Western Governors’ Association
Clean and Diversified Energy Initiative

Water Energy White Paper

At the invitation of the Western Governors’ Association’s Clean and Diversified Energy Advisory Committee (CDEAC), the individuals below prepared this white paper on Combined Heat and Power. The white paper was presented to the CDEAC on March 7, 2006 and it was accepted for further consideration as the CDEAC develops recommendations for the Governors. At their Annual Meeting in June, 2006, Western Governors will consider and adopt a broad range of recommendations for increasing the development of clean and diverse energy, improving the efficient use of energy and ensuring adequate transmission. The CDEAC commends the individuals listed below for the thorough analysis and thoughtful recommendations.

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Preface

Water energy from multiple resources captured by existing and emerging technologies offer important energy options for consideration as the Western Governors’ Association considers ways in which to meet growing energy demand with a clean and diversified energy portfolio.

At the invitation of the Western Governors’ Association’s Clean and Diversified Energy Advisory Committee (CDEAC), the National Hydropower Association (NHA), collaborating with the Electric Power Research Institute (EPRI), and several of its member companies, and the Idaho National Laboratory, prepared this White Paper for consideration as the Advisory Committee considers a new path forward. The Association respectfully urges consideration of these important renewable resources, offers background information on resource potential, technologies, costs, impediments to development, and policy recommendations for inclusion in the CDEAC’s final report. We sincerely hope that the WGA will include these recommendations when it adopts its broad range of policy recommendations to increase the development of clean and diverse energy at its annual meeting this June.

NHA presented a case for clean and economical hydropower before CDEAC on December 8, 2005. The Association has significantly added to that material based on a very timely Department of Energy, Idaho National Laboratory report released in January of this year. We appreciate the many long months of work that CDEAC has given to this effort and believe that inclusion of hydropower -- conventional, and new and emerging technologies such as tidal and ocean -- in your final work product will serve to increase the options before the states and add to WGA’s ultimate success in meeting its target for 30,000 megawatts of new, clean and diversified energy.
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Executive Summary

The WGA Clean and Diversified Energy Initiative is an important step toward the future of clean and diversified energy in the West. Hydropower is the backbone of clean energy and reliability in the West today. Water energy offers tremendous opportunity for growth, both at existing facilities, undeveloped sites through damless installations, and through the deployment of new emerging hydrokinetic, tidal, wave and ocean technologies.

Conventional hydropower has played an important role in the development of the West. In addition to clean energy, it has contributed greatly to western water planning, offering flood control, water supply, recreation, and irrigation. Natural streams are an important energy source within the West, yet their full potential remains untapped. There is tremendous room for growth by upgrading existing conventional hydropower facilities, adding powerhouses to non-power dams (98 percent of the dams in the United States have no power component), and developing new sites deploying traditional and advanced technologies without building new dams.

The potential in the western states for kinetic hydropower application is significant. From among the strong ocean tidal currents in the Pacific Northwest, California, Alaska, and Hawaii, the fast rivers flowing throughout the West, and man-made canals and channels, the kinetic hydropower potential is in the thousands of megawatts.

Western States have diverse, unused water energy resources that offer clean, renewable generation. In its latest assessment released just last month, the Idaho National Laboratory reports that nearly 30,000 MW of prime hydropower opportunities exist within the United States. In fact, 20,000 MW of this untapped potential is in the West. Western states could develop this potential without building a single new dam. Developing these untapped conventional and advanced hydropower technologies, coupled with pursuing ocean energy potential, could make more than a significant contribution to the WGA goal of 30,000 MW of new, clean and diversified energy. In fact, the western states could well exceed that goal by fully developing its water energy resources and pursuing a path of clean, renewable energy, including wind, geothermal, and solar powered generation. NHA supports and encourages greater deployment of these technologies and their integration to maximize the full benefit of our renewable resources.

Despite the West’s rich water energy resources, much of this energy could be left untapped because of impediments to development. There is a lack of public policy, at both the state and national level, needed to nurture and further this growth. Regulatory barriers impose uncertainties and delays in obtaining licenses and approvals that make investment risk too high.

There are a number of public policy recommendations that, if adopted, could encourage development of these important, clean, diversified, energy resources. The WGA could
play a leading role in demonstrating the means to meeting increasing demands for affordable electricity using water energy resources by setting the right policies and advocating policy change at the national level.

**Policy Recommendations**

This paper offers a number of recommendations to spur the development of water energy resources in the West -- conventional, hydropower at non-hydro dams, run of river hydrokinetic, small hydropower, tidal, ocean and wave power. We hope that the WGA will give careful consideration to these recommendations as it moves forward with its clean and diversified energy path.

As with any emerging technology, if the West’s untapped water energy resources are to reach their full potential, they will need support from the states in three critical areas:

- Incentives for development
- Research and development
- Permitting.

We urged that the WGA and its member states support financial incentives for development by recognizing hydropower and its emerging technologies in its own state incentive programs and supporting inclusion of these technologies in clean energy incentive programs at the regional and federal level. We encourage the WGA to support research and development programs to further these technologies. Specifically, WGA could encourage states to foster these technologies through their own state university systems and state R&D agencies, and could call on the federal government to build its own hydropower – conventional and non conventional – R&D capacity at the DOE and its energy laboratories with increased funding. Finally, we encourage the WGA to support improved and streamlined permitting processes and establish a streamlined permitting process for demonstration projects so as to encourage untested yet promising technologies.

Specifically, we urge the WGA’s consideration of the following:

**Small Hydropower, Incremental Hydropower, and Hydropower at Non-Hydropower Dams**

**Recommendation 1.** Pursue the development of incremental hydropower (i.e. efficiency and new capacity upgrades at existing facilities with currently nearly 3,000 MW available in the West), small hydropower and hydropower at non-hydropower dams by:

A. Supporting extension of the Section 45 production tax credit, and pursuing federal appropriations for incentive programs for efficiency improvements (provisions included in the Energy Policy Act of 2005), as well as supporting
federal efforts to streamline the licensing amendment process to bring incremental hydropower on-line more timely;
B. Supporting inclusion of small hydropower and hydropower at non-hydropower dams within the Section 45 production tax credit.
C. Including hydropower (incremental, small hydropower, and hydropower at non-hydropower dams) in state clean and renewable energy initiatives (e.g. portfolio standards and incentives).
D. Streamlining the state regulatory process involved with incremental hydropower, small hydropower, and hydropower at non-hydropower dams.

