MODIFICATION

All modifications to the Request for Information (RFI) are highlighted in yellow in the body of the RFI.

Mod. No.	Date	Description of Modifications
0001	07/18/2017	Change the submission deadline for responses to this RFI from 07/28/2017 to 08/28/2017.

This is a Request for Information (RFI) only. EERE will not pay for information provided under this RFI and no project will be supported as a result of this RFI. This RFI is not accepting applications for financial assistance or financial incentives. EERE may or may not issue a Funding Opportunity Announcement (FOA) based on consideration of the input received from this RFI.

DE-FOA-0001676: REQUEST FOR INFORMATION ON CLEAN WATER TECHNOLOGIES

ISSUE DATE: May 30, 2017
RESPONSES DUE: August 28, 2017 (5PM ET)
SUBJECT: Request for Information (RFI)

Description

This RFI seeks feedback on technologies with the potential for early stage research and development (R&D) that if successfully advanced could impact the cost-effective and energy efficient availability of clean water processed from a variety of sources such as surface water, ground water, brackish water, seawater, wastewater and produced water for a range of applications including municipal drinking water, agricultural uses, and industrial needs. Results from this research and development would further the administration's priority to ensure clean air and clean water for the US.

Background

Water and energy systems are interdependent.[1] In terms of clean water production, energy is required to extract, convey, and deliver water of appropriate quality for diverse human uses, and then again to treat wastewater prior to return to the environment. As population grows (and shifts) and traditional water sources become a less sustainable option, the demand for clean water from non-traditional sources (e.g., seawater, brackish water, produced water, etc.) are expected to grow. New technologies to ensure clean water are also essential to the production of energy including fuels, electricity, mineral resource, agricultural and forest products. As current technologies are energy-intensive, costly and at time somewhat inflexible, it is imperative that technology research and development is done now to minimize energy consumption and optimize the way in which energy sources can be integrated to produce clean water in a wide range of applications.

Producing water at sufficient quality for various applications can take a significant amount of energy, and the exact amount of energy used depends on the water source and target purity for the aimed application. As an example, to produce potable water from seawater takes about

[1] http://energy.gov/under-secretary-science-and-energy/downloads/water-energy-nexus-challenges-and-opportunities

3-5 kWh/m^3 (for reverse osmosis (RO) based technologies), when considering intake, pre-treatment, purification, effluent processing and post-treatment, whereas the corresponding amount of energy for producing pipe parity water, from fresh water, for public use ranges from 0.12 kWh/m^3 in New York to nearly 2.6 kWh/m^3 in Southern California[2]. As a national average, there is 135 TBTUs (39.2 Billion-kWh) of electrical energy used to deliver 60.8 Billion m^3 of water for municipal use, or approximately 0.65 kWh/m3 of on-site energy representing a pipe-parity for energy.[3] The purpose of this RFI is aimed at identifying the key technological opportunities for research and development to produce clean water from a variety of sources and for a variety of end uses at cost and energy pipe-parity relative to current methods of delivering water.

One motivation for this RFI lies in the amounts of untapped water resources that could be utilized if key technical challenges are addressed to produce clean water from a variety of sources at the lowest possible energy and economics. The potential for advancement of technologies that can lower energy consumption and cost, exists at all the stages of clean water production. As Figure 1 schematically shows this includes intake, purification, post treatment, transport and handling or treatment of residuals/wastes. Furthermore, there is an opportunity to address early stage R&D challenges which, if solved, would advance technologies for the supply of energy in water processing, to allow for the optimum use of renewable energy (solar, geothermal and wave), waste energy and nuclear energy in addition to electricity derived from fossil energy sources.

