Water Power Program

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

Quadrennial Technology Review:

Conventional Hydropower and Marine and Hydrokinetics

Jim Ahlgrimm
DOE Wind and Water Power Program

Water Power Program
Funding Profile

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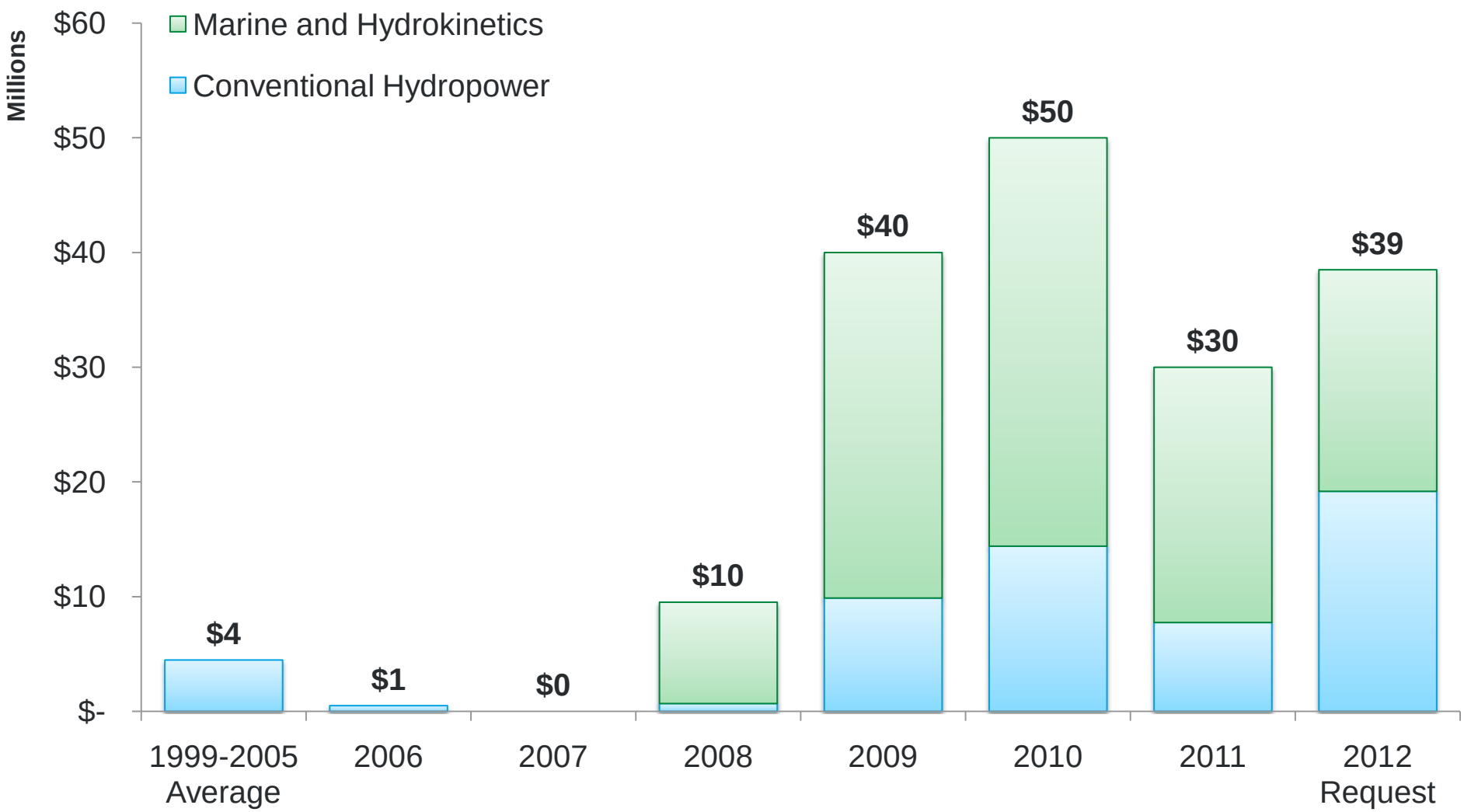
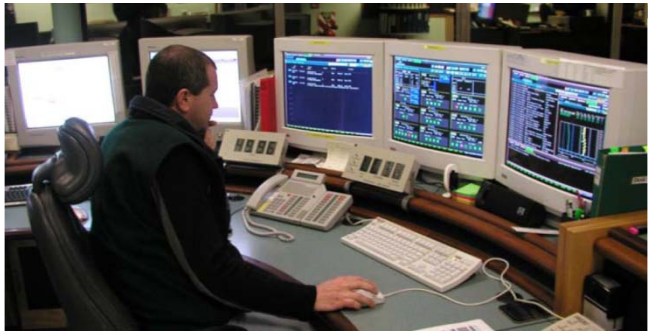
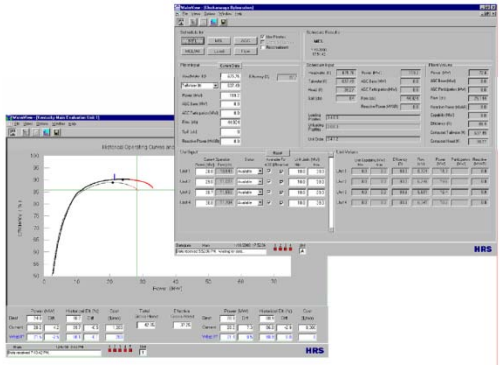


Wind and Water Power Technologies Program

Conventional Hydropower





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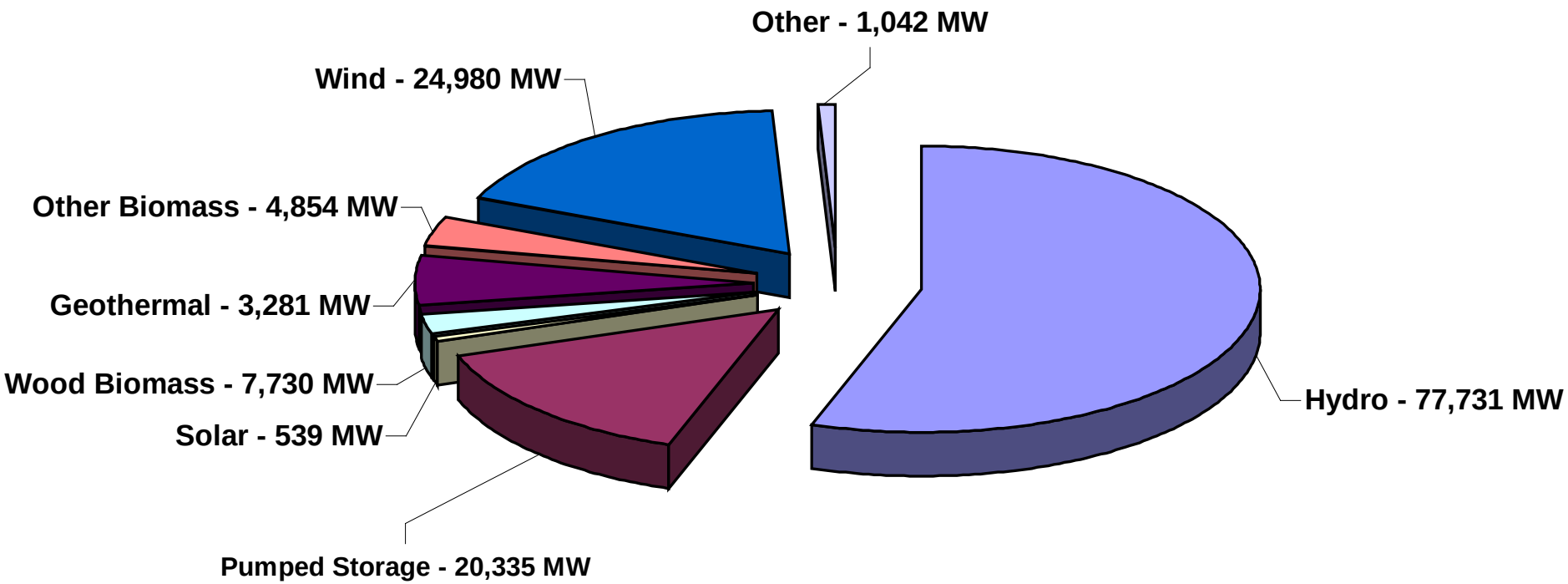
U.S. Installed Renewable Capacity (EIA, 2008*)