New Technologies – General Recommendations:

Recommendation 2. Pursue demonstration projects to support further development and application of new technologies – conventional, advanced and emerging. For example, support demonstration projects of underwater turbines in deep rivers (tidal or river) and small turbines within irrigation aqueducts.

Recommendation 3. Provide financial support for development of emerging water technologies with state research and development programs. Programs offered by the California Energy Commission are extremely important in helping developers assume the risk of demonstration projects to test new technologies.

Recommendation 4. Support federal funding of research and development for water energy sources, including conventional and non-conventional hydropower, ocean and tidal power by advocating for increased appropriations and attention within the Department of Energy. Moreover, the advanced hydropower technologies developed by the DOE and currently undergoing testing at Grant PUD, have demonstrated that advanced technologies can increase power and hydraulic capacity, result in better survival of juvenile salmon, and improve water quality from reduced spill during periods of high flow. The West has much to gain by supporting federal efforts to complete the work of the advanced hydropower turbine program within the DOE.

Hydrokinetic, In-stream and Tidal Power Recommendations:

Recommendation 5. Encourage and fund new commercial hydrokinetic power projects, establish low cost renewable energy debt financing instruments/grants that include hydrokinetic power generation as a qualified generation source to be used to fund construction of hydrokinetic projects.

Recommendation 6. To encourage deployment, urge Congress to add hydrokinetic power generation to the definitions as part of the Section 45 production tax credit and to make these credits tradable.

Recommendation 7. To provide financial incentive at the state level, establish tradable tax credits similar to Section 45 credits that would include hydrokinetic power generation
and allow not-for-profit energy providers such as municipal utility districts to trade the tax credits to other entities.

**Recommendation 8.** To encourage the deployment of renewable, secure, locally distributed energy, include hydrokinetic power generation as a qualifying source in the following programs in individual states:

- Renewable Portfolio Standards (RPS)
- Renewable Energy Credits (REC)
- Net Metering Programs

**Recommendation 9.** Support research, development and deployment projects to collect information on the technical performance and environmental impacts of hydrokinetic power systems. This should be done on a state and regional policy basis. It should include financial support for research and demonstration projects. The efforts could be funded from states’ user benefit funds as part of a comprehensive program that incorporates the test center(s).

**Recommendation 10.** Encourage Congress to fund research programs for the Department of Energy to identify new resources and (hydrokinetic) technologies and support their development as identified in the Energy Policy Act of 2005 (EPAct 2005).

**Recommendation 11.** Clarify permitting programs to encourage demonstration projects by making a distinction between the requirements for demonstration projects and long term commercial development. This would speed the process to put demonstration projects in the water to gather performance and environmental information. Information gathered from these demonstrations could serve as the basis for conditions for licensing of full scale commercial operations.

**Recommendation 12.** Amend permitting programs to make a distinction in the requirements for deployment in manmade channels as opposed to natural streams and estuaries to acknowledge the anticipated lesser environmental impacts and allows projects in manmade channels to proceed at an accelerated pace. This would advance information gathering on technical performance and aid in the decision process for technologies to be deployed in natural streams and estuaries.

**Recommendation 13.** Develop collaborative permitting programs at the state and regional level that coordinate requirements from all of the jurisdictional agencies, including federal, to avoid duplicative processes and reduce the time and cost to deploy demonstration and ultimately commercial projects.

**Ocean Energy and Wave Power Recommendations:**

**Recommendation 14.** Provide leadership for the development of an ocean energy RD&D program to fill known R&D gaps identified in this report, and to accelerate
technology development and prototype system deployment; encourage the federal
government to do the same.

Recommendation 15. Support the operation of a national offshore wave test center to
test the performance and reliability of prototype ocean energy systems under real
conditions.

Recommendation 16. Lead activities to streamline the process for licensing, leasing,
and permitting ocean and wave energy facilities in U.S. waters.

Recommendation 17. Study provision of production tax credits, renewable energy
credits, and other incentives to spur private investment in ocean energy technologies and
projects, and implementing appropriate incentives to accelerate ocean wave energy
deployment.

Recommendation 18. Ensure that development rights are allocated through a
transparent process that takes into account state, local, and public concerns.

Conclusion

The WGA Clean and Diversified Energy Initiative is an important step toward the future.
The West has a remarkable opportunity to lead the way in showing leaders at all levels of
government the real potential that lies within our borders, and along our coastline, for
clean, renewable and diversified energy. Nearly 20,000 MW of water energy, including
conventional and non-conventional hydropower, nearly 3,000 MW of incremental
hydropower, and an unknown amount of ocean energy lays untapped mostly as a result of
the failure of public policies to nurture this development, and as a result of a
misconception that new development would require new dams. In reality, this energy
could be captured without building another impoundment. Pursuing this energy resource
sets a wise course for the future, one that builds and improves upon the existing resource,
will build state, regional and local economies, and will add to our energy security. We
encourage the WGA to consider the information contained within this paper and give
serious consideration to its recommendations.
1. Opportunities for Hydropower

Prepared by:
National Hydropower Association (NHA), Idaho National Laboratory (INL), and Bahleda Management and Consulting, LLC

Hydropower opportunities are significant in the western states without developing new water impoundment areas or large dams. The INL assessment published in January 2006\(^1\) shows nearly 30,000 MW of prime hydropower opportunities in the US of which about 20,000 MW is located in the western states. This potential damless hydropower is based on realistic development criteria using a run of river model where flow into a penstock then passes through the powerhouse and back into the stream with no impoundment of water.

There are also significant opportunities for hydropower capacity additions to existing dams, with and without powerhouses, and the development of previously identified, but undeveloped sites. A study focusing on capacity additions for conventional hydropower was completed in 1998 by INL. For the western states, the estimated available resources are 13,000 MW at existing dams with and without powerhouses and 5000 MW at selected, but undeveloped sites.

