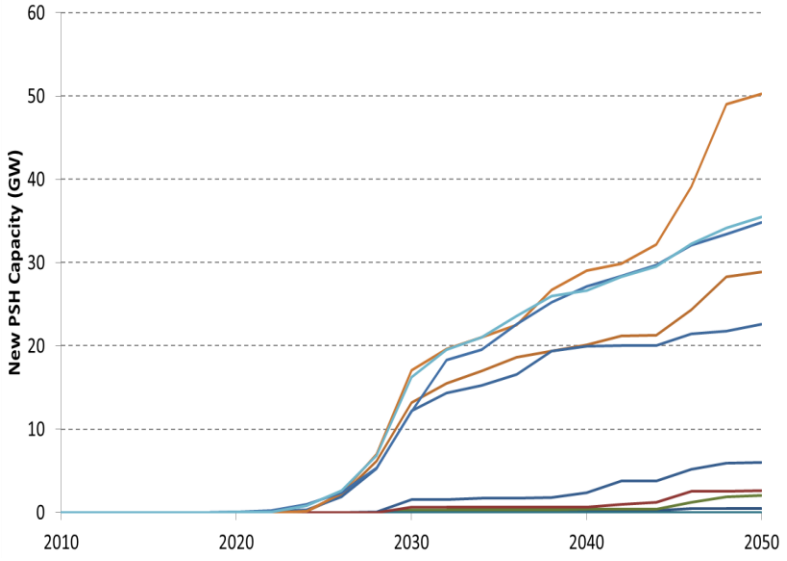
- The primary tool used to assess potential growth trajectories and the basis to evaluate resulting cost and benefit impacts is the National Renewable Energy Laboratory's (NREL's) **Regional Energy Deployment System (ReEDS) model**.

- Hydropower resource opportunities for **potential growth** fall into four distinct categories:
  1. **Upgrades** to existing power plants and dams
  2. New power plants at existing **non-powered dams (NPDs)**
  3. **New stream-reach development (NSD)**
  4. New and existing **pumped-storage hydropower (PSH)**

Modeling Hydropower's Contribution and Future Potential

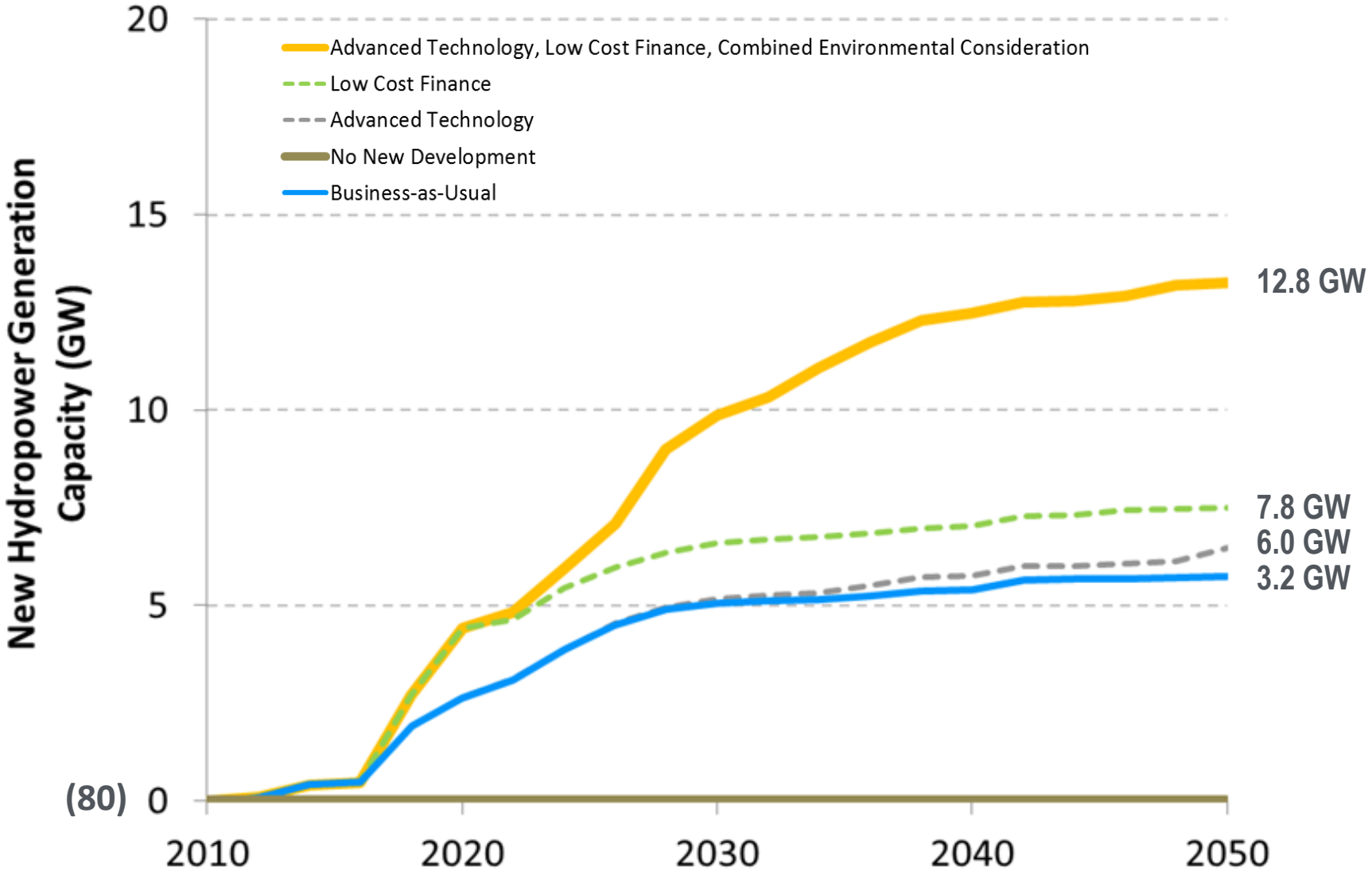
- More than **50 total hydropower deployment scenarios** were evaluated by varying hydropower-specific parameters as well as broader non-hydropower specific parameters





