

m·werc STRATEGIC



ROADMAP ON THE ENERGY WATER NEXUS



Final Report for the Energy Water Nexus (EWN)
Strategic Roadmap Project for the
Midwest Energy Research Consortium (M-WERC).

Sponsoring Organizations

The Mid-West Energy Research Consortium (M-WERC) is a regional industry consortium that focuses on three mission areas: technology research and innovation; market, industry, and technology roadmap development; and start-up company commercial acceleration. M-WERC has funded more than 30 research projects, developed four industry roadmaps, and launched numerous start-up companies. The organization has grown to nearly 100 industry, academic, and government organization members. M-WERC is headquartered in Milwaukee, WI. M-WERC's active working groups, including the Energy Water Nexus (EWN) and the Industrial Energy Efficiency working groups, can provide information and insight to EWN and related initiatives. For more information, visit <http://m-werc.org/>.

The Water Council was founded on a century of discovering inventive solutions for water issues. The organization was established as a not for profit economic development organization in 2009 by Milwaukee-area business, education, and government leaders. With a mission of aligning the regional freshwater research community with water-related industries, it takes great pride in having coalesced the leading water technology cluster in the United States and one of the most powerful in the world. Headquartered in the Global Water Center in Milwaukee, WI, The Water Council links 180 members comprising global water technology companies, innovative water entrepreneurs, government agencies, nongovernmental organizations, acclaimed academic research programs, and energetic water professionals. It operates through collaboration between public, private and academic sectors and the shared commitment to finding innovative solutions to critical global water issues. For more information, visit <http://thewatercouncil.com>.

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Robert Eckard, PhD, provides market analysis, technical water and energy sector consulting, and business consulting in the energy, water, and environmental industries. He has supported the US Department of Energy, the US Air Force, the California Energy Commission, various local agencies, and private industry in the development of comprehensive market evaluations, technical and strategy roadmaps, environmental analyses, and water and energy sector evaluations and advanced planning. He maintains a working familiarity with numerous conventional and advanced/renewable energy and water technologies and markets. Robert completed his dissertation in water quality and carbon management at the University of California at Davis; he also holds a BA in ecology from the University of California at Santa Barbara.

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The project was developed, organized, and coordinated by the following participants.

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Elizabeth Thelen	The Water Council – Project Leader
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STRATEGIC ROADMAP ON THE ENERGY WATER NEXUS

EXECUTIVE SUMMARY

Introduction

The Energy Water Nexus (EWN) strategic roadmap project involved close collaboration between the Midwest Energy Research Consortium (M-WERC) and The Water Council, two regional leaders in energy and water efficiency and clean technology (“cleantech”) promotion. M-WERC is a leading energy, power, and control consortium that develops proprietary industry and technology roadmaps. These drive the organization’s platforms for technology innovation, market, business, and start-up growth, where M-WERC is focused on the generation, storage, distribution, control, and management of energy and power. The Water Council is a premier freshwater hub linking global water technology companies, innovative water entrepreneurs, government agencies, nongovernmental organizations, acclaimed academic research programs, and some of the nation’s brightest and most energetic water professionals.

The EWN roadmap project focused on the interdependency between energy and water and identified opportunities for the Midwest region, M-WERC, The Water Council, and their members to further develop their leadership role in this emerging market space.

On a worldwide basis, the largest category for water consumption is electric power generation. Similarly, the largest demand for electricity is water extraction and distribution. This strong interdependency drives great opportunity in EWN to impact both energy and water consumption.

Available EWN literature is extensive, but almost exclusively carries a broad-brush focus: global projections, nationwide estimates, and power-industry summaries of potential energy and water savings. EWN is often defined conceptually, as a nebulous grouping of interconnections between water and energy. Unfortunately, these numbers and definitions are difficult to apply to real-world applications such as product commercialization, business development, and strategic planning. This disconnect arises because there is no easy or reliable way to downscale from the broad EWN numbers and concepts that are commonly reported, to the specifics and details needed for business or utility planning and decision making.

This report is a first-of-its kind compilation of currently available national and global EWN data, supplemented by input from dozens of EWN experts from industry, government, and academic institutions. The report seeks to provide a usable tool for M-WERC and The Water Council members to identify specific EWN applications, benefits, target markets, industry categories, technologies and

products, and active companies within the EWN market space. Additionally, this report will allow members to focus on, reposition, and analyze their products and services within the framework of the growing global and regional EWN market space. The report draws on extensive collaboration among experts, industry leaders, and thought leaders in energy, water, and related sectors.