*Accessed 6-21-10: http://www.eia.doe.gov/cneaf/electricity/epa/epat1p2.html

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Conventional Hydropower
Installed US Capacity

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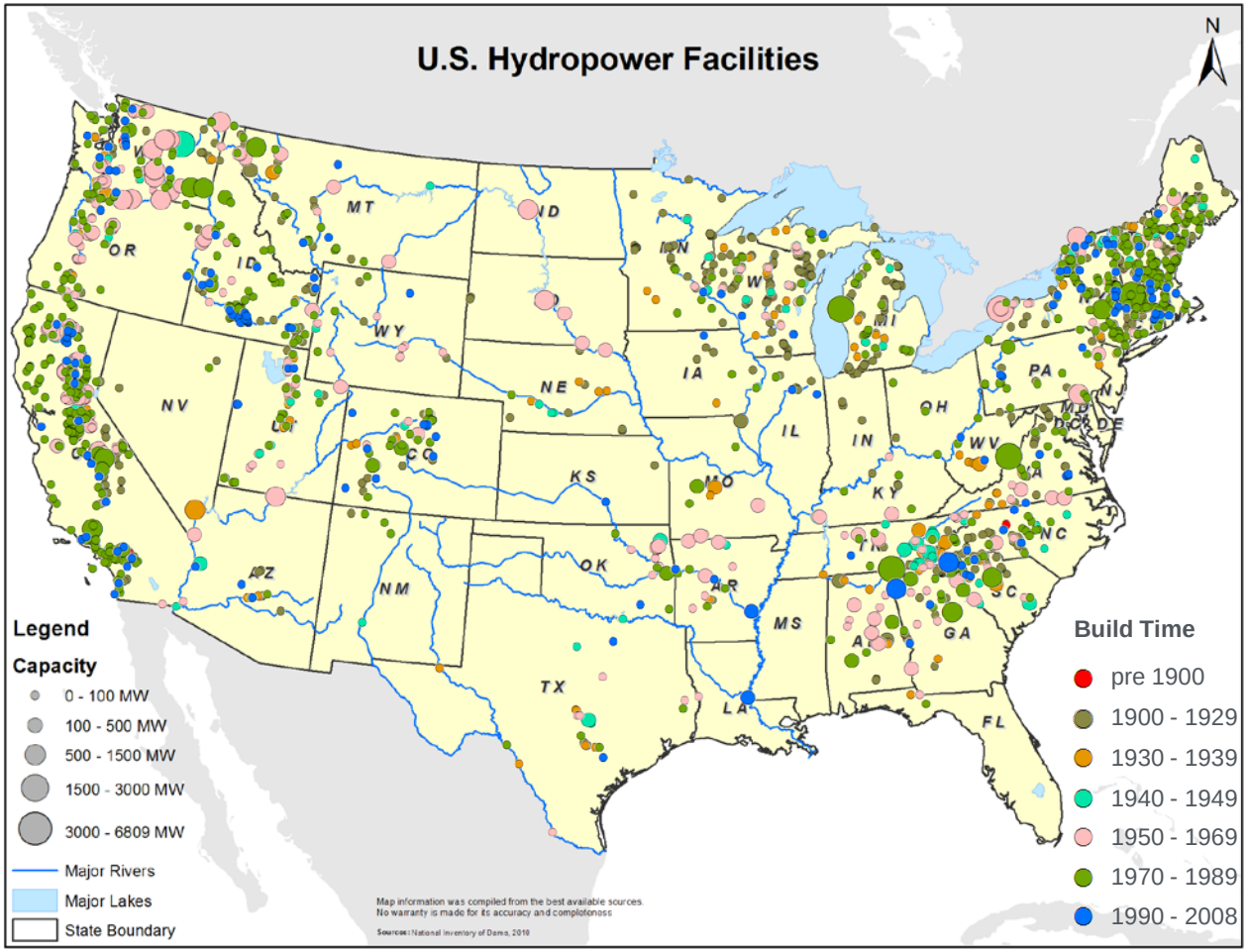

United States:

- 7% of Electric Production in 2009
- 77 GW Conventional Hydropower

Worldwide:

- 16% of Electric Production
- 723 GW

Hydropower is currently the nation's largest source of renewable energy, comprising 70% of all renewable capacity.

Conventional Hydropower
Status of the Existing Fleet

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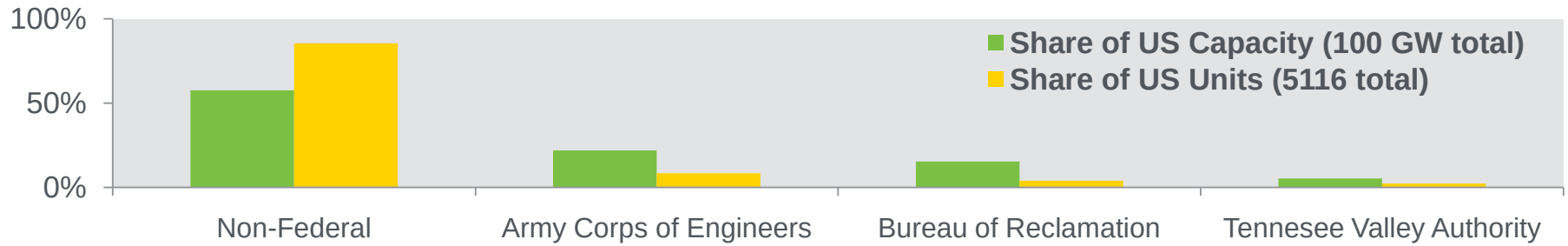
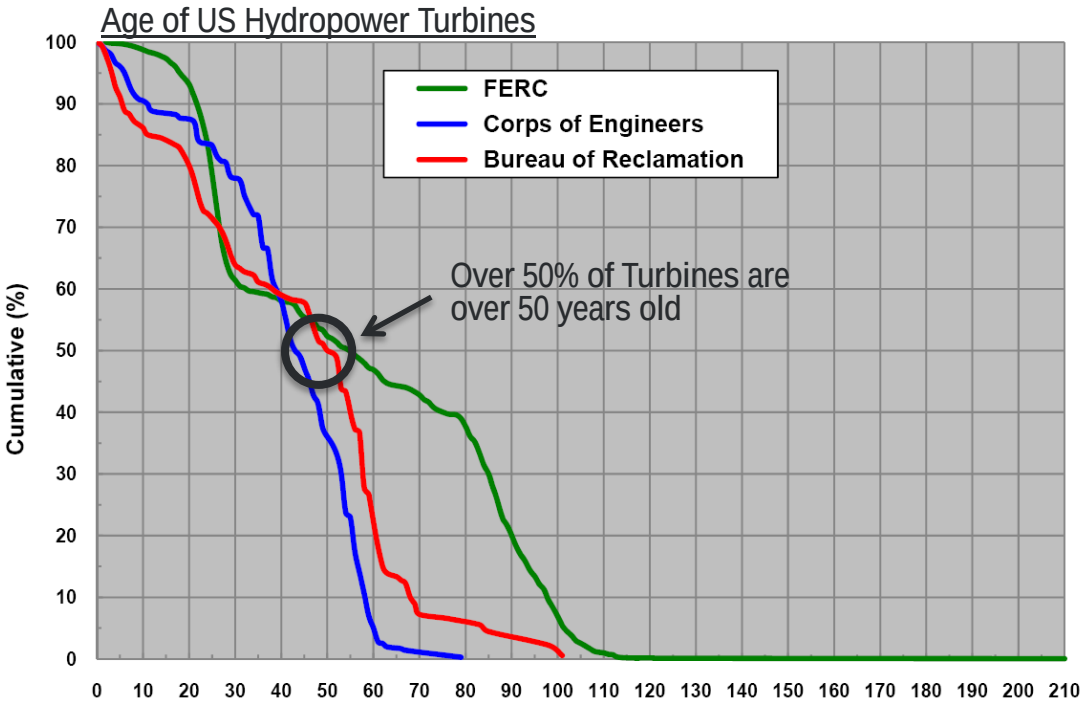