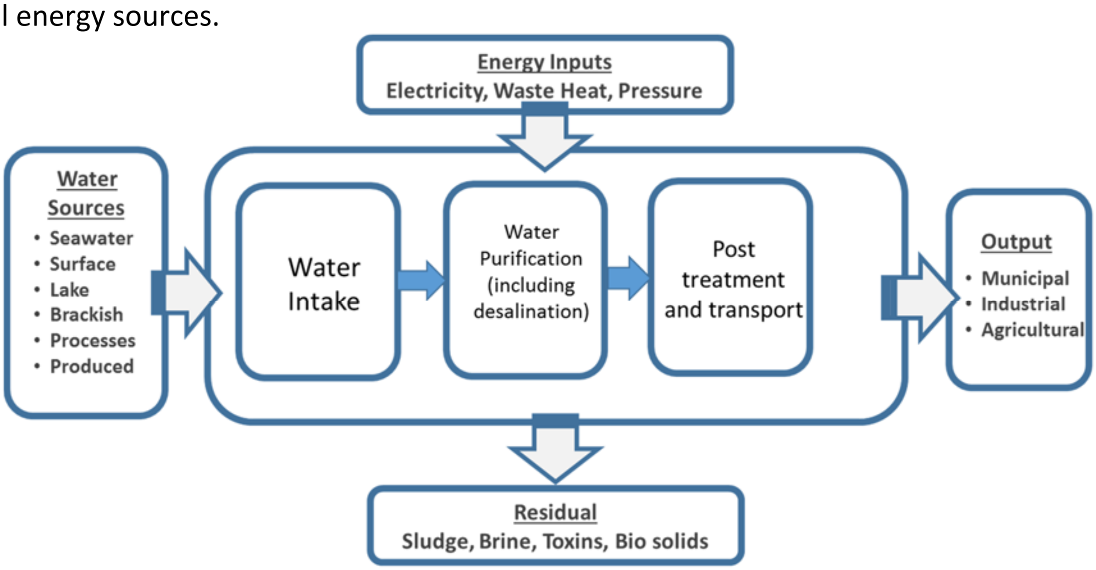

Figure 1: Water purification steps when considering a range of sources and targets.

[2] http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001433
[3] *Ibid.*

Finally, clean water production has the opportunity to adopt technologies that enable flexibility in terms of water source. Opportunities for advancement of technology in these areas include:

- **Fresh surface, lake, and ground water**: Fresh water sources can feed municipal systems and agricultural needs but also are used for industrial, mining and thermoelectric applications. These sources constitute only about 3% of all the world's water. Technologies for water treatment includes coagulation and flocculation, sedimentation, filtration, and disinfection and removal of bio contaminants.
- **Brackish water** (0.05-3% NaCl)**:** Brackish water may result from the mixing of seawater with fresh water, as in estuaries, or it may occur in brackish fossil aquifers. Domestic sources include Louisiana and Florida (lakes), Delaware and Chesapeake Bays (estuaries), and agricultural water. Treating brackish water requires a degree of desalination in addition to the other steps, and the technology may be a compliment to technologies for desalination of seawater.
- **Seawater** (3-5% NaCl)**:** Seawater provides a vast source for water and could potentially supplement the water needs in coastal areas, some of which currently experience water stress. Furthermore, civilian and military populations in islands could be self-sufficient in terms of water needs if seawater was efficiently utilized. Domestic processing of seawater currently relies on large-scale, energy-intensive desalination facilities. The most energy efficient current approaches are based on reverse osmosis technology.
- **Produced waters:** (3-5% to 30%) This includes, but is not limited to waters produced as a byproduct during the extraction of oil and gas (produced water) and injection of CO_2 (extracted water). This water is brine and contains a variable range of NaCl (from 3-5% in produced water to up to 30% in extracted water) in addition to a higher amount of other dissolved solids. Currently, the cost of re-injecting the contaminated water amounts to \$5-6/m^3. Such a source could potentially offset water needed for agricultural use, mineral extraction and processing or for reuse in oil and gas production. Desalination of produced waters offers a particular challenge with regards to the hard-salts clogging pores, but also opportunities since the high concentration of salts makes new technology approaches such as forward osmosis potentially favorable.

Because most water sources have a varying degree of salinity, breakthrough enabling technologies for clean water production could potentially form a core focus of a larger strategic investment in clean water production and processing, complemented by early stage R&D in areas like pre-treatment, waste treatment, and systems-level optimization, among other areas. As an example, the theoretical minimum energy for desalinating water of 35,000 ppm salt to pipe parity (<500 ppm) at a recovery of 50% is around 1 kWh/m^3. State of the art RO membranes are reported to perform at 2 times this theoretical limit and therefore a practically approachable limit may be close. Nevertheless, any improvement on the water recovery percentage, salt (and other impurity) rejection percentage, membrane resilience to corrosion and bio-fouling will have a significant impact on total system cost and energy consumption due to potentially large amounts of water that would be processed. In addition, an estimated >1 kWh/m^3 of energy is spent on intake, pre- and post-treatment and waste discharge. Further, if water transport through pipes is considered, the pumping cost could very quickly exceed the other costs depending on the distance and landscape for water distribution. Clearly, the energy costs are a significant barrier to reaching the pipe parity cost and technical breakthrough to overcome these challenges is needed. Considering the geographical variations in available water sources and needs (municipal, agricultural and industrial) it is important to develop technologies for a holistic and sustainable solution (or set of solutions) for clean water production that can be applied to lake, surface, brackish and produced waters in addition to traditional seawater desalination.