Uniqueness of this Project

Existing analyses of EWN suffer from two key pitfalls. First, most of the analyses available in the current literature assess potential EWN water savings and energy savings using a very high-level, regional or global top-down approach. Similarly, micro studies or applications are not placed in a macro context. Both approaches limit the utility of key information (energy use, water consumption, and water stress). Second, because EWN markets have been loosely defined or have multiple definitions, EWN market values have never before been quantified. This project addresses these two issues by:

- (1) explicitly defining EWN equipment, products, and services
- (2) assessing their market value to the extent that they can provide EWN benefits, based on current available data and input from dozens of industry, government, and academic experts in the EWN space

Market and Forecast

The market analysis evolved based on a definition of EWN that was refined over time during a series of expert/industry workshops. As a result, EWN markets for facilities, equipment, products, and services can be broken into the following categories:



Energy Cycle: Energy extraction and acquisition activities (such as mining, pumping, and extracting of fossil fuels and other energy sources) and energy production (which includes both electricity generation and fuel refining) as well as the processes required therein.



Water Cycle: Water extraction from natural sources and its (wholesale) conveyance to water treatment plants and other distribution facilities, water treatment for municipal and industrial use, and water distribution to agriculture and other end users.



Process Improvement Energy: Technologies that specifically enhance energy conservation by end users (primarily industrial).



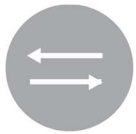
Process Improvement Water: Technologies that specifically enhance water conservation by end users.



Energy Efficiency: Technologies and systems that primarily focus on enhancing energy efficiency.

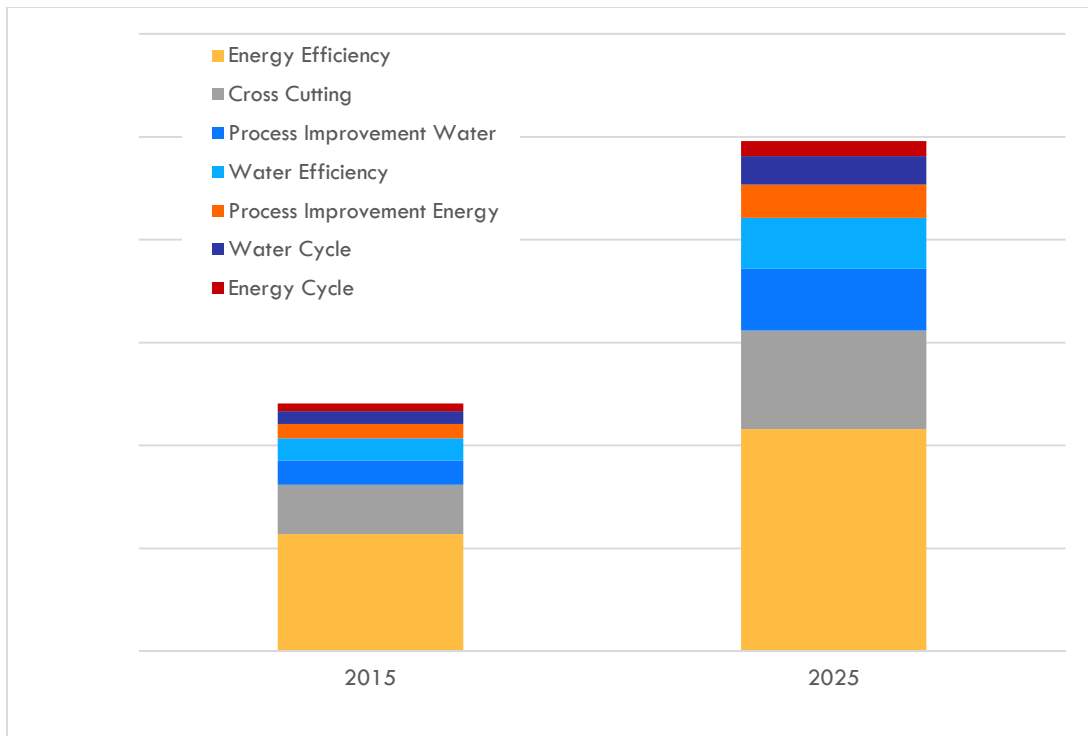


Water Efficiency: Technologies and systems that primarily focus on enhancing water use efficiency or reducing water consumption.