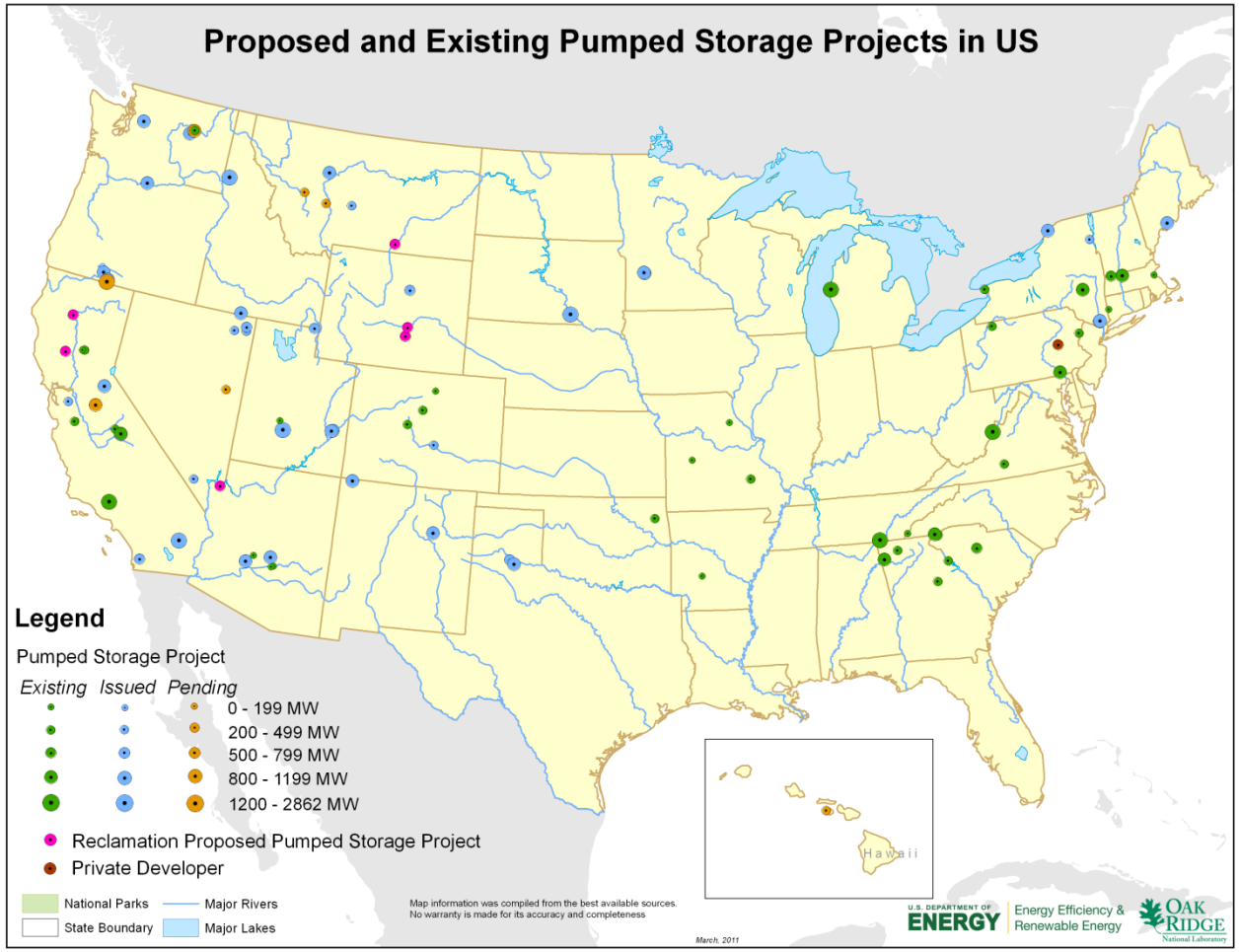


RD&D Needs:

- Demonstrate Best Practices
- Develop More efficient small hydropower technologies
- Accelerate the development of environmental mitigation technologies

The status of the existing fleet demonstrates the need for, and potential of, targeted RD&D to modernize hydropower for additional flexibility and generation

Conventional Hydropower
Pumped Storage



23 GW of Installed PSH Capacity in the US

New, advanced pumped storage designs provide rapid response capability

Pumped storage is the only widely deployable grid-scale storage technology available for variable renewables integration

Conventional Hydropower
Deployment Potential

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Resource	Deployment Risk	Permitting Timeframe	Construction Timeframe	Deployment Potential
Additional generation from existing powerhouses	Low	1-2 years	1-3 Years	~16 GW
New generation from unpowered dam development	Low	1-3 years	2-4 Years	12.6 GW
New sustainable development	Medium to High	1-6 years	2-4 Years	~50 to 150+ GW
Advanced Pumped-Storage Development	High	2-6 years	3-6 Years	43 GW of Preliminary Permits
TOTAL POTENTIAL				120 to 220+ GW

Upgrades and unpowered dams can provide considerable new generation. New hydropower and advanced pumped storage opportunities are plentiful.