Challenges to the wide-spread adoption of clean water processing and production of these water sources include: (1) the cost of installation and operation of treatment and processing systems and (2) the energy use and carbon emissions resulting from traditional processes associated with high-salinity water sources. For example, the economic cost of producing water through seawater desalination is two to four times higher than the current cost of providing fresh water from traditional sources, depending on location. For example, the San Diego Water Authority is reportedly paying $1,849-$2,064 per acre-foot in 2012 dollars for desalinated seawater from the water treatment plant in Carlsbad in California, while the average price of municipal drinking water in the United States is approximately $617 per acre-foot. Similarly, the energy used in the production of clean water through desalination is four to five times higher than the energy consumption associated with providing fresh water by traditional means. It is also noted that the energy used to power pumps and other machinery is supplied through electricity generated through fossil fuel and herein lies an opportunity for reducing cost if renewable sources and/or waste heat can be effectively and appropriately utilized for the production of clean water. Finally, there is an urgent need to develop the necessary infrastructure to ensure reliability of the water quality. This requires continuous on-site monitoring of the entire water supply line, from intake to supply, and measures for containment of inorganic toxic impurities such as cyanobacteria or inorganic toxins such as heavy metals. There will be a need to develop transformational bio-engineering that can be integrated in current and future water production facilities (regardless of water source) to handle an increased threat posed by bio-organisms amidst increase in population and global warning. There will also be a need to develop pipes and pumps that can withstand environmental degradation regardless of water source.

Purpose

The purpose of this RFI is to solicit feedback from industry, academia, research laboratories, government agencies, and other stakeholders on issues related to opportunities for the research, development and demonstration of technologies with the potential to reduce the cost and energy and increase performance of approaches to clean water processing and production. There is a need for technological breakthroughs for enabling a water infrastructure that is resilient towards climate change, population growth and movement, changes in industrial landscape and energy supply which were identified as a key opportunities in the FY14 DOE "Water-energy Nexus: Challenges and Opportunities" report[4].

This is solely a request for information and not a Funding Opportunity Announcement (FOA). EERE is not accepting applications.

Request for Information Categories and Questions

Respondents may provide answers to as many of the questions in the categories below as they wish.

Depending on source and use, production of clean water includes several steps connected in series, such as water intake (pumping, storage, pipe transport etc.) followed by a set of purification steps (e.g. screening, filtration, desalination, sedimentation, and coagulation/flocculation) and treatment steps (e.g. disinfection), then waste processing (from each purification step) and transport to the target user. The specific steps will vary depending on water source and target use but as an example could be those shown earlier in Figure 1. The underlying strategic goal behind this RFI, is to enable clean water production from (i) a variety of sources, (ii) through the least possible energy consumption and (iii) by optimizing the use of renewable and waste energy sources.

Category 1: Benchmarking state of the art commercial water purification.

Considering that there are a number of sources for water, applications of this water, and treatment technology types, it is important to benchmark the input water quality, required

[4] http://energy.gov/under-secretary-science-and-energy/downloads/water-energy-nexus-challenges-and-opportunities

water quality for each application, and the energy and cost intensities of each treatment technology type. The following table was developed to capture this benchmark data.

Source	Quality (TDS)	Application	Quality (TDS)	State of the art Treatment Technology	Energy Intensity (kWh/cubic meter)	Cost Intensity ($/cubic meter)
Fresh Water	XX	Drinking Water	XX	XX	XX	XX
		Agriculture	XX	XX	XX	XX
		Industrial	XX	XX	XX	XX
Brackish Water	XX	Drinking Water	XX	XX	XX	XX
		Agriculture	XX	XX	XX	XX
		Industrial	XX	XX	XX	XX
Seawater	XX	Drinking Water	XX	XX	XX	XX
		Agriculture	XX	XX	XX	XX
		Industrial	XX	XX	XX	XX
Produced Water (from oil/gas)	XX	Drinking Water	XX	XX	XX	XX
		Agriculture	XX	XX	XX	XX
		Industrial	XX	XX	XX	XX

1) Please provide a quantitative value to the table where you find the parameters relevant, including citation in support of these values when possible.
2) When calculating the energy and cost intensities of water processing and purification, we have to consider benchmarking for all types of contaminants. Is there another metric for water quality that would better capture the presence of all contaminants and thus more accurately represent energy and cost intensities of water processing and purification? Candidates may include Silt Density Index (SDI) or a combination of TDS and total suspended solids (TSS).
3) Are there additional categories of water sources or applications we should consider? If so, please list them and their associated water qualities.