Cross Cutting: Technologies that support process improvement and energy/water efficiency in multiple categories.

Figure a – EWN Opportunity Space Market Categories, 2015 and 2025 (\$billions)



As shown in Figure a, the global market for all EWN related categories totaled an estimated \$241 billion in 2015, with total market values projected to increase to \$496 billion in 2025. This is equivalent to a compound annual growth rate (CAGR) of 7.5% overall. This rate of increase suggests a strong overall growth rate; however, as discussed in the body of this report, this growth rate is not uniform across all sectors, with some categories showing rates well in excess of this average.

Because EWN encompasses a large array of widely variable systems, products, and services, drivers for the individual technologies included in the EWN market are also highly variable. Nonetheless, several foundational drivers that affect the need for water and energy savings and/or efficiency are widely applicable. Globally, key drivers include the following:

Water availability or scarcity: In regions where water is scarce, a much greater emphasis is placed on water conservation and reuse. Also, energy intensity of water in these areas is often greater, because more treatment, including desalination, water recycling, and associated pumping, combined with longer conveyance distances may be required. Water scarcity can occur as a result of the naturally uneven distribution of water across a region (supply), increased human and ecosystem/environmental need for water (demand), or a combination of both of these factors.

Climate variability: Episodic droughts, heat waves, and cold spells can drive temporary changes in energy and water use. Climate variability can also encourage local and regional planners to implement energy and/or water saving technologies and systems and other conservation methods.

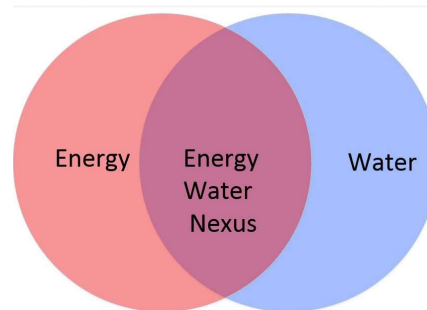
Regulation: Minimum energy and water efficiency standards, green building standards, net zero energy goals, greenhouse gas (GHG) emissions reduction targets, and other standards and guidance can support EWN market development.

Global economic status: Developed nations are generally more effective at enforcing regulations that support EWN markets, whereas basic infrastructure needs may drive markets in developing countries.

Environmental stewardship: Energy and water conservation is also promoted in some areas as a facet of environmental stewardship and efforts to mitigate or reduce the effects of global climate change. For example, a given city or other local or state governing body may implement water conservation measures to minimize potential environmental effects or employ strategies and plans to reduce GHG emissions including increased energy efficiency. In practice, however, GHG emissions reduction or energy efficiency planning is strongly influenced by the stringency of overarching regulations, while most water conservation measures related to environmental stewardship are deployed in areas where water availability and scarcity are major concerns.

This analysis enabled the project team to identify a threshold for determining which market categories and products should be considered in EWN. Early efforts to develop an EWN definition used several tools to introduce the EWN concept. For example, the Venn diagram in Figure b shows EWN as the intersection between the energy and water market categories. Further analysis and data, however, showed that this “definition” oversimplifies the relationship of the energy and water segments.

Figure b – Early Visualization of EWN Concept



In continuing the development of this concept, we deconstructed the EWN Opportunity Space into six EWN market categories, as indicated in Figure c, in a diagram resembling a pie chart. Data was captured on sub-markets within each category, and analysis was completed along these categories throughout the project.

Please note that the figure on the right is a diagrammatic representation and not meant to be quantitative.

Finally, after developing the EWN Opportunity Space concept and testing various definitions against assembled data, we identified the EWN Core. Figure d represents the six EWN market categories with the center depicting the EWN Core, which intersects all of the categories.

It became evident during the analysis that some opportunity segments crossed multiple EWN market categories. Although originally identified as part of one EWN market category, each was placed in the special “Cross Cutting” category. This category of cross-cutting technologies, which intersects all categories and the core, is also shown in Figure d.