- The *Hydropower Vision* analysis found that the **key drivers** influencing deployment of new hydropower capacity were:
  - **Technology innovation** to reduce cost
  - Improved **financing** that **values the long asset life** of hydropower facilities
  - The concurrent influence of several **environmental considerations**

Hydropower Deployment: Selected Scenario to 2050



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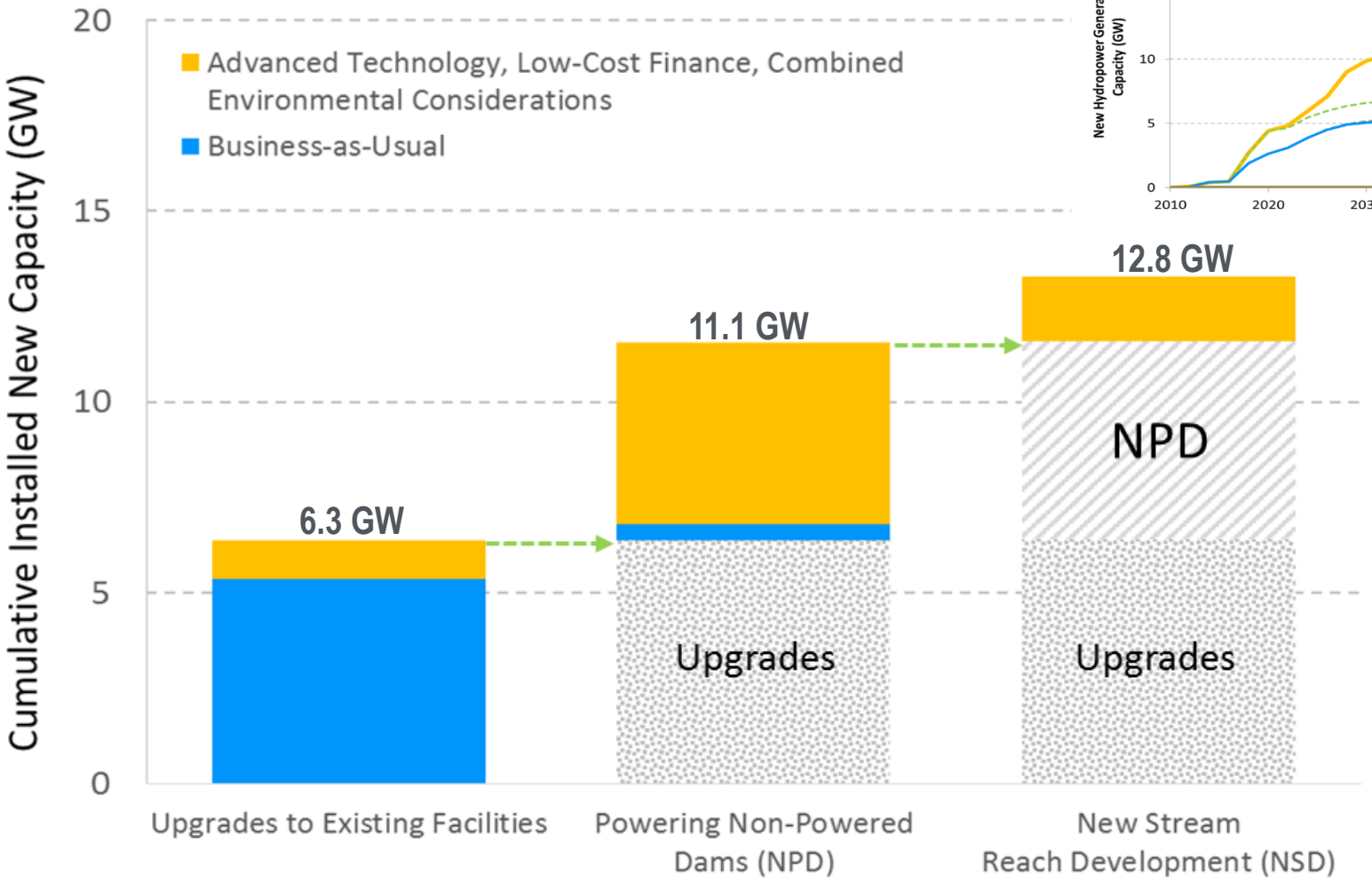
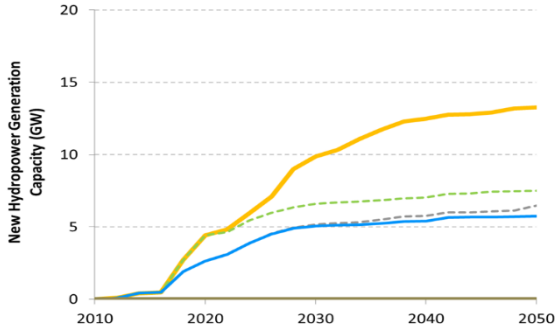
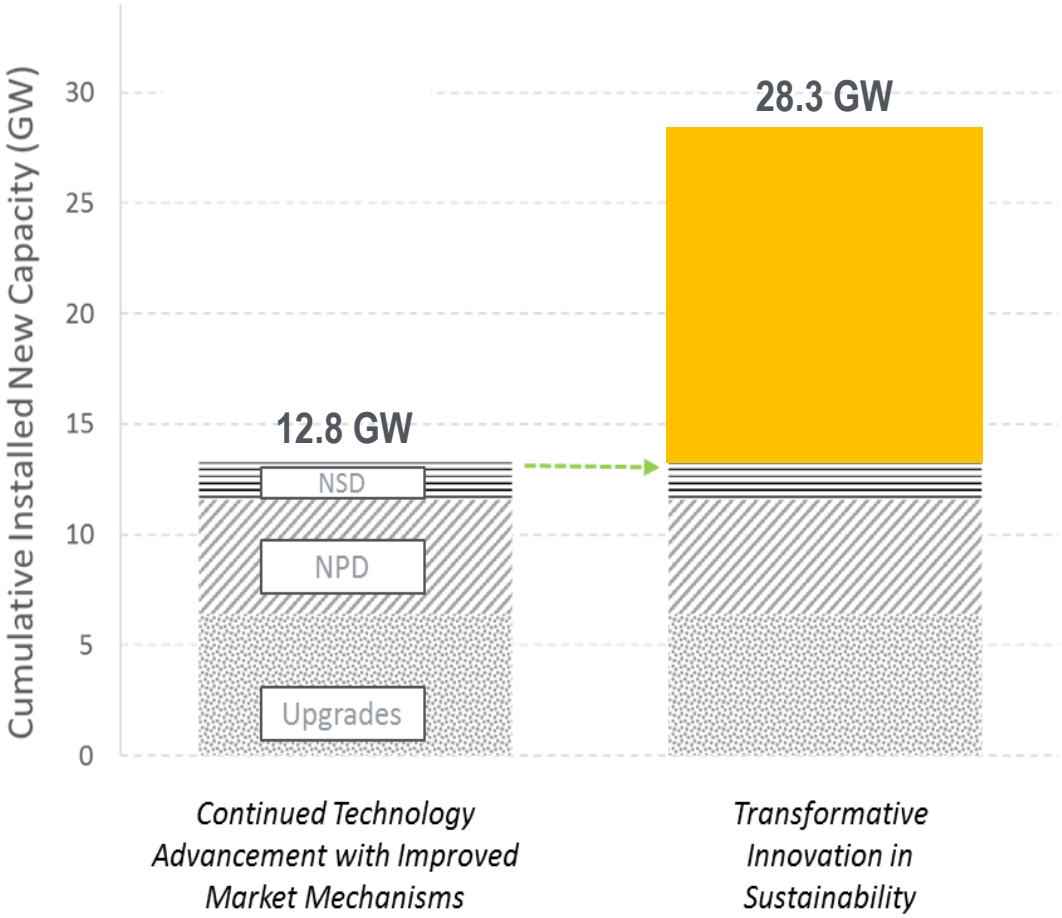
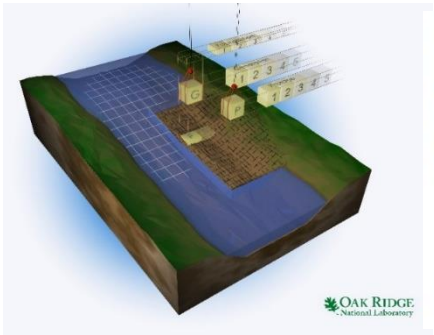