Category 2: Identifying opportunities in water intake, purification and pre-treatment before desalination. When determining the energy and cost intensities of water processing and purification, material replacement/shut down due to environmental degradation and containment of bio-fouling elements needs to be considered, especially for pre-treatment of salt and brackish water which may share commonalities with purification of fresh water.

1) What science and technology improvements can be done on lowering the cost and energy required for water intake and pre-treatment for clean water processing?
2) What (if any) commonalities are there in fresh water purification and seawater pre-treatment in terms of technical challenges and opportunities?
3) What science and technology improvements can be made in the water intake infrastructure for seawater in terms of pump efficiency and low friction pipes and fouling/corrosion resistance of these parts?
4) What science and technology improvements can be made in water pre-treatment in conjunction with Reverse Osmosis (RO), with regards controlling the bio-environment?

Category 3: Identifying opportunities for water sources with high salt levels (brackish-, sea-, produced- and extracted water). When determining the energy and cost intensities of water processing and purification, desalination is an energy intensive step, contributing to the overall operating cost. RO is often considered to be a mature membrane technology. Two particular concerns have developed in the last few years. The first is energy use accompanied by a high carbon footprint. The second is biofouling which increases both energy use and chemical cleaning frequency, giving a higher carbon footprint and creating a waste sludge for disposal. Literature suggests that there is room (albeit limited) for improvement of the energy efficiency when applying state of the art RO membranes for desalination[5] but notes that there are significant opportunities in the robustness of the membranes and in optimizing their performance. Alternatives to RO are also needed depending on contaminant type and level.

1) What are the technical barriers for narrowing the gap in energy consumption between what is practically achievable (considering the thermodynamic limits) and the current best practice?
2) What opportunities are there for scientific and technological advancements to narrow the gap between theoretical and current state of the art RO membranes in energy consumption (e.g. increased salt and other impurity rejection, and increase in water recovery percentage) in terms of materials, system design etc.?

---

[5] M. Elimelech and W.A. Philip, "The Future of Seawater Desalination: Energy, Technology and the Environment", SCIENCE, Vol. 333, 2011, pp. 712-717

3) Frequent cleaning reduces RO membrane life and impairs performance so that replacements are more frequent and costs are higher. Biofouling is an extremely challenging issue, experienced routinely offshore: How is the environmental footprint of RO membranes being reduced through biofouling improvements?
4) What science and technology alternatives to RO are promising for and could narrow the gap between theoretical and practical limits for energy consumption?
5) What thermal desalination technologies have potential to compete with RO on either cost of treated water or total energy consumption? What technical innovations are necessary?
6) What technological barriers need to be overcome for making FO (Forward Osmosis) energetically competitive in terms of e.g. membrane technology and draw solution?
7) Produced water is currently re-introduced to the environment at a very high cost and the re-injection inland has been associated with potential seismic activities. It would therefore be desirable to find alternative uses for produced water through breakthrough technologies to reduce the cost of oil/gas extraction and to reduce stress in fresh water usage.
    a. What is the range of the quality of produced water from oil and gas operations by basin?
    b. Current technologies implemented offshore to monitor water quality are either labor intensive, or are not robust in the offshore environment. There is a gap in Automated Water Quality Analysis as a reliable continuously monitored and recorded system that can measure SDI (Silt Density Index) and TSS (Total Suspended Solid): how is this gap being addressed?
    c. What is the capability of existing water processing and purification technologies to treat large and small ranges of produced water salinity?
    d. Are there novel approaches that can be employed for desalination of produced waters with very high TDS (TDS >180,000ppm) that are cost effective and energy efficient in comparison to existing technologies?
    e. What are the current technologies (and their limitations) to remove heavy metals, trace metals, and naturally occurring radioactive materials from produced water?
    f. Produced water also contains a wide range of dissolved and suspended materials that include fatty acids, dissolved gases and hydrocarbons. What are the current technologies to remove these and what are their limitations?
    g. Is a critical science and technology breakthrough necessary for treating produced water for different beneficial end-uses? E.g., agriculture, thermoelectric, municipal, manufacturing and oil and gas production.

Category 4: Identifying opportunities for post-desalination treatment and treatment/ handling of residue. The cost and energy associated with the post-treatment after desalination and handling of residue (sludge, brine etc.) needs to be considered when evaluating the operating cost. What science and technology opportunities exist for wider utilization of water residues from other sources and is there critical science and technology breakthrough needed to enable this?