The assessments conducted to date point toward 20,000 MW of new, water energy sources of electricity in the western states that is both feasible and economic. This section provides the technical background, research results, and economic comparisons that support consideration of this important renewable energy resource by WGA.

Background

In June 1989, DOE held public hearings to support the expanding demand for energy in the United States. The conclusion of these hearings was that undeveloped hydropower resources were not well defined. As a result DOE established an interagency hydropower resource assessment team to ascertain the country’s undeveloped hydropower potential. A number of studies have been completed including: site-based assessments that identified and evaluated capacity increase opportunities in 49 states, an economic study that estimated the cost of developing those opportunities offering 1 MW and greater increases, and stream-based assessments that evaluated the power potential of all U.S. streams and identified feasible, potential low power and small hydro sites. In addition, these studies produced software tools for locating and further evaluating potential sites and capacity increase opportunities. The goal of these efforts has been to assess all undeveloped hydropower potential in the United States for use in planning development of new renewable energy generating capacity.

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Results

Hydropower is currently providing about 7% of the U.S. electrical energy supply from approximately 192 large plants and 2,186 small and low power plants. These hydroelectric plants produce 75% of overall electricity production from renewable sources. The results of assessments to identify and quantify undeveloped hydropower potential, an economic evaluation of sites, and development of site evaluation tools are provided here.

Hydropower Potential:

INL assessed feasible hydropower potential at water energy resource sites assuming a dam-less development model. The results show that there are approximately 130,000 feasible, hydropower development opportunities in the U.S. The total power potential of the feasible sites (~25% of all sites evaluated) is 30,000 MW based on estimated annual average power output. The energy available from these renewable energy sites represents about 5% of current U.S. electric energy needs and ~20,000MW is located in the western states.

All of the potential projects that were identified in all power classes are run of river projects. (Note that one configuration of our development model would be a power channel in which a natural or constructed secondary stream channel is dammed, but operation is still run of river with water in equaling water out and no creation of a reservoir affecting the main channel.) The following two charts show the types of new feasible hydropower projects and the estimated annual average power output.

New hydropower plants and corresponding annual average power potential by power class and low power technology classes. (from INL reference 1, January 2006)
The feasibility assessment considered development restrictions based on federal statutes and policies and environmental sensitivity and economics related to site assess and load and transmission proximity.

INL also conducted an assessment of capacity increase opportunities considering additions to existing dams with and without powerhouses and development of previously identified, but undeveloped sites. The results of this study are presented in the chart below and show the potential for a total of 18,000 MW of capacity increases within the western states.

The six states with the most feasible hydropower potential are Alaska, California, Idaho, Montana, Oregon, and Washington. The following table shows in more detail capacity increases that are available at the existing plants and dams in the west. The total is 13,000 MW with no new sites developed.

<table>
<thead>
<tr>
<th>State</th>
<th>Potential at Existing Hydropower Projects (MW)</th>
<th>Potential at Existing Non-Hydro Dams (MW)</th>
<th>Totals (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>58</td>
<td>1,609</td>
<td>1,667</td>
</tr>
<tr>
<td>Arizona</td>
<td>157</td>
<td>15</td>
<td>172</td>
</tr>
<tr>
<td>California</td>
<td>653</td>
<td>1,893</td>
<td>2,546</td>
</tr>
<tr>
<td>Colorado</td>
<td>78</td>
<td>377</td>
<td>455</td>
</tr>
<tr>
<td>Hawaii</td>
<td>3</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Idaho</td>
<td>504</td>
<td>447</td>
<td>951</td>
</tr>
<tr>
<td>Kansas</td>
<td>0</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Montana</td>
<td>234</td>
<td>502</td>
<td>736</td>
</tr>
<tr>
<td>Nebraska</td>
<td>28</td>
<td>61</td>
<td>89</td>
</tr>
<tr>
<td>Nevada</td>
<td>3</td>
<td>31</td>
<td>34</td>
</tr>
<tr>
<td>New Mexico</td>
<td>5</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>North Dakota</td>
<td>43</td>
<td>6</td>
<td>49</td>
</tr>
</tbody>
</table>

Feasibility of the capacity increases is based on legal, institutional, and environmental attributes. Nineteen site attributes including such things as: cultural, fishery, geologic, historic, recreational, and scenic value were evaluated to produce a composition project environmental suitability factor. Multiple sources of information are used to assign attributes. A combination of attributes resulted in a lower suitability factor because multiple environmental considerations reduce the likelihood that a site may be developed to its physical potential.

The results of assessing undeveloped hydropower potential presented above show that there is significant untapped power potential in natural streams and opportunities for capacity increases at existing facilities throughout the West. All of these new energy sources are available without the need for more dams or reservoirs. NHA requests the CDEAC take this renewable energy potential information into consideration.

Capacity increases at existing hydroelectric plants can be achieved while maintaining or improving environmental factors. This has been demonstrated by the installation of an advanced hydro turbine system at Grant County Public Utility District’s Wanapum hydroelectric facility. Grant County PUD tested a new fish-friendly advanced turbine design. Their studies indicate that an advanced turbine with a rated output of 111 MW compared to the original turbine with 89 MW not only increased capacity, but did so while maintaining or increasing fish survivability factors.

The research and development of advanced turbines is a success story of the collaboration between the U. S. Department of Energy and industry. Advanced turbines increase power and hydraulic capacity, result in equal or better survival of juvenile salmon, and improve water quality from reduced spill during periods of high flow. NHA requests the CDEAC consider the results of the Grant County PUD study and support increased federal funding for hydropower research and development in their recommendations.

**Economics of New Hydropower:**

The question of the cost of developing, operating and maintaining new hydroelectric plants or expanding the capacity at existing plants has been addressed in DOE work. INL completed a study in June 2003\(^3\) to provide policymakers with documented and

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peer-reviewed estimates of new generation and the associated costs. The report covers the following types of hydropower resources: undeveloped sites, dams without hydroelectric plants, and expansion of existing hydroelectric plants.