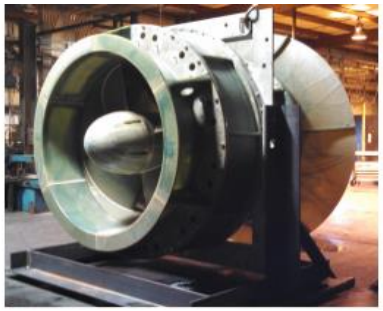


Additional New Stream Reach Development: National Sustainability Challenge

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



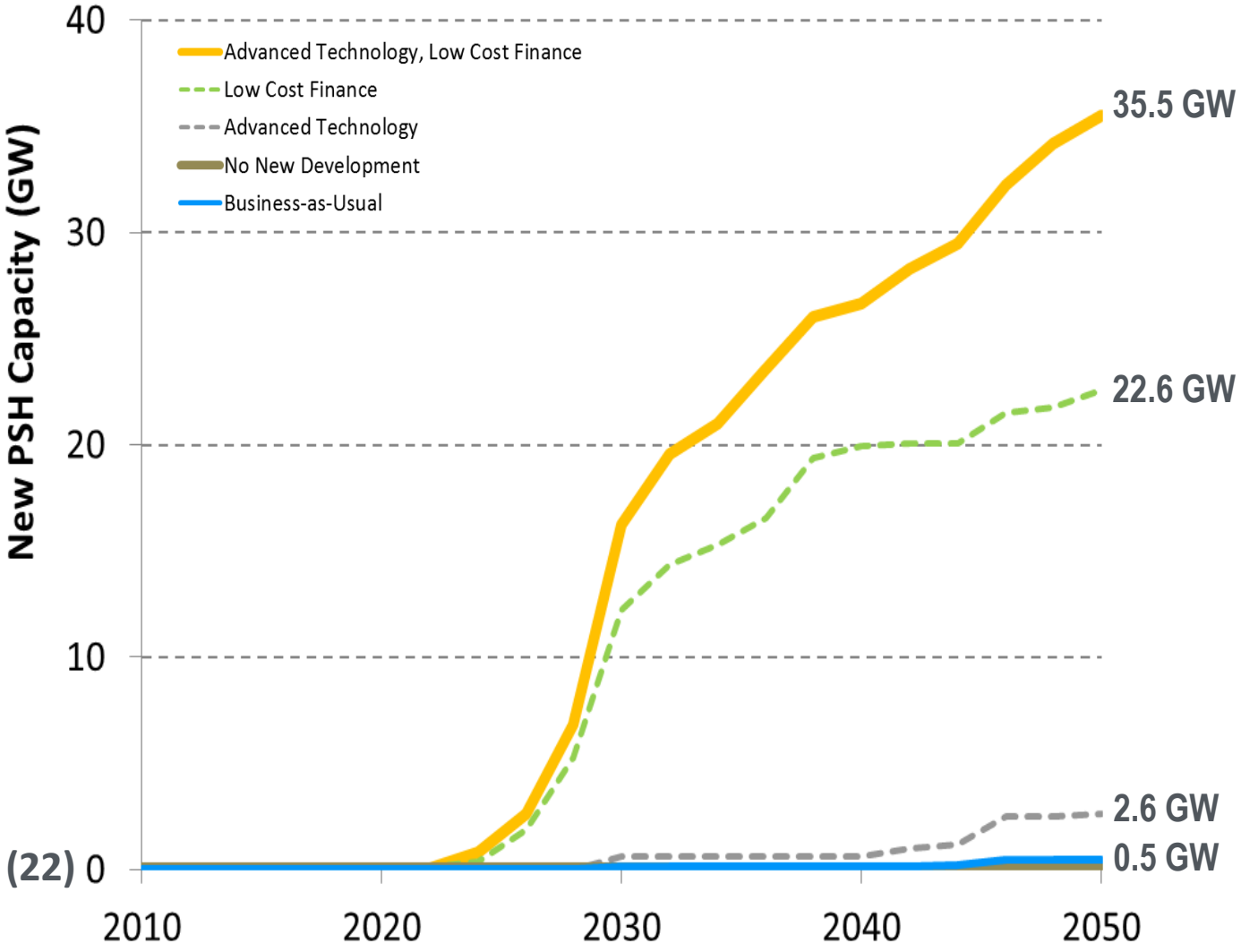




Innovative designs and cost reductions are needed

Up to 15.5 GW of additional new stream-reach development is contingent on transformational innovations - performance and environmental

Pumped Storage Deployment: Selected Scenario to 2050



Under the scenario combining *Advanced Technology and Low-Cost Finance,* **35.5 GW of new PSH capacity** deployment occurs by **2050.**

DOE Hydropower Vision
Key Takeaways

- Hydropower can provide **system benefits** and **enable growth** in variable generation.
- PSH is the **lowest cost grid storage** option currently available.
- Existing and new hydropower will continue hydropower's role in **energy security** by maintaining **grid stability.**
- Optimizing and expanding existing and new hydropower by 2050 **creates jobs and revitalizes infrastructure**.