The EWN Core represents the highest leverage, threshold-tested EWN opportunities, while the EWN Opportunity Space represents markets that are related to EWN but do not have a major impact on energy and water savings. This topic is discussed in more depth in “**Error! Reference source not found.**” in the body of this report.

Figure c – EWN Opportunity Space

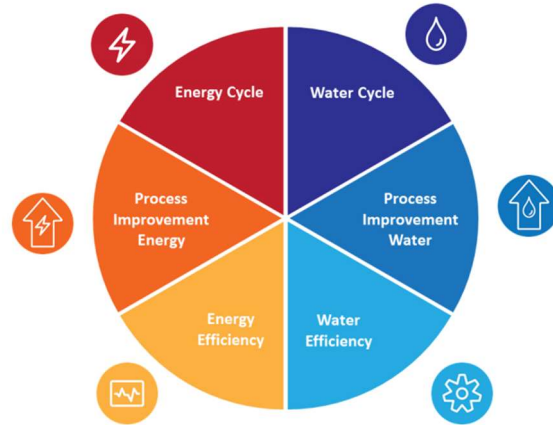
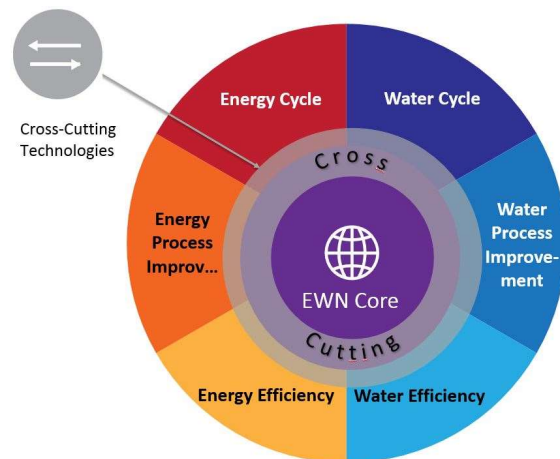


Figure d – The EWN Framework



The following definition for the EWN Opportunity Space captures the spirit of these discoveries:

Energy Water Nexus (EWN) Opportunity Space is composed of products and technologies that optimize the conjunctive use of water and energy by:

- Reducing the energy and water required to produce services or products that use intensive water and energy inputs
- Increasing the availability of clean energy and useable, fit-for-purpose water
- Leveraging efficiency improvement strategies and methods developed in other markets for energy and water

Industries associated with the EWN achieve this optimization by focusing on the interdependency of major energy and water uses through end users, policies, suppliers, and technologies in both mature and developing markets.

The adoption of this definition and segmentation allows clear market stratification and identification, the clarification of regional priorities and competing interests, and the start of implementation of the EWN roadmap. Additionally, project- and technology-level goals can be applied for near-term thresholds. More details on the thresholds, market categories, and companies included in the analyses are contained in the body of this report.

The EWN industry achieves optimization by focusing on opportunities where major energy and water consumption converge. This optimization occurs in both mature and developing markets, through the efforts of industry suppliers that introduce technologies, and through the efforts of users whose choices are influenced by policy. Another part of this effort, without intentionally focusing on an EWN framework, involves commercializing and expanding the market share of efficiency products and services (i.e., building efficiency) that reduce indirect water use from power generation. As a result of EWN-focused efforts, great advances are being made in the optimization of energy and water consumption worldwide.

To further refine our ability to identify the strongest and most promising opportunities, an analysis was performed to determine the thresholds that would identify the EWN Core.

The following definition of the EWN Core emerged in our search for thresholds:

The Energy Water Nexus (EWN) Core represents the highest leveraged opportunities that can make significant improvements to energy and water consumption worldwide. Selection as an EWN Core opportunity requires meeting at least one of the following thresholds (2025 global potential):

- 49 billion gallons water per year – or –
- 90 terawatt hours electricity per year – or –
- \$ Equipment market over \$25 billion

Examples of products and technologies included in the EWN Core are wastewater recycling equipment, energy efficiency control systems, water leak detection equipment, variable-speed drives, and

medium-speed engine power plants. More discussion on these and other important EWN technologies, products, and companies is included in the body of this report.

EWN opportunities will vary regionally and even locally. To facilitate evaluation of local opportunities, the project team has identified attributes that will help members and teams determine the most impactful opportunities that may be applicable in their areas.