According to this report, nationwide capacity increase opportunities at dams with greater than 1-MW hydroelectric plants (incremental capacity) is 4,917 MW. The report states the median unit cost of developing this incremental capacity is $700/kW in 2002 dollars. The median unit cost of developing new capacity by adding a powerhouse to an existing dam is $1,200/kW. Capacity increase opportunities at 2,155 sites through the country can be attained for a median cost of $1,600/kW. All of these unit costs are competitive with other sources of electricity.

Unit cost, while a good indicator of total development costs, is not the only measure of the efficacy of an energy source. Using it alone for comparison with other technologies penalizes hydropower projects that have high initial costs, but offer long life, no fuel costs, and low operating costs. Hydropower also has significant economic advantages in terms of reliability, dispatchability, and peaking power supply, among others.

Here, it is also important to note that the Energy Policy Act of 2005 included incremental hydropower in the Section 45 production tax credit. The ten-year tax credit for incremental hydropower is 0.9 cents per kWh. The Act includes:

- incremental and qualified hydropower in the Section 45 production tax credit (PTC),
- new incentive programs for development of new hydropower at existing dams or conduits and for efficiency investments at existing facilities
- incremental hydropower in the federal government renewable energy purchase program.

Another good reference for the overall energy outlook, with details on the electricity sectors is the Energy Information Administration Annual Energy Outlook 2006 Report. This annual report and analysis includes capital, fixed O & M, variable O & M, and transmission costs and shows development by zone, including the West, and projected out to 2030. NHA encourages the CDEAC to consider DOE, EIA, and Idaho National Laboratory reports during its deliberations.

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Site Evaluation Tools:
The Hydropower Evaluation Software (HES)\textsuperscript{5} developed by INL uses a uniform set of assessment criteria and a probability factor computer model to provide estimates of developable hydropower potential in any region of the United States. HES offers the PC user the ability to factor in the environmental attributes of a hydropower site to calculate a relative development suitability factor for a project.

The HES was developed as a tool for regional or state agencies to obtain regional or state totals and is not intended to provide definitive potential development factors for individual sites. Further, because the software was developed as a generic measurement tool encompassing national issues, the use of regional and state totals must be conducted judiciously; various local issues may skew hydropower potential totals. Employing HES as a national measurement tool will smooth any local anomalies.

Another tool developed by INL is the \textit{Virtual Hydropower Prospector} (VHP)\textsuperscript{6}, a geographic information system (GIS) tool designed to assist in locating and assessing natural stream water energy resources and feasible, potential, hydropower project sites in the United States. A web site is available that includes the tool accessible using a user-interactive regional selector, a downloadable user’s guide, and links to all data sources. The methods used to identify the water energy resources and feasible, potential, hydropower project sites displayed by this tool, and their attributes are described in previously cited INL reports\textsuperscript{1,2}.

Summary
The WGA Clean and Diversified Energy Initiative is an important step toward the future of clean and diversified energy in the West. Hydropower is the backbone of clean energy and reliability in the West today. Far from being tapped out, hydropower resources in the West can make significant contributions toward achieving the Initiative’s goal of 30,000 MW of additional clean power by activating capacity increase opportunities at existing facilities and developing distributed generation at new, small hydroelectric plants – all without the construction of new dams. Tomorrow holds even greater promise for hydropower with the evolution of new technologies capable of harnessing unconventional water energy resources. The new technologies will expand the perceptions and applications of hydropower from the critical backbone of traditional hydropower, to the distributed presence of minimal impact installations in rivers, agricultural irrigation canals, water treatment plants, tidewaters, and ocean sites.

Links to Hydropower Resource Assessment Reports


\textsuperscript{5} The HES software is accessible at: \url{http://hydropower.inl.gov/resourceassessment/software/}.
\textsuperscript{6} The Virtual Hydropower Prospector is accessible at: \url{http://hydropower.inl.gov/prospector/}.

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Available at: Main Report and Appendix A (4.5MB PDF), Appendix B, Part 1 (12.0MB PDF), Appendix B, Part 2 (10.2MB PDF)

2. *Estimation of Average Annual Streamflows and Power Potentials for Alaska and Hawaii*, INEEL/EXT-04-01735, May 2004 (1.1MB PDF)

   - Main Report (3.7MB PDF)
   - Appendix A (12.4MB PDF)
   - Appendix B, Part 1 (10.6MB PDF)
   - Appendix B, Part 2 (11.2MB PDF)
   - Appendix C (217kB PDF)


6. The state resource assessment reports are available for 49 states.

2. Opportunities for Hydrokinetic or In-stream and Tidal Power

Prepared by: Michael Bahleda and Ronald F. Smith
Verdant Power, LLC

New turbine technologies are enabling effective energy recovery from the natural flow of rivers, tides, and even irrigation and cooling water systems. This renewable energy resource is most abundant in the rivers and offshore in the Northwest and Alaska. California also has promising opportunities to increase energy production from renewable resources connected with the state's water system. In-conduit hydropower - turbines installed within conduits to generate electricity from flowing water in pipelines, canals and aqueducts - is an attractive possibility because it is relatively easy to permit and has fewer environmental impacts.

Resource assessments have been done by EPRI, TVA, NYSERDA, and others. Based on experience gained in their development of the Roosevelt Island Tidal Energy project, Verdant Power, LLC assembled preliminary cost and supply information for hydrokinetic generation that could be deployed in natural streams, tidal estuaries and man-made channels in the western states. They estimate that with the appropriate federal and state incentives and permitting programs 4,000 MW of generation could be developed from rivers alone, without the need for additional dams or other impoundments. Nine specific Recommendations are provided that we believe would aid this fledgling part of the hydropower industry to make a significant contribution to the WGA’s goals.

Background:

Water is critical for the survival of mankind. It is this close proximity relationship that presents the opportunity for us to utilize additional aspects of its character to sustain our existence. The natural movement of flowing water, prompted by simple gravitational pulls of the earth and moon, contains an amount of kinetic energy that can be converted into electrical energy many times greater than what is consumed worldwide. This is emission and by-product free, sustainable, predictable, and indigenously sourced energy. The flows manifest themselves in rivers, tidal currents, tailraces, spillways, canals and aqueducts.