Conventional Hydropower
Hydropower Resource Availability in Context

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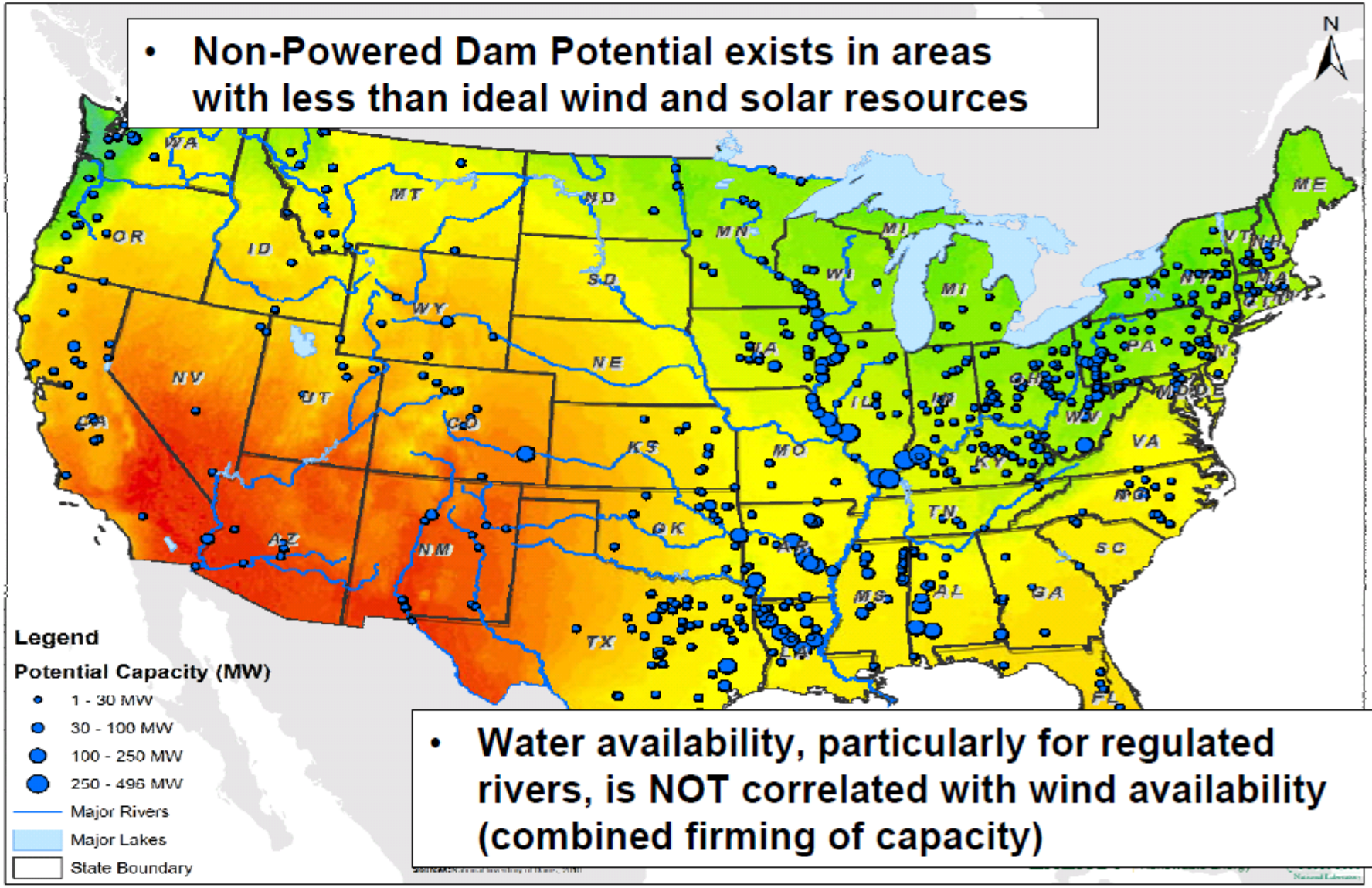

- **Non-Powered Dam Potential exists in areas with less than ideal wind and solar resources**

- **Water availability, particularly for regulated rivers, is NOT correlated with wind availability (combined firming of capacity)**

Barriers to Hydropower Development

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Hydropower industry not positioned to take advantage of opportunities

- Lack of resources (especially small entities)
- Difficult to quantify the value of generation opportunities & benefits
- High capital costs and long payback periods
- Low prioritization (among larger companies)

Expensive and uncertain regulatory process

- Time-consuming and costly permitting process generates unnecessary litigation and deters timely upgrades and construction;
- Decreased incentive to research and demonstrate advanced technologies
- Renewed licenses often reduce generation and flexibility

Technology costs remain high in certain sectors

- Small hydropower and pumped storage technologies remain expensive
- Most innovative R&D is occurring in Europe and Asia

Environmental impacts (real or perceived) lead to limited policy support

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Hydropower Near-Term DOE Deployment Actions

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Support immediately-available, low-cost upgrades and feasibility studies to identify additional opportunities

- Deployment support for immediate, lowest-cost opportunities (ARRA)
- Feasibility studies to identify and publicize additional low-cost, advanced-technology opportunities; targeted deployment support to catalyze private sector investment
- Develop operational tools to maximize generation at existing and new facilities

Identify resources and address technology/policy needs to maximize medium-long term opportunities

- Integrate resource assessments and cost curves with key pumped storage and small hydro technology needs to identify critical COE drivers
- Market analysis to accurately quantify and monetize hydropower ancillary services

Engage regulators and environmental stakeholders to reduce license time and cost

- Align energy generation and environmental priorities across river basins to facilitate development
- Generate data to more accurately correlate generation and water use with environmental impacts

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Technology Development

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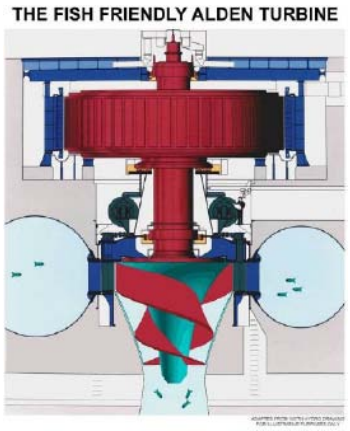
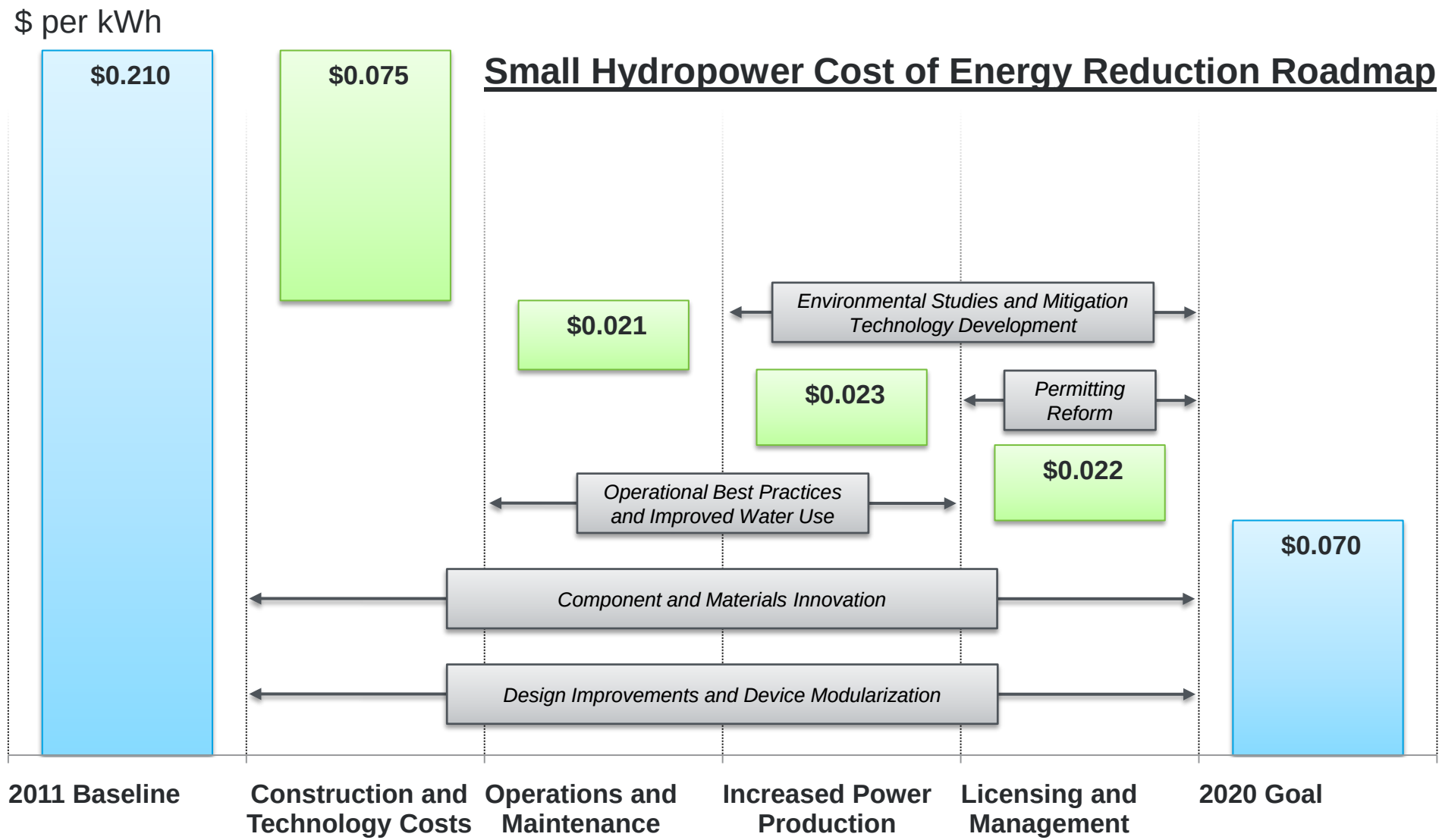
- Address hydropower development barriers and industry needs:
  - Pumped storage hydropower technologies
  - Environmental mitigation technologies
  - Small hydropower
- Small Hydropower Reference Model Development
  - Initial steps to develop a small hydropower reference model
    - Determine baseline cost of energy, evaluate key cost reduction pathways, and establish achievable cost of electricity goals
- Fish-Friendly Turbine Development (EPRI)