Regional Gaps, SWOT, and Action Planning

After identifying strengths, weaknesses, opportunities, and threats (SWOT), the project team determined that the Midwest region, M-WERC, and The Water Council are positioned well for leadership in the growth of EWN:

Strengths	<ul style="list-style-type: none"> • Large cluster of EWN companies with industrial base for EWN projects. • Extensive regional EWN research and demonstration projects. • Established energy and water industry and innovation clusters located in same region and city.
Weaknesses	<ul style="list-style-type: none"> • Regional market limited by Midwest region’s low energy and water prices. • Pipeline limited for securing large grants. • Limited collaboration across major Midwest metropolitan centers.
Opportunities	<ul style="list-style-type: none"> • Expand M-WERC and The Water Council cooperation. • Solicit EWN research hub (DoE, NSF) and promote regional investment of EWN and demonstration projects. • Develop innovative funding model.
Threats	<ul style="list-style-type: none"> • Water’s value as an incentive for action is tied to availability or lack of availability of acceptable-quality water within a local jurisdiction. • Lack of water scarcity affects Midwest region’s urgency to act and thus dampens innovation and project investment. • Other strong regional clusters outside Midwest region divert resources and dilute The Water Council and M-WERC’s message.

Regional gaps center around lack of a common definition for EWN, inconsistent data on water use and efficiency, inadequate system-level water efficiency standards, and integrated water and energy policy and regulations. These gaps also drive lost opportunity from well-established energy efficiency programs that do not reward water efficiency.

The regional strengths and opportunities are sufficient to offset the major weaknesses and gaps related to lack of awareness and categorization of EWN opportunities. The EWN project identified a comprehensive action plan encompassing over 20 potential action areas. A linchpin recommendation is the formation of an EWN working group which would act as a regional platform for EWN development and the implementation of the comprehensive roadmap plan. The EWN working group will be founded by the EWN project Steering Committee and will include numerous members of M-WERC and The Water Council who participated in the EWN industry roadmap as well as subject matter experts. This approach will continue the significant momentum and working knowledge built during the project to carry forward implementation of EWN opportunities. During the first year, the

working group will focus on building awareness for the opportunity, expanding regional participation and the initiation of several specific projects identified by the plan.

Previous strategic roadmap projects developed by M-WERC – most notably, for energy efficiency technology, systems, and solutions (EE-TSS); energy storage systems (ESS); and distributed energy resources and systems (DERS) (microgrids and self-generation) – offer lessons learned and best practices that can be applied to the implementation of EWN roadmap:

- Initially prioritize tasks that are readily achievable in a reasonable timeframe.
- Initiate actions with creative application of resources (i.e., do not postpone actions until major funding is available).
- Establish champions in key decision-making areas to support the activities.
- Recruit a working group whose participants have sufficient focus and available resources to complete tasks, meet goals, execute the plan, and then hand off the project through a dialogue with the project team.
- Periodically reinforce the working group mission and refresh the background roadmap and its assumptions.

As proven in other related industries, many factors and developed resources including extensive market databases and market information, established working groups for economic development, and ongoing technology research can contribute to the success of this EWN project. Further details on the specific recommendations for the working group to consider are included in the body of this report.

Insights from EWN Roadmap

The following summarizes some of the key insights developed during the EWN project:

- A complete and broadened definition of EWN with expanded focus on saving embedded energy and water.
- The EWN market is extraordinarily large and is poised for strong growth over the coming decade. Currently estimated at \$241 billion, the global EWN market will double in size by 2025, when it will reach approximately \$496 billion.
- The highest impact, or Core EWN market, applications represent \$259 billion, or just over one half of the market by 2025.
- The vast majority of the new EWN market opportunity lies outside of the Water and Energy Cycles in Energy Efficiency, Water Efficiency and Energy and Water Process Use Efficiency
- Energy Efficiency is the largest single EWN market opportunity (44% in 2025) followed by Cross-cutting technologies (19% in 2025) and Water process technologies (12% in 2025).

- Wisconsin and the Midwest Region are well positioned to be a national and international market leader.
- The geographic market for EWN is global and regional needs vary based on core differentiators.
- This is the first integrated, comprehensive view of EWN providing a detailed, bottom-up, quantification of the market potential including key EWN products, market segments and companies.