The Western States are blessed with an abundant and varied water resource base. There are thousands of miles of coastal tidal areas, rivers, and aqueducts flowing throughout the region, with many of the major population centers and industrial energy users within a short distance. The movement of water resources from the resource rich areas to the resource scarce areas is a major economic activity in many of the member States. Significant portions of the region’s electrical output is currently consumed in facilitating the flow of these water resources, rather than utilizing the same resources to add to the region’s electrical supply base.

Technological advances, beginning several decades ago, have reached the level of early commercial development of a number of approaches to harness energy from the
variety of water flows available in the region. Building from early prototype work performed in the mid 1970’s by Scottish Power in the United Kingdom (UK), critical theoretical and applied research was independently conducted by several development teams in the UK, the US and Europe. The US 1980’s work, focused at Northeastern and New York Universities, was supported and monitored by the US Department of Energy, New York Power Authority, the NY State Energy Research Development Authority, assisted by the US Navy, and deployed as a prototype courtesy of partial United Nations funding. Additional amounts of private equity capital were dedicated to carrying on the needed R&D to advance the technology to its present level of repeated successful proof of concept demonstrations and product reliability trials. Notice of these advances, and the future potential of their implementation, was taken by CEC Commission staff, most recently in its report on Water-Energy Relationship: 2005 Integrated Energy Policy⁷.

Illustrations of In-Stream Hydrokinetic Technologies

Reflecting the diversity of physical characteristics of flowing water there are a number of technical approaches and resulting operating parameters that are being pursued by leading hydrokinetic power developers. The systems come in differing physical sizes ranging from only several meters in length/width to 30 meters or more in diameter. The weight of a single unit can vary from several thousand pounds to many tons, with preferred operational water depths of less than 10 feet up to 100 feet. The power output, as with wind units, is a function of the velocity of the water flow. Thus an identical unit might produce anywhere from 1x to 10x, depending on resource quality.

The class of systems pictured here are consistently evaluated as having successfully attained the early commercial stage, include both an axial and vertical axis flow, completely or partially submerged turbine, many with blades similar to those commonly found on wind power units. The units may be ducted or unducted, depending on developer preference.
There are additional approaches to the conversion of kinetic energy to electrical generation that are being pursued particularly in North America and continental
Europe, promising to contribute to the richness of the knowledge base and diversity of technical approaches becoming available over the next several years. These include recent advances made by Clean Current Turbines in Vancouver, CN, the Gorlov Helical Turbine under the sponsorship of GCK Technologies, Inc., and others by Copper Union College in NYC and University of Naples in Italy.

**Present Demonstration Activity**

All of the above developers have had a series of progressively more sophisticated and productive proof of concept demonstrations. Several models are currently continuing field trials with additional enhanced iterations scheduled for deployment during 2006, both in North America and the UK. The frequency, sophistication, and duration of deployments are progressing at exponential levels of activity. Strong national government support in the UK, and more recently in Canada, coupled with the leadership of several of the State Energy Commissions/Authorities promises to maintain a growing intensity of developer focus on this technology area, although at a pace which is presently constrained by financial resources.

**Supply and Cost Curves**

Current hydrokinetic turbine generators are produced in a very labor intensive, one-off manner. Systems are deployed in single units, rather than fields. The same supporting equipment, personnel, overhead, deployment equipment and crew costs are needed and used for a single unit rather than spread over arrays of many units. Little or no purchasing power exists in the hands of the developer due to a lack of volume. Therefore comprehensive cost of energy comparisons between present day systems and alternative forms of generation are largely negative, although rapidly shrinking.

Economic feasibility studies have been conducted and updated by many of the developers, but most of this information is treated as proprietary. Several generic industry studies have been performed and published, with results consistent with each other and the private confirmations of several of the major developers. A seminal work, *The Commercial Prospects for Tidal Stream Power*, (2) prepared in 2001 by Binnie Black & Veatch for the UK Department of Trade and Industry projected near term costs, with scale manufacturing of systems, to be as low as 4.56 pence per kWh (about 8¢ US). The more recent, March 2004 work, *The Costs of Generating Electricity*, by The (UK) Royal Academy of Engineering, projected a decrease from current estimated costs of 6.63 to 5.70 pence per kWh (about 11.8 to 10¢ US) in the future.

Alternate predictions of estimated useful lives, ultimate O&M costs, and learning curve assumptions can increase or decrease this current 8 to 12¢ range by several cents. Given the low production volumes that are being extrapolated, coupled with the relative infancy of the industry, these cost estimates are exceptionally low relative to the wind energy cost history. With current wind technology applied in a well chosen site producing electricity as low as 4¢/kWh, one should anticipate
similar hydrokinetic costs after several doublings of its cumulative production volume.

These attainable low costs, coupled with the predictability of the water flows, and benign environmental impacts support the inclusion of hydrokinetic power systems in a diversified energy generation portfolio.

**A Megawatt Recommendation and a Timeline for Technology and Policy Implementation**

Hydrokinetic tidal and ocean turbine systems are now being developed and demonstrated in the United States and the United Kingdom. Verdant Power in the US, and Marine Current Turbines in the UK have deployed prototype systems toward commercializing their technologies. Lunar Energy in the United Kingdom has a prototype under development. In the first quarter of 2006, Verdant Power will deploy a multi-turbine system delivering electricity to customers on Roosevelt Island from the tidal flows of the East River in New York City. The company is working with the California Energy Commission (CEC) for developing technology approaches for extracting electricity from California’s aqueducts and canals. The two UK firms are positioning to exploit ocean currents for major projects around the world.

The potential in the western states for kinetic hydropower applications is significant. From among the strong ocean tidal currents in the Pacific Northwest, California, Alaska, and Hawaii; the fast rivers flowing throughout the West; and man-made canals and channels; the kinetic hydropower potential is in the tens of thousands of megawatts.

Verdant Power estimates, assuming that the US, or the Western State governments as a whole, implement policy and tangible measures to stimulate kinetic hydropower energy technology electricity generation no later than 2006-2007, that the commercial capacity installed in the US over the next ten years will be:

- 2008 – 2010  5 – 100 MW
- 2011 – 2013  500 – 1000 MW
- 2014 – 2015  1000 – 3000 MW

Delays in policy implementation will result in much of this capacity being initially directed to Canada and the UK, followed by deployments in other resource rich off-shore areas.