	Economic Investment	Air Pollution	Water	Jobs
Existing Fleet and New Capacity Additions Combined (149.5 GW)	$148 billion in cumulative economic investment[d] $110 billion for hydropower generation and $38 billion for PSH	$58 billion savings in avoided mortality, morbidity, and economic damages from cumulative reduction in emissions of SO_2, NO_x, and $PM_{2.5}$ 6,700–16,200 premature deaths avoided	Cumulative 30 trillion gallons of water withdrawals avoided for the electric power sector	Over 195,000 hydropower-related gross jobs spread across the nation in 2050

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Public-Private Partnership in Hydropower
Roadmap Actions

The *Hydropower Vision* roadmap identifies a high-level portfolio of new and continued actions and collaborations across many fronts to help the nation realize the significant long-term benefits of hydropower, while protecting the nation's energy, environmental, and economic interests.

The roadmap is the beginning of an **evolving, collaborative, and necessarily dynamic process**.

Six organizations were selected to receive up to $9.8 million to develop innovative technologies that will reduce capital costs and deployment timelines for PSH and non-powered dams.

Pumped-Storage Hydropower

- **Shell Energy North America (US), L.P.** – *Hydro Battery with a Submerged Membrane Storage Reservoir*
- **National Renewable Energy Laboratory** – *Transforming the U.S. Market with a New Application of Ternary-Type Pumped-Storage Hydropower Technology*
- **Obermeyer Hydro Accessories Inc.** – *Cost Effective Small Scale Pumped Storage Configuration*

Non-Powered Dams

- **Natel Energy, Inc.** – *Efficient, Modular Low-Head Linear Pelton Turbine with Simple, Low-Cost Civil Works*
- **Canyon Industries, Inc**. – *Optimization of Archimedes Screw Turbines for use in Hydroelectric Projects*
- **Rickly Hydrological Company, Inc.** – *PROPEL Hydro System*

Thank you!

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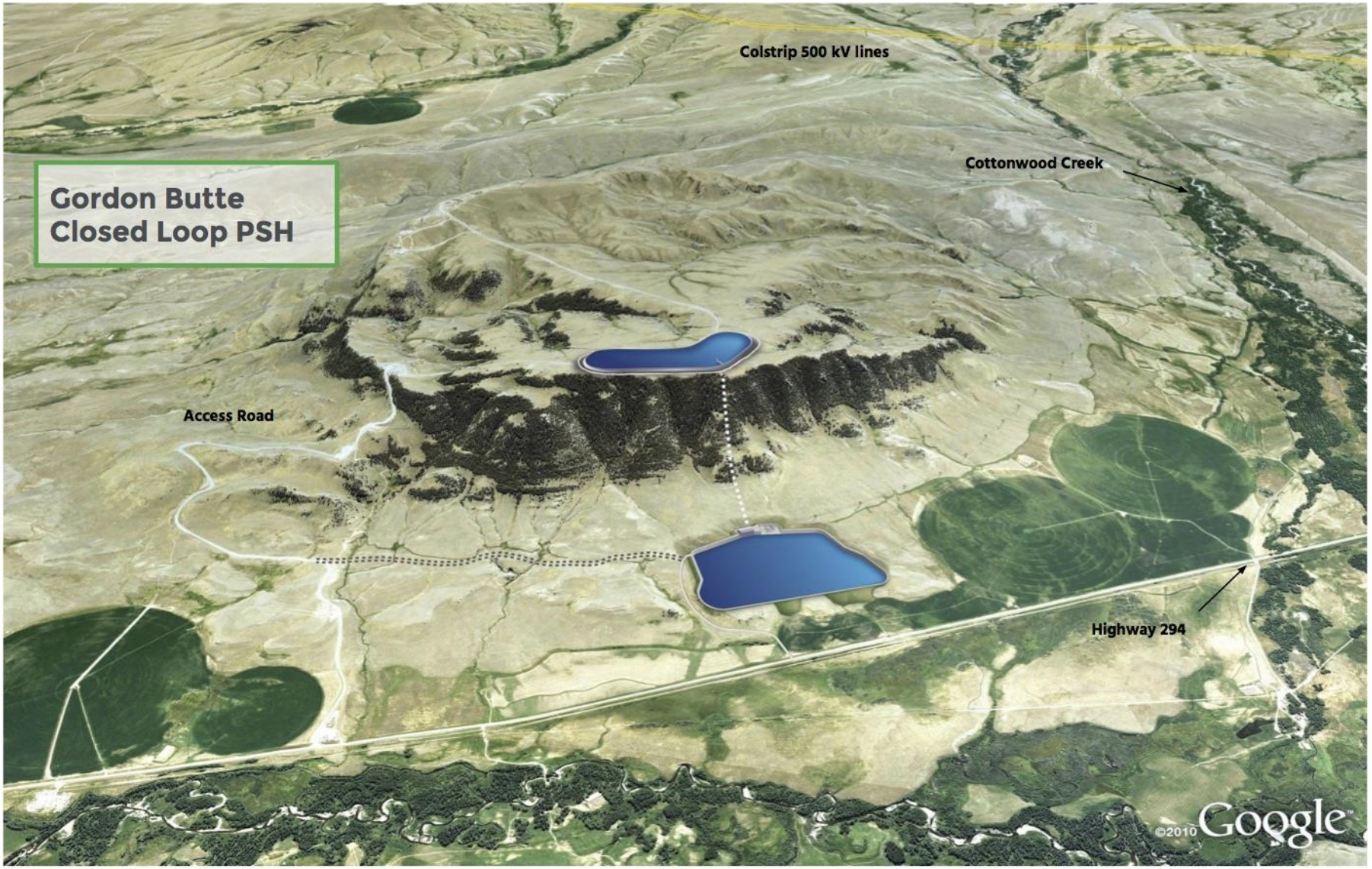
ABSAROKA ENERGY