Conventional Hydropower
Deployment Pathways *(estimate of resource)*



Conventional Hydropower
Funding Profile

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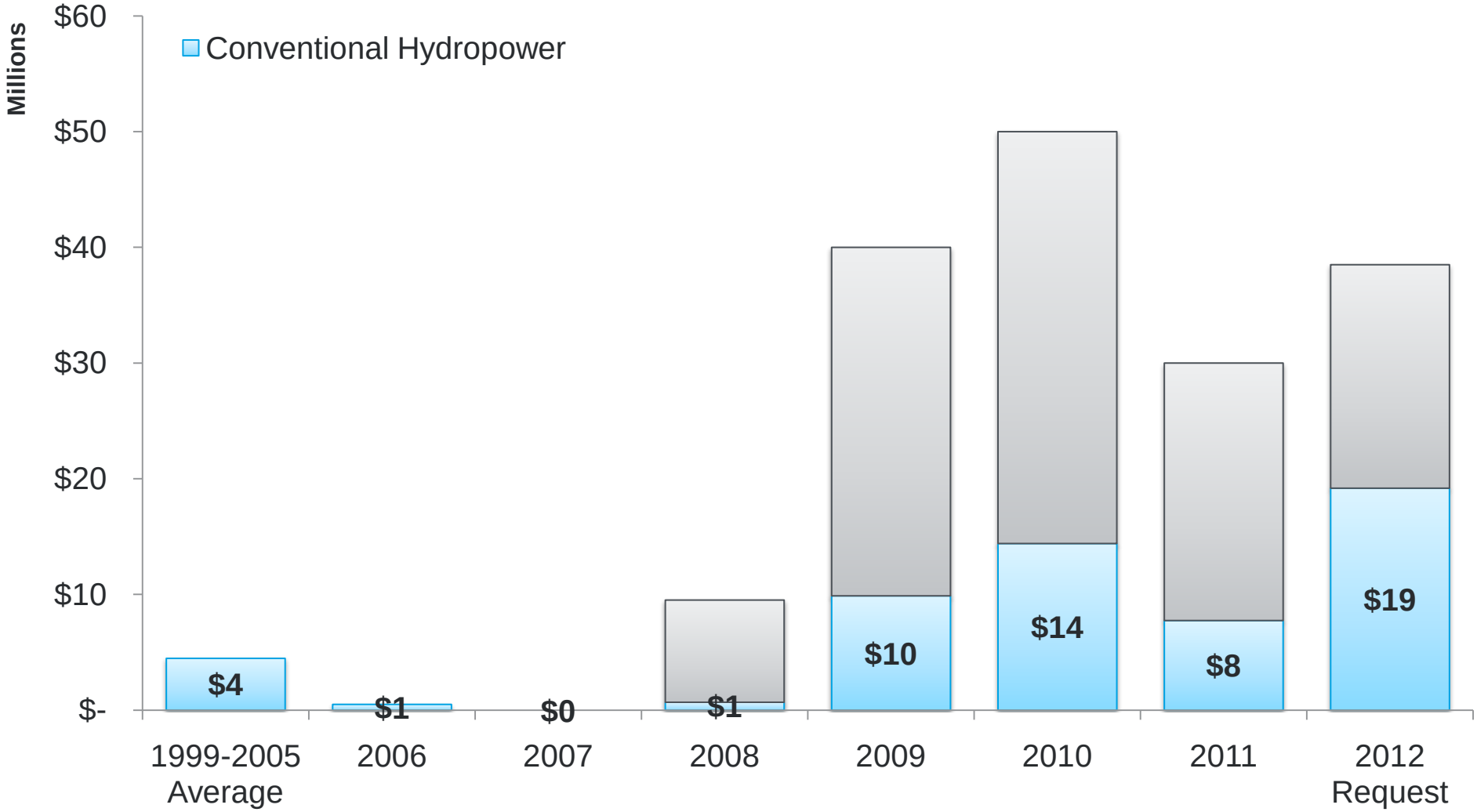

Conventional Hydropower Summary

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- Opportunities exist to add significant generation through upgrades and unpowered dams
- With the right technology and policy support, new development available in small and low head hydro
- Advanced environmentally friendly turbines are needed (fish passage and water quality)
- Hydropower is excellent resource for balancing variable renewable integration

Marine and Hydrokinetic

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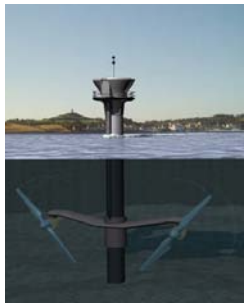
- **Marine and Hydrokinetic (MHK):**
  - Devices which capture energy from waves, tides, ocean currents, the natural flow of water in rivers and marine thermal gradients without building new dams or diversions.
- **Assess the Resource:**
  - Assess the potential extractable energy from domestic rivers, estuaries and marine waters
- **Support Industry:**
  - Support industry efforts to harness this renewable, emissions-free resource to produce cost-competitive electricity in an environmentally sustainable manner.
  - Cost-share RD&D of innovative water power technologies

Marine and Hydrokinetics (MHK)

Current Technologies

(tidal, river in-stream, ocean current)



Wave Technologies

(point absorber, oscillating water column, attenuator, wave surge converter, overtopping)