**Barriers for the Technology and Proposed Solutions**

The primary barriers to the above capacity being installed in the US and a commercialization of hydrokinetic technology in general are as follows:

1. **Financial.** There is little investment financing to support new technology
development in long-term resource based industries. The private investment financing model requires investment payback in 5-7 years when a single project may take 2-3 years to license for operation following technology development and demonstration. Financial instruments are needed for technology demonstration and development to allow technology developers to mature to commercialization. Also, aggressive front-end project financing and project buy-downs are needed to get the early-stage commercial projects in place and on the way to improving a technology to a cost-competitive, commercial scale.

2. **Regulatory.** Regulatory processes and perspectives are not kind to new technologies. Regulators survive by allowing no risk and using precedent to guide their decisions. Where no precedent exists, the burden of evidence is entirely shifted to the technology developer regardless of cost or delay. New streamlined resource regulatory approaches and perspectives supportive of beneficial new technologies must be developed and implemented to allow these technologies to emerge and get commercialized.

3. **Technical.** Conventional utility industry practice and the installed electrical infrastructure are not necessarily supportive of new technologies. Distribution and transmission grids do not have the flexibility to work with new technologies and small scale and/or distributed grid interconnection approaches. Interconnection issues with fault currents and short circuiting challenge existing grids. Integrated technical development teams from utilities and facilities developers must work together to address and simplify interconnection issues.

**Policy Recommendations to help hydrokinetic power generation meet the WGA Clean and Diversified Energy Initiative goals**

Hydrokinetic (in-stream and tidal) power generation offers the opportunity to utilize abundant western generating resources without the need to construct dams or other impoundments. The energy that can be harvested from flowing water offers the advantages of being clean, renewable, reliable, predictable and secure. This technology and natural resource can play a vital role in helping the Western Governors Association (WGA) in meeting its goal to provide 30,000 MW of clean power generation to the region by 2015.

Like any emerging technology, if hydrokinetic power generation is to full fill its potential it needs support from the state(s) in three critical areas:
- Incentives for Development
- Research and Development
- Permitting

As the Western States have seen with other technologies such as wind and geothermal, when support in these areas is provided the technologies are able to develop and help to meet the needs of the region. Fundamental to the deployment of these technologies is facilitating the ability to get the initial commercial projects in operation. With that in mind the following recommendations are offered as steps the
Western States can take collectively or individually to encourage hydrokinetic power generation to play a major role in meeting the WGA’s goal of 30,000 MW of clean power.

**Incentives for Deployment**

1. To encourage and fund new commercial hydrokinetic power projects, establish low cost renewable energy debt financing instruments/grants that include hydrokinetic power generation as a qualified generation source to be used to fund construction of hydrokinetic projects.

2. To encourage deployment, urge Congress to add hydrokinetic power generation to the definitions as part of the Section 45 production tax credit and to make these credits tradable.

3. To provide financial incentive at the state level, establish tradable tax credits similar to Section 45 Credits that would include hydrokinetic power generation and allow not-for-profit energy providers such as municipal utility districts to trade the tax credits to other entities.

4. To encourage the deployment of renewable, secure, locally distributed energy, include hydrokinetic power generation as a qualifying source in the following programs in individual states:
   - Renewable Portfolio Standards (RPS)
   - Renewable Energy Credits (REC)
   - Net Metering Programs

**Support Research and Development**

5. Support research, development and deployment projects to collect information on the technical performance and environmental impacts of hydrokinetic power systems. This should be done on a state and regional policy basis. It should include financial support for research and demonstration projects. The efforts could be funded from states’ user benefit funds as part of a comprehensive program that incorporates the test center(s).


**Improve Permitting Processes**

7. Clarify permitting programs to encourage demonstration project by making a distinction between the requirements for demonstration projects and long term commercial development. This would speed the process to put demonstration projects in the water to gather performance and environmental information.
Information gathered from these demonstrations could serve as the basis for conditions for licensing of full scale commercial operations.

8. Amend permitting programs to make a distinction in the requirements for deployment in manmade channels an opposed to natural streams and estuaries to acknowledge the anticipated lesser environmental impacts and allows projects in manmade channels to proceed at an accelerated pace. This would advance information gathering on technical performance and aid in the decision process for technologies to be deployed in natural streams and estuaries.

9. Develop collaborative permitting programs at the state and regional level that coordinate requirements from all of the jurisdictional agencies, including federal, to avoid duplicative processes and reduce the time and cost to deploy demonstration and ultimately commercial projects.

References:


(2) The Commercial Prospects for Tidal Stream Power, Binnie Black & Veatch for the UK Department of Trade and Industry, (dti/Pub URN 01/1011), (ETSU T/06/00209/REP), 2001

(3) The Costs of Generating Electricity, by The (UK) Royal Academy of Engineering, March 2004
3. Opportunities for Ocean Wave Power

Prepared by:
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Wave power is an emerging energy resource thanks to new technology innovations that enable effective conversion to electric power. The CDEAC expressed interest in ocean wave energy technology during the NHA presentation at the December 8 meeting. CDEAC member and Oregon State Senator Vickie Walker also spoke of wave power technology at previous CDEAC meetings.

This section is intended to inform the Western Governors Association why wave energy technology should be evaluated as a potential energy supply source to balance and diversify the energy supply portfolio of the Western U.S.

Have you ever watched the swell of an ocean wave surging towards the shore, perhaps carrying a surfer, and pondered its enormous strength? The power of ocean waves is truly awesome. Aside from thrilling surfing enthusiasts and enthralling beachgoers, their destructive potential has long earned the respect of generations of fishermen, boaters, and other mariners who encounter the forces of the sea. Wouldn’t it be wonderful if the power of ocean waves could somehow be harnessed into useful energy to reduce our dependence on fossil fuel? Instead of burning depleting fossil fuel reserves that pollute the air and water, wouldn’t it be wonderful to obtain energy from a resource as clean, pollution free, and abundant as ocean waves? The technology, though young, exists to convert the power of ocean waves into electricity.