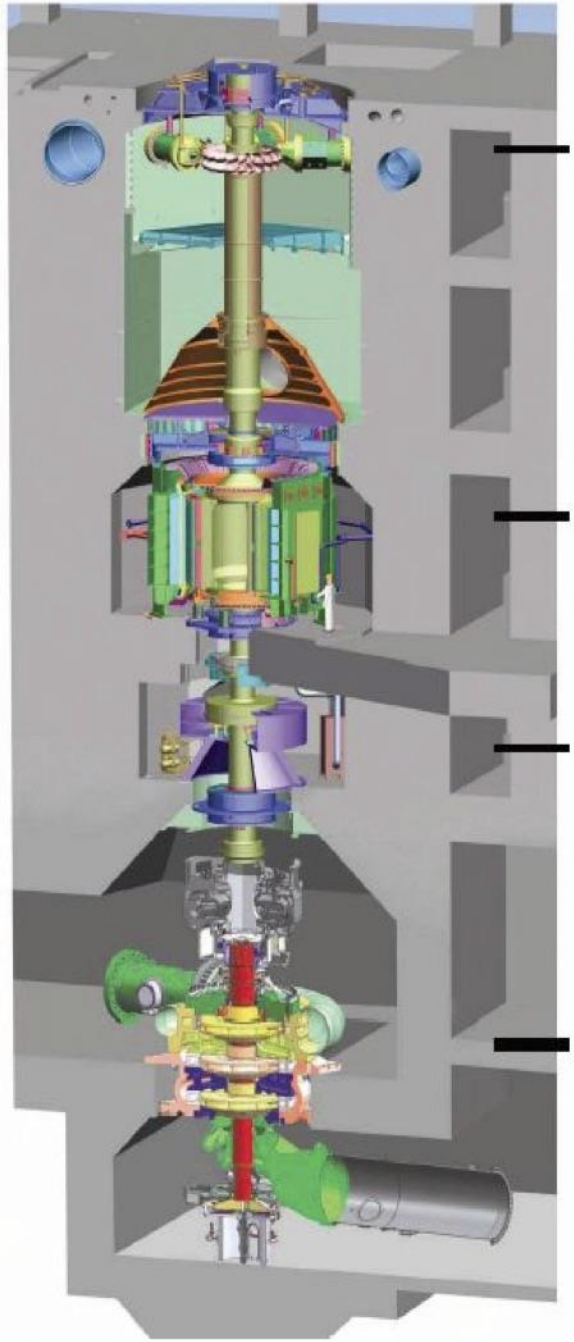
GORDON BUTTE PUMPED STORAGE HYDRO

Chairman Brad Johnson, Montana
Public Service Commission

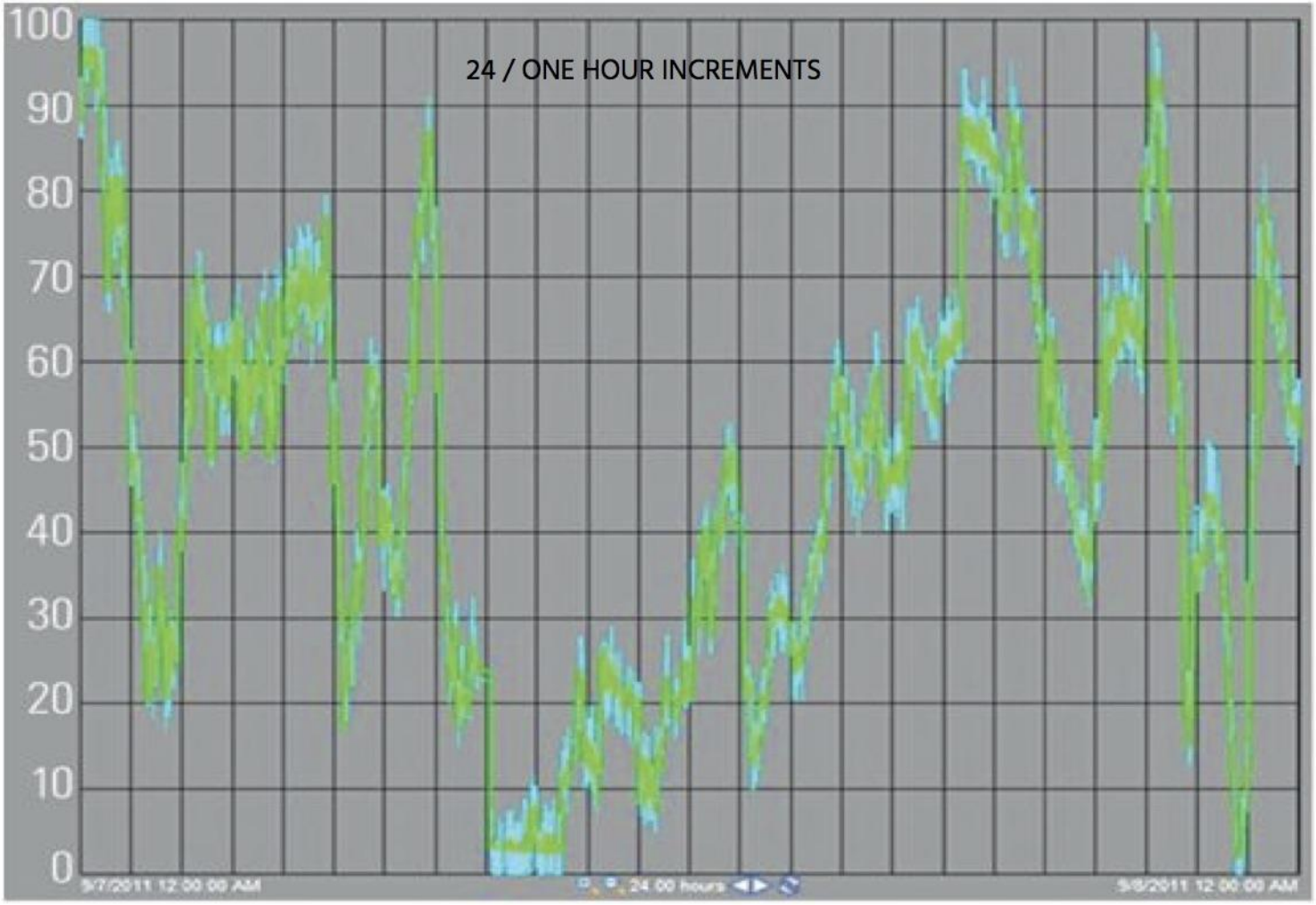

Gordon Butte
Closed Loop PSH
Colstrip 500 kV lines
Cottonwood Creek
Access Road
Highway 294
©2010 Google

Proven Technology

Gordon Butte is modeled/engineered on an existing facility - KOPS II in Austria. KOPS II was commissioned in 2009 and operates the same Ternary PSH units and hydraulic short-circuit configuration planned for Gordon Butte.