Marine Hydrokinetics
Resource Potential

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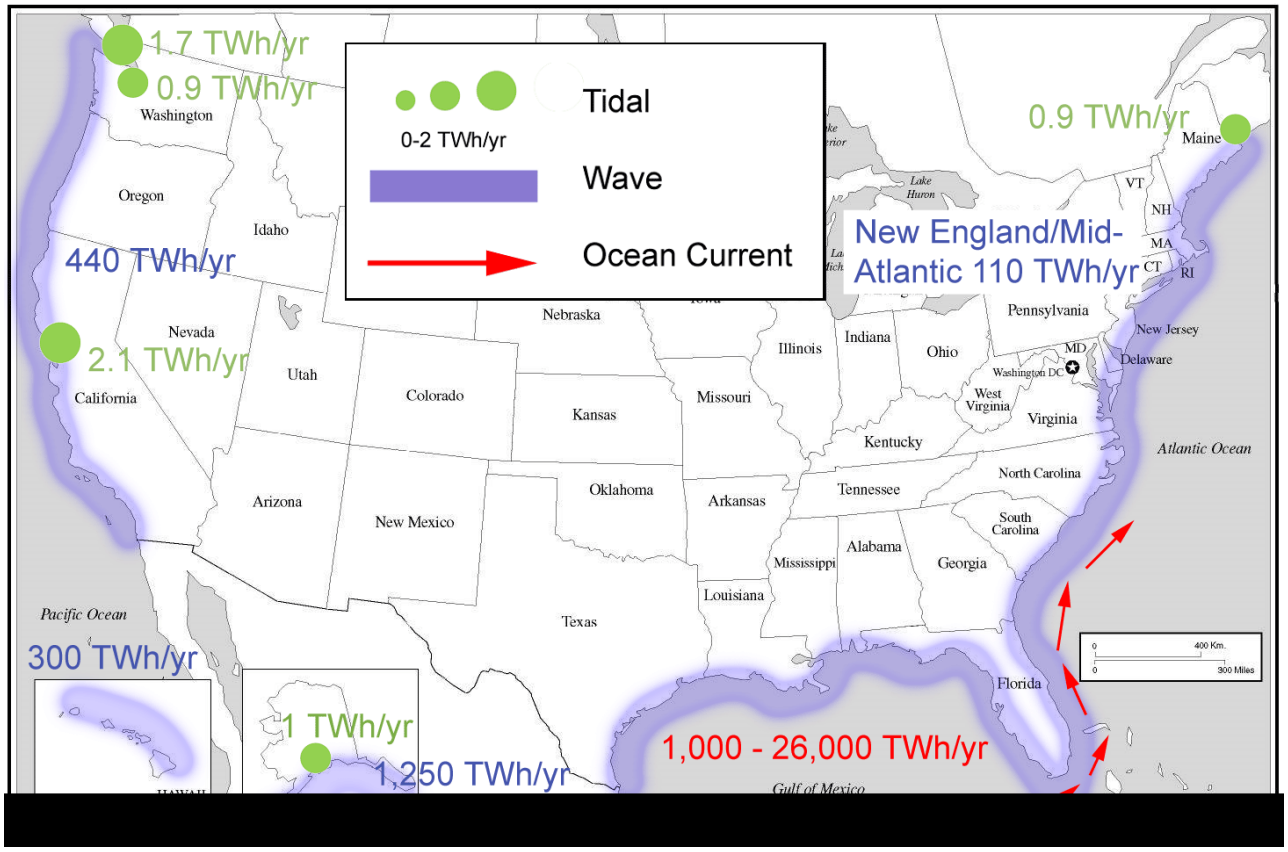
- Electric Power Research Institute (EPRI) research suggests that **ocean wave and tidal hydrokinetic** energy resource energy production potential is equal to about **10% of present U.S. electricity consumption** (about 400 TWh/yr).

- A full range of MHK resource estimates will be completed by early FY12.



DOE Funded Resource Assessments:

1) Wave: EPRI

2) Tidal: Georgia Tech

3) Ocean Current: Georgia Tech

4) Instream Hydrokinetic: EPRI

5) Ocean Thermal Energy Conversion (OTEC): Lockheed Martin

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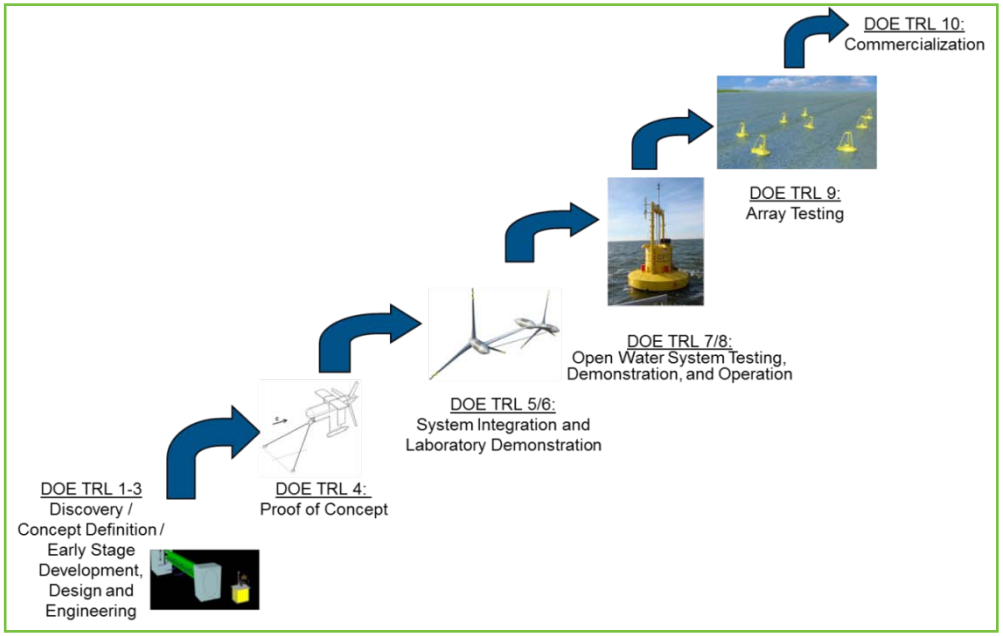
The MHK industry can be described as:

- **Emergent** - strong parallels to wind industry in the 1970s
- **Diverse** - at least 40 MHK concepts being developed in the U.S., many more overseas
- **Dependent** – technologies advancing rapidly but still require public financing to bring devices to market



DOE's development efforts have helped the industry advance through the R&D stage and into pre-commercial demonstration projects.