In 2004, an Electric Power Research Institute (EPRI) Feasibility Definition Study made a compelling case for investment in offshore wave energy technology for three (3) western states; Hawaii, Oregon and California, see references 3, 4 and 5. Sites and wave energy conversion devices were identified and assessed. Based on specific sites and devices selected by state electricity stakeholders, pilot and commercial scale plants were designed, their performance and cost was estimated, and their economics assessed.

Feasibility studies for Alaska, with more than one-half of the nation’s offshore wave energy resource, but sparse population and electrical load, and Washington State, with no transmission from the coast to the inland load centers, were also considered but not performed.

Benefits Identified for Hawaii, Oregon and California

Using wave energy to generate electricity would provide many far-reaching benefits. The construction, operation, and maintenance of wave power plants would create jobs, promote economic development, and improve the energy self-sufficiency of coastal
states. Other compelling arguments for offshore wave energy technology in these states were reported. First, with proper siting, converting ocean wave energy to electricity is believed to be one of the most environmentally benign ways to generate electricity. Second, offshore wave energy offers a way to minimize the aesthetic issues that can plague other energy infrastructure projects.

Since wave energy conversion devices have a very low profile and are located at a distance from the shore, they are generally not visible. In addition, wave energy is more predictable than direct solar or wind energy, and therefore can be more easily integrated into the overall electricity grid for providing reliable power. This characteristic of wave energy will contribute to a balanced and diversified portfolio of renewable energy sources. Consequently wave energy is an important renewable energy source and deserves a fair evaluation of its potential to add to the supply mix of HI, OR and CA.

Since this technology is in the early states of development, a relatively minor investment today can stimulate a future West Coast industry. With moderate success, this investment could generate billions of dollars of economic output and employ thousands of people, while using an abundant and clean natural resource.

**Description of Wave Energy Conversion Technology**

The Ocean Power Delivery (OPD) Pelamis WEC device, shown below in Figure 1, is one of the most technologically mature device available today. It consists of 4 cylindrical steel sections that are connected by 3 joints. The total length of the device is about 400 ft (120m) and the device diameter is about 15 ft (4.6m). The wave-induced motion of these joints is resisted by hydraulic rams which pump high-pressure oil through hydraulic motors via smoothing accumulators. The hydraulic motors drive electrical generators to produce electricity. Power from all 3 joints is fed down a single umbilical cable to a junction on the sea bed.

![Figure 1 Ocean Power Delivery Pelamis](image-url)
Other wave energy conversion technologies that are close behind the OPD technology are the overtopping Wave Dragon shown in Figure 2, other point absorbers as represented by the Wave Swing shown in Figure 3, the PowerBuoy in Figure 4, the AquaBuOY shown in Figure 5, and the oscillating water column technology of Energetech shown in Figure 6. In addition, there are several other wave energy devices being developed in the U.S. and around the world.

Oregon State University (OSU) Research Center

Oregon State University is one of the national leaders in wave energy conversion research and is now proposing to develop a national-scale research, development and demonstration test center off the coast of Oregon. A research center may be one option for attracting a wave energy project to Oregon. OSU has a track record of successful wave energy technology research. They have developed three direct drive prototype buoys designed to be anchored 1-2 miles offshore, in typical water depths of greater than 100 feet, where the buoys will experience gradual, repetitive waves. OSU’s Permanent Magnet Linear Generator Buoy prototype is shown in Figure 7, along with the research team that developed the technology. OSU’s research team continues to pursue optimum wave energy topologies and have also developed a Permanent Magnet Rack and Pinion Generator Buoy; and a Contact-less Force Transmission Generator Buoy. OSU’s goal is to expand its wave energy program and to develop a wave park in Oregon.
The long term vision of OSU is shown in the following figure depicting an array or park of direct drive buoy modules.

**Supply and Cost Curves**

It is an established fact that learning through production experience reduces costs – a phenomenon that follows a logarithmic relationship such that for every doubling of the cumulative production volume, there is a specific percentage drop in production costs. The specific percentage used in this study was 82%, which is consistent with experience in the wind energy, photovoltaic, shipbuilding, and offshore oil and gas industries.

A challenge to the wave energy industry is to drive down O&M costs. Still lower capital cost of a wave machine (compared to a wind machine) compensates for the higher O&M cost for the remotely located offshore wave machine. Figure 10 shows the industry-documented wind energy learning curve compared to wave energy costs in California. The cost of electricity from wind is about 4 cents/kWh in 2005 U.S. dollars based on
40,000 MW of worldwide installed capacity (at the end of 2004) and a good wind site. The lower and higher bound cost estimates of wave energy in California are also shown. EPRI performed a design, performance and cost system definition study for entry 100 MW commercial scale plants. The 82% learning curve is applied to the wave power plant installed cost, but not to the operation and maintenance part of the cost of electricity (hence the reason that the three lines are not parallel).

![Wave Upper Bound vs Wave Lower Bound vs Wind](image)

**Figure 10. California Wind and Wave Energy COE as a Function of Cumulative Installed Capacity**

**Status and Potential of Wave Energy**

As of September 1, 2005, there is 2.29 MW worldwide offshore installed wave energy capacity. The total installed in the U.S. is 0.04 MW.

- 0.75 MW OPD Pelamis at European Marine Energy Centre (EMEC), Orkney, Scotland
- 1.0 MW WaveSwing at Lexious, Portugal
- 0.5 MW Energetech at Port Kembla, Australia
- 0.04 MW Ocean Power Technology, Hawaii

EPRI predicts, assuming that the U.S. or the HI, OR or CA state governments decide on policy and measures to stimulate wave energy technology electricity generation in the latter half of the first decade of the 21st century, that the capacity installed in the U.S. in the following years will be:

- 2006 = 0 MW
- 2007 = 1 MW
- 2008 = 4 MW
- 2009 = 8 MW
- 2010 = 120 MW
Barriers for the Technology and Proposed Solutions

The primary barriers to the above capacity being installed in the US and a commercialization of wave energy technology in general are as follows:

1. Lack of U.S. Federal Government support. The U.S. government is and has supported the development and demonstration of all electricity technologies except for ocean wave energy. A current example is the clean coal technology development and the $1 billion for a Future Generation clean coal demonstration program.
2. Lack of U.S. Federal Government production subsidies. The entry cost of an emerging technology is high relative to established technologies. For those technologies deemed to be in the public benefit, the Federal Government has in the past subsidized early production of the emerging technology. A current example is the renewable production tax credits, which does not include renewable wave energy.
3. U.S. Federal, State and Local Government regulatory uncertainty. Given the uncertainties of permitting an offshore project, the private investment communities will chose to invest its capital in projects with less risk.