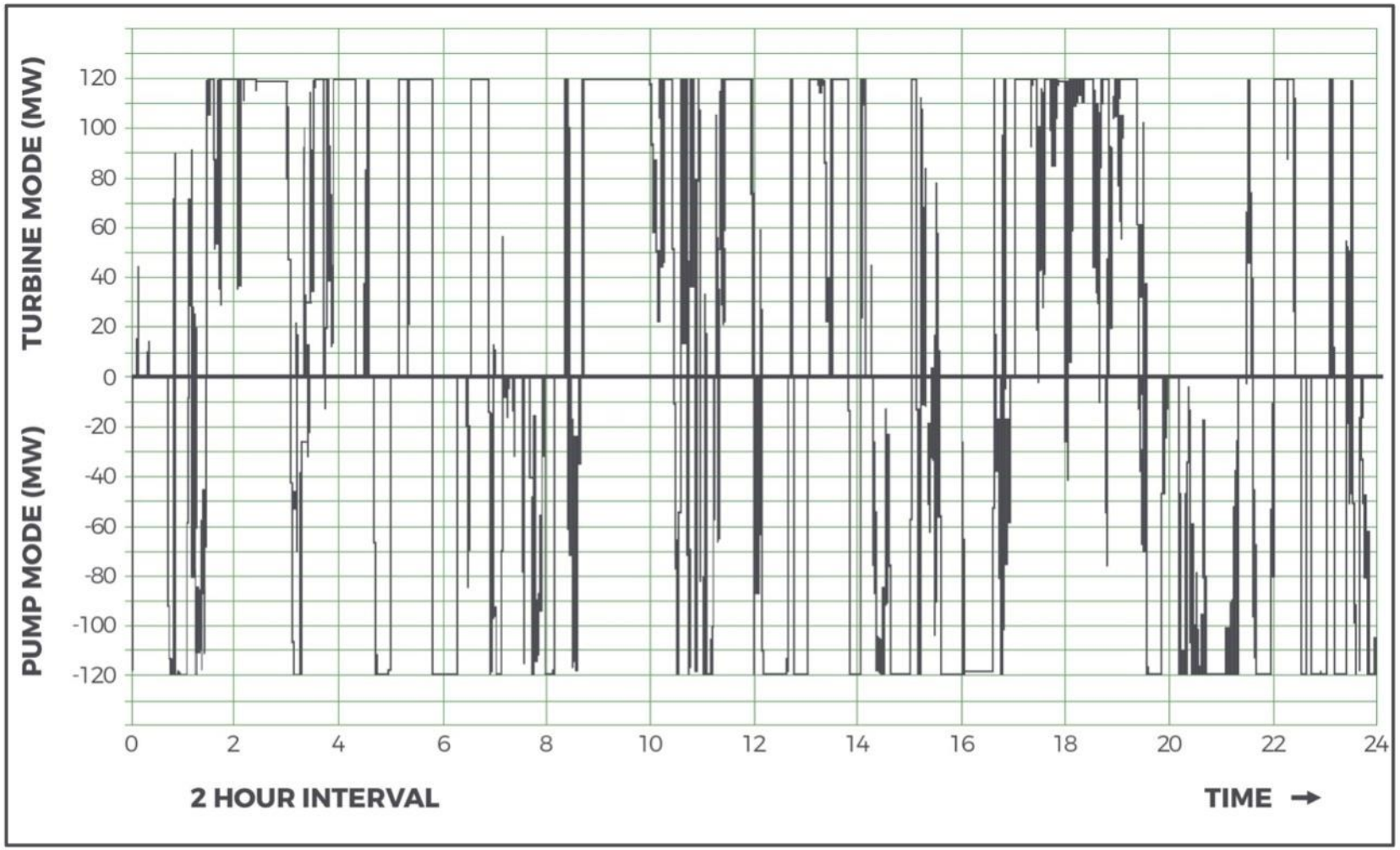
DAVE GATES GENERATING STATION



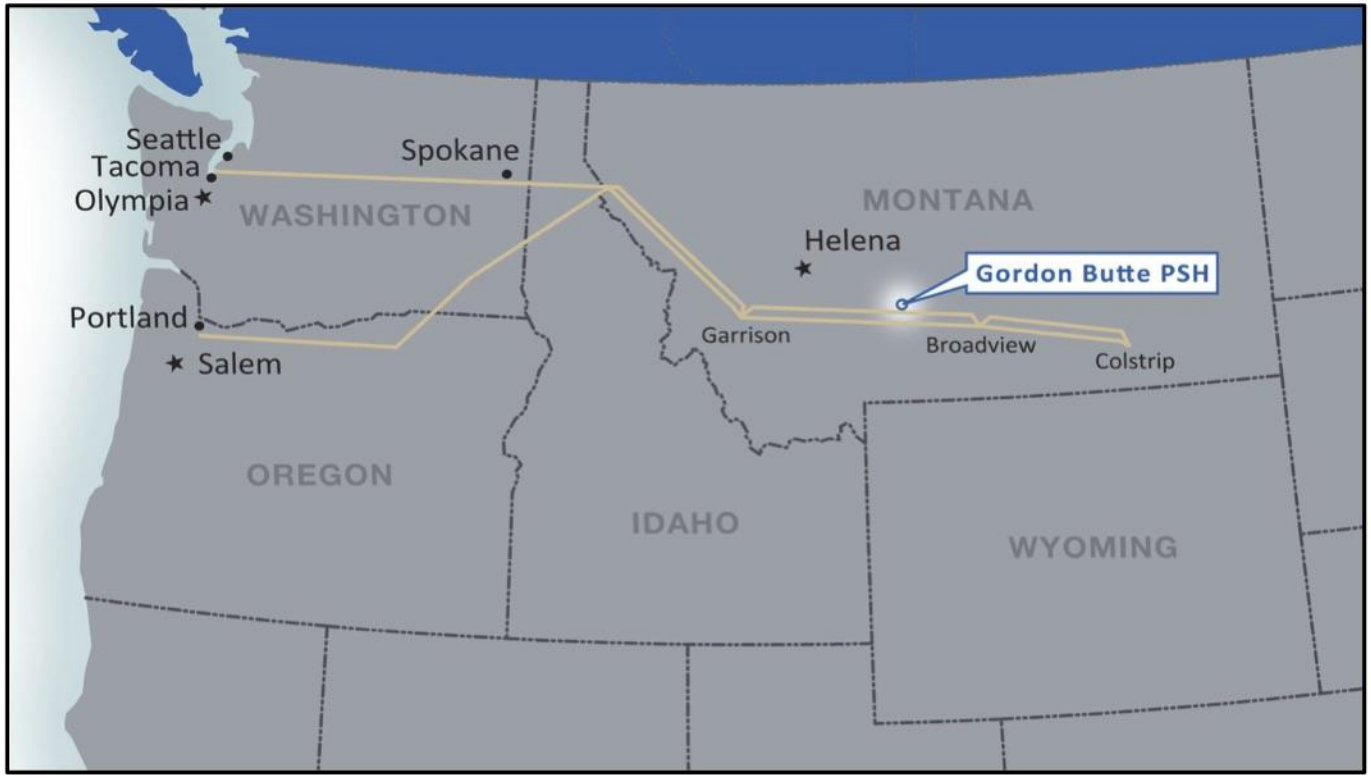
Source: "NorthWestern Energy Builds a Regulating Reserve Plant" December 1, 2011

ULTIMATE FLEXIBLE CAPACITY

PSH can move faster (40 MW/sec) than gas (40 MW/min)



PROJECT LOCATION
(Colstrip System)



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