European Leadership

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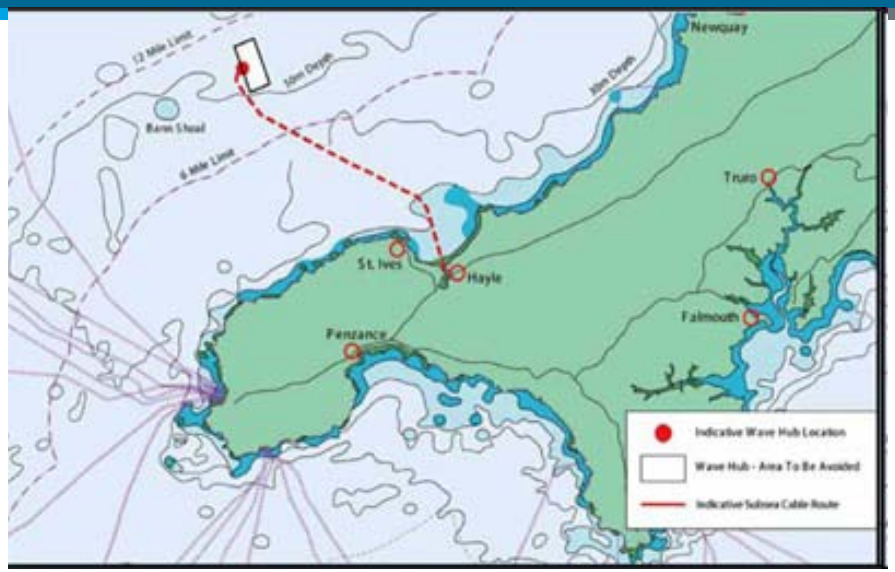
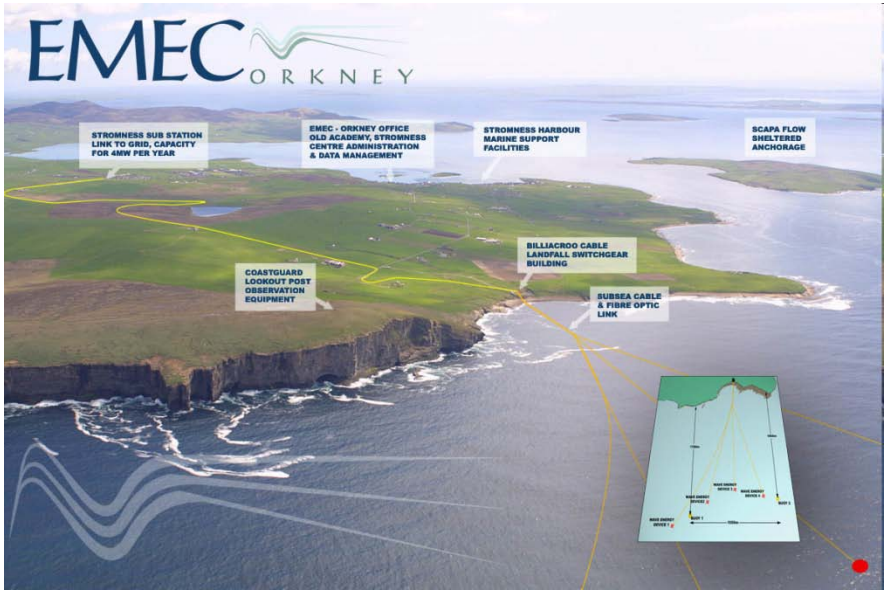
- Established Testing Capabilities:
  - European Marine Energy Centre (EMEC) in Scotland's Orkney Islands
  - New and Renewable Energy Centre (NaREC) in England
  - WaveHub in England
  - Nissum Bredning in Denmark
  - Gallway Bay and proposed Belmullet Bay site in Ireland
- Industry leaders initially tested/deployed in EU
- Numerous commercial deployments planned in the North America
  - OpenHydro, Marine Current Turbine, OPT, Aquamarine





Test Centers

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DOE has established 3 National Marine Renewable Energy Centers (NMRECs):

- Northwest National Marine Renewable Energy Center (NNMREC)
  - Operated by Oregon State University and the University of Washington
  - Emphasis on wave and tidal energy
  - Efforts focused on test berth design and permitting, community outreach and education, expanding evaluation capabilities for anti-fouling research, characterizing both wave and tidal energy testing sites and enhancing acoustic monitoring and acoustic deterrence capabilities.
- Hawaii National Marine Renewable Energy Center (HINMREC)
  - Operated by the University of Hawaii
  - Emphasis on wave energy and Ocean Thermal Energy Conversion (OTEC)
  - Test facility development focused on four distinct sites to accommodate WEC and OTEC testing.
- Southeast National Marine Renewable Energy Center (SNMREC)
  - Operated by the Center for Ocean Energy Technology at Florida Atlantic University
  - Emphasis on ocean currents / OTEC (Located near the Florida Straits and Gulf Stream)
  - Deploying ocean current observation systems to establish environmental baselines. Will ultimately perform full-scale field testing of prototype devices.

Marine Hydrokinetics
Technology Pathways

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The Water Program advances the MHK industry towards commercialization by:

- Supporting demonstration projects
- Developing standardized testing infrastructure and design tools
- Evaluating the technical, environmental and economic viability of MHK devices and working to overcome any barriers

Point absorbers
Wave attenuators
Oscillating water columns
Overtopping devices
Inverted pendulums

Axial-flow turbines
Cross-flow turbines
Articulated oscillating hydrofoils

Open-cycle
Closed-cycle

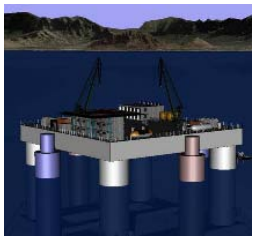
Wave

Tidal

Ocean Current

Instream Hydrokinetic

Ocean Thermal



Marine Hydrokinetics
Deployment Pathways

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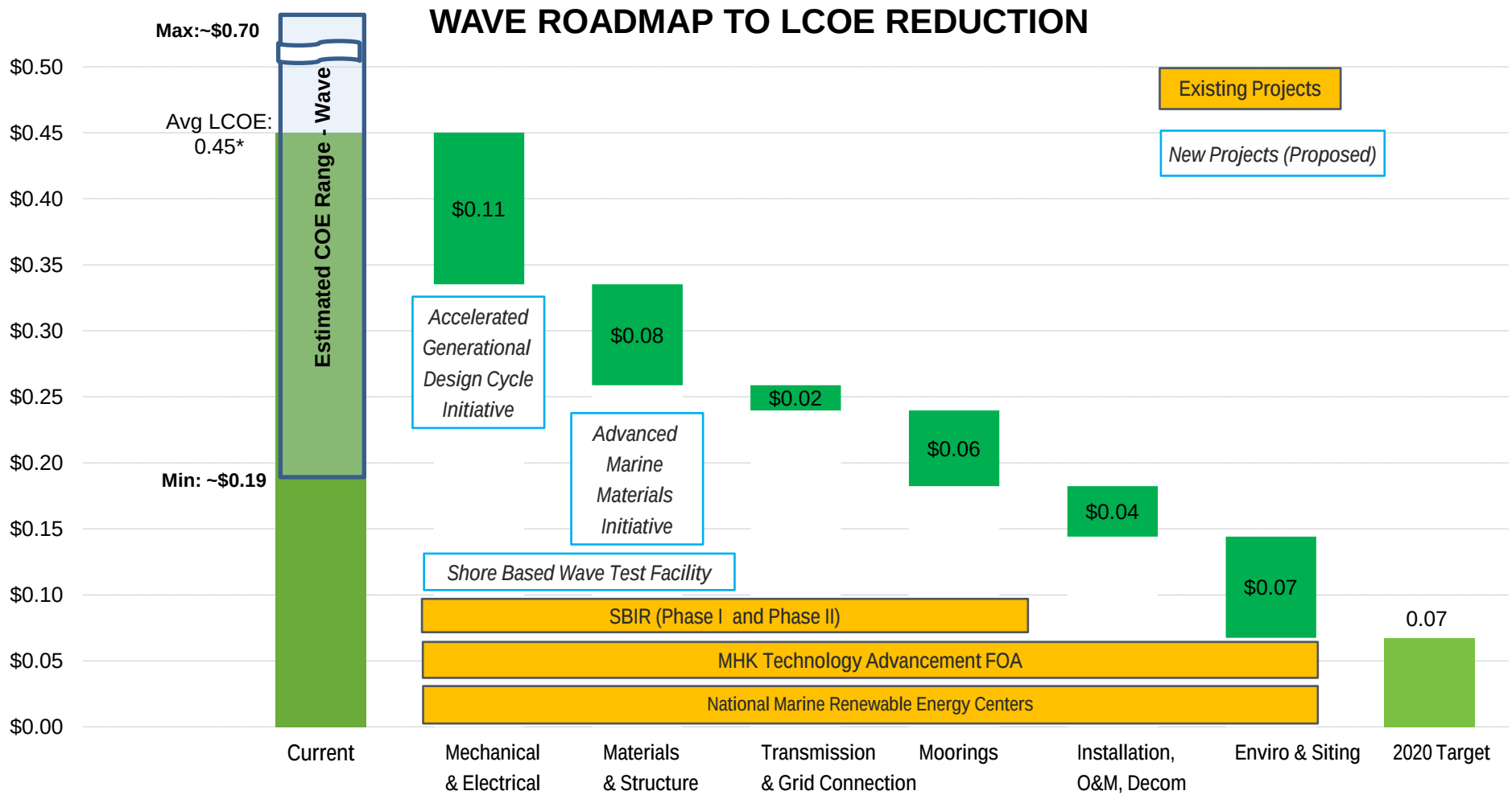