Category 5: Clean energy for water purification. This RFI seeks information that could inform the technical potential for design and implementation of water processing and purification technologies directly integrated with renewable and waste energy, where cost may be reduced via the use of renewables and enable grid independent modular operations. DOE is particularly interested in innovations to utilize solar thermal resources for desalination technologies. This includes, but is not limited to, the following questions:

1) What are the advantages and disadvantages of a renewable and/or waste energy water desalination station compared to current commercial water desalination plants that use electricity from the grid?
    a. Powered directly by photovoltaic panels
    b. Powered by solar thermal energy
    c. Powered by wave energy
    d. Powered by geothermal energy
    e. Powered by wind energy
    f. Powered by waste heat from other processes
2) What are the impacts of variable energy sources (e.g., a variable solar resource) on such a plant? What storage technologies (thermal, electric, or other) are available to mitigate that variability?
3) What are the characteristics (cost and performance) of a thermal desalination technology based on renewable heat (e.g. solar thermal) that would be competitive with current membrane-based technologies? What are the most appropriate market applications for renewable thermal desalination?
4) What analysis is necessary to quantify the geographical overlap of solar, wind, wave and geothermal energy resources, saline water, and the market demand for desalinated water?
5) What technological challenges need to be overcome with regards to the infrastructure required in coupling power from various clean energy sources and waste energy from other sources to water purification?

Category 6: Analysis, Monitoring, and Control.

1) What analyses are necessary to quantify the geographical overlap of solar, wind, wave and geothermal energy resources, saline water, and the market demand for clean water?
2) In what ways could the ability to sense and respond to changes in pressure, flow, chemistry etc. in the system enable breakthrough in cost and/or energy through optimization in process control?
3) What analytical tools need to be developed to quantify the economic and technical potential of clean energy sources for desalination/purification in potential markets?

Category 7: Identifying opportunities for operational flexibility. There are several benefits to having a water processing and purification facility that can operate flexibly. For example, the fact that water, unlike electricity, is easily stored allows desalination plants to potentially provide services to the electricity system through time-shifting of electricity consumption, demand response, ancillary services, and potential utilization of over generation by variable energy resources. Such a facility would need to vary its operations depending on current conditions and successfully balance input and output flows of water, electricity, and wastes, while addressing water demand, electricity system services market opportunities, and environmental goals. There are also spatial and market flexibility aspects to consider.

1) How technically responsive to changing conditions would a desalination system need to be in order to cost-effectively maximize potential benefits to the electricity system? How would you quantify and monetize the value of the electricity system services provided by a flexible desalination system?
2) What technical characteristics would a desalination system need to have in order to offer the level of spatial flexibility required to serve islanded communities or provide mobile water purification services for emergency response?
3) What is a useful metric (or set of metrics) for measuring the flexibility of a desalination system?
4) What are the technical barriers to successful implementation of a flexible desalination system?

Category 8: Other. Please add any relevant information not covered under the previous categories.

Disclaimer and Important Notes

This RFI is not a Funding Opportunity Announcement (FOA); therefore, EERE is not accepting applications at this time. EERE may issue a FOA in the future based on or related to the content and responses to this RFI; however, EERE may also elect not to issue a FOA. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if EERE chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of EERE funded awards, will be subject to Congressional appropriations and direction.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. EERE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. EERE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that EERE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind EERE to any further actions related to this topic.

Proprietary Information

Because information received in response to this RFI may be used to structure future programs and FOAs and/or otherwise be made available to the public, **respondents are strongly advised to NOT include any information in their responses that might be considered business sensitive, proprietary, or otherwise confidential.** If, however, a respondent chooses to submit business sensitive, proprietary, or otherwise confidential information, it must be clearly and conspicuously marked as such in the response.

Responses containing confidential, proprietary, or privileged information must be conspicuously marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Federal Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

If your response contains confidential, proprietary, or privileged information, you must include a cover sheet marked as follows identifying the specific pages containing confidential, proprietary, or privileged information:

Notice of Restriction on Disclosure and Use of Data:
Pages [List Applicable Pages] of this response may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI DE-FOA-0001676. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

In addition, (1) the header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure" and (2) every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

Evaluation and Administration by Federal and Non-Federal Personnel

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to EERE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be reviewed by support contractors and private consultants.

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to AMOCleanWater@ee.doe.gov no later than 5:00pm (ET) on the response due date listed on page 1 of the RFI. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (.docx) attachment to the email, and no more than 10 pages in length, 12 point font, 1 inch margins. Only electronic responses will be accepted.

Please identify your answers by responding to a specific question or topic if applicable. Respondents may answer as many or as few questions as they wish.

EERE will not respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Respondents may wish to provide the following information at the start of their response to this RFI:

- Company / institution name;
- Company / institution contact;
- Contact's address, phone number, and e-mail address.