Policy that Would Support Development of Wave Energy

The following recommendations are documented in the EPRI Wave Energy Project Final Summary report, March 2004. This report is available on EPRI’s public website (see www.epri/oceanenergy/). One of these recommendations, #4 has come to pass. The U.S. has joined the IEA Ocean Energy Systems for the years of 2005 and 2006. Others may be appropriate for individual state action. And such action may influence other state and federal efforts.

The development of ocean energy technology and the deployment of this clean renewable energy technology would be greatly accelerated if the Federal Government were supporting the development. Appropriate roles for the Federal Government in ocean energy development could include some, or all, of the following:

1. Providing leadership for the development of an ocean energy RD&D program to fill known R&D gaps identified in this report, and to accelerate technology development and prototype system deployment;
2. Supporting the operation of a national offshore wave test center to test the performance and reliability of prototype ocean energy systems under real conditions
3. Development of design and testing standards for ocean energy devices;
4. Providing support for the U.S. to join the International Energy Agency Ocean Energy Systems Implementing Agreement to collaborate RD&D activities, and appropriate ocean energy policies with other governments and organizations;
5. Leading activities to streamline the process for licensing, leasing, and permitting renewable energy facilities in U.S. waters;
6. Studying provision of production tax credits, renewable energy credits, and other incentives to spur private investment in ocean energy technologies and projects, and implementing appropriate incentives to accelerate ocean wave energy deployment;
7. Ensuring that the public receives a fair return from the use of ocean energy resources;
8. Ensuring that development rights are allocated through a transparent process that takes into account state, local, and public concerns.

Examples of European Support and Mechanisms

Portugal
In 2004 the Portuguese Government set ambitious renewable energy targets of 39% and chose to effectively “import” a wave energy industry to help them achieve it. To attract technology developers they offered a dedicated marine energy tariff (some 24€cents currently and indexed linked) per kilowatt hour delivered for the first 20MW of connected capacity. The capacity figure is expected to be raised to 50MW as more projects apply for permits etc. There are a number of competing projects currently underway and OPD’s, phased wave farm development will be the first project installed under this initiative.

United Kingdom
The UK has a longer history of support for the Marine Energy Industry. Over recent years the Government has:

- Established the “European Marine Energy Centre” in Orkney, Scotland. EMEC enables machine developers a “plug in” facility where they can have their wave or tidal prototype devices independently tested and outputs verified.
- Launched the “Carbon Trust, Marine Energy Challenge” an initiative whereby device developers could get access to high level engineering design and verification through partnering with renowned engineering consultancies
- Through the Department of Trade and Industry (DTI), awarded over £25 M to support the ongoing development of marine energy devices.
- Launched a £50M support fund which earmarks £8M direct funding for EMEC and the Wave Hub initiative with the remaining £42M available to support demonstration projects. Project funding comprises both capital and revenue funding.

Wave Hub, will offer a “plug in” facility with all the necessary permits etc to allow “next generation” multi device demonstration projects to negate the cost of grid connection. Such initiatives have fostered a vibrant industry and enticed other overseas device developers to either relocate entirely to or open subsidiary companies in the UK.

Figure 11 Wave Hub Concept
Frequently Asked Questions About Wave Energy

What is wave energy?
Waves are the movement of water near the surface of the sea. Waves are formed by winds blowing over the water surface which make the water particles adopt a circular motion. The energy of this circular motion is determined by the speed and duration of the wind, the length of sea it blows over, the water depth and the sea bed conditions. The characteristic of wave energy that makes it especially attractive for electricity generation is its high power density compared to the power density of solar and wind energy.

Will these devices survive storms and the hostile marine environment?
Yes. Today’s wave energy conversion technology is the result of many years of testing, modeling and development many developer organizations. Full scale prototype have been continuously operating and providing electricity into the since the summer of 2004. The core theme of the current design concepts is survivability.

Will these devices affect the environment?
Given proper care in site planning, offshore wave power promises to be one of the most environmentally benign electrical generation technologies. We recommend that early demonstration and commercial offshore wave power plants include rigorous monitoring of the environmental effects of the plant and similarly rigorous monitoring of a nearby undeveloped site in its natural state (before and after controlled impact studies). With proper siting, offshore wave energy power plants should not cause any permanent damage to the environment.

Will the regulatory authorities grant a permit for this offshore wave power plant?
The novelty of the technology at the federal and state level will likely trigger conservative evaluations and extensive approval processes. The difficulty of obtaining a permit for a wave power plant presents a significant barrier to the development of WEC technology because:

- There is a wide variety of regulations and agencies involved with no clear jurisdictional responsibilities.
- No specific “fast-track” regulations have been developed for short-term marine renewable demonstration projects.

Permitting early wave energy plants will be a challenge since there is no precedence in the US for regulatory authorities to base an approval decision. Nevertheless, we believe that, with strong public support and the positive experiences in the UK and other countries, the Federal Energy Regulatory Agency Commission (FERC) and other federal, state and local agencies will allow this emerging technology power plant project to go forward.

Will offshore WEC technology provide reliable and cost-effective electricity?
Yes. Once WEC technology is a commercial technology, it will provide a cost of electricity equivalent or lower than that produced by existing power plant technology today.
Summary
The authors believe that a diversified and balanced portfolio of energy sources is the foundation of a robust and reliable electrical system and that offshore wave energy technology needs to be evaluated for its role in contributing to our national portfolio of energy supply technologies.

References:
All are available at www.epri.com/oceanenergy/

(1) EPRI Report WP-003-OR
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(3) EPRI Report WP-006-CA, Pilot and Commercial System Level Design Study
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