*Preliminary LCOE based on estimated cost and performance data of a limited number of devices. Source: EPRI and UK Carbon Trust. Program activities and goals aligned to establish baseline LCOE by resource and device design by FY 2013 and establish resource-specific LCOE goals and identify key cost reduction pathways by FY 2014

Marine and Hydrokinetic Barriers

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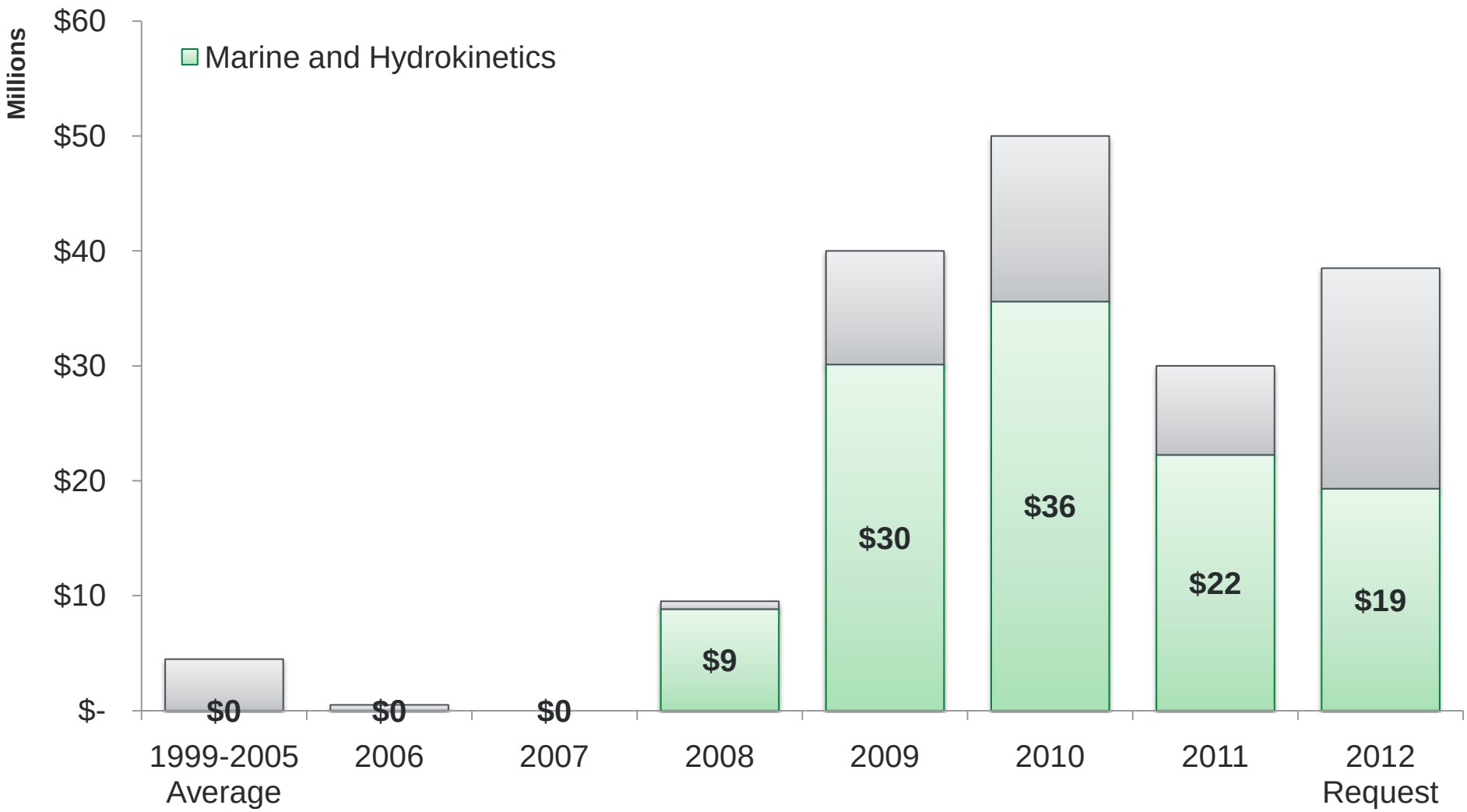
Barriers	Solutions	Program Activities
Cost and performance data does not yet exist to establish baseline LCOE	Establish and verify baseline LCOE for each resource class and device type and quantify key cost drivers by FY 2013	Characterization & Evaluation
Technologies are not yet cost competitive	Develop tools, models, and materials to maximize efficiency and ensure survivability	System Development Research, Tools & Models
Device functionality not yet demonstrated	Support comprehensive testing at progressive technology stages to quantify cost and performance drivers	Test Facilities
Resource assessments are very basic and incomplete; show moderate resource size	Integrate resource assessments, technology cost and performance data, advanced cost/performance models to identify critical drivers to reduce overall COE	Resource Assessments Environment & Siting
Lack of data on environmental risks to permitting and deployment	Develop and disseminate environmental data to reduce siting and permitting costs; incorporate siting costs into LCOE models	Economic Analysis & Market Development

GOAL:

Reduce COE to $0.07/kWh by 2030

Marine and Hydrokinetics
Funding Profile



Summary

- Marine and hydrokinetic energy can be a significant regional energy source, close to population centers
- Need to understand the baseline costs associated with diverse technology types
- DOE investment will accelerate design improvements and cost reduction
- Regulatory and permitting processes will have great impact on industry deployment

Marine Hydrokinetics
Additional Resources

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- DOE Water Power Program - http://www.eere.energy.gov/topics/water.html
- Marine and Hydrokinetic Technology Database - http://www1.eere.energy.gov/windandhydro/hydrokinetic/default.aspx
- MHK Factsheet - http://www1.eere.energy.gov/windandhydro/pdfs/mhk_factsheet.pdf
- Grant Solicitations – www.grants.gov and www.fedconnect.net
- DOE Office of Science – http://science.energy.gov/
- Loan Guarantee Program Office – www.lgprogram.energy.gov