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Testimony
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United States House of Representatives

Hearing on H.R. 1071, a bill to direct the Secretary of Energy to make incentive payments to the owners or operators of qualified desalination facilities to partially offset the cost of electrical energy required to operate such facilities, and for other purposes; and a Hearing on "Reducing Power and other Costs of the Desalination Process."

Mr. Chairman,
In your letter of invitation to me to present testimony on desalination, you noted that, “Ensuring a continual supply of affordable clean water is vital, and the process of desalination is one direction policy makers can pursue“. I agree strongly with the identification of clean water supply as a national issue and with desalination as being a principal solution to the emerging problem. The situation in the United States is a reflection of an impending world water crisis, as the combination of increasing demands and degrading natural fresh water supplies move us toward the tipping point where without new sources of fresh water, severe water restrictions and steeply elevating water costs will become inevitable. The impending water crisis is a national issue now because States share water resources. When large scale desalination becomes a reality, more than one state is likely to use the water produced by any coastal state. This sharing of resources will continue to be important as some current net water importing states may assume the role of water exporters. Thus, water supply is and will continue to be a national issue.

My background is extensive in a number of areas of scientific investigation and in the development and execution of basic and applied research. I talk about desalination not from the viewpoint of an established technology or company but from the viewpoint of a scientist who felt that the impending worldwide water crisis was important enough to try to make a difference by developing a promising new desalination technology. So, I left my post at the Naval Research Laboratory in 1999 and established a small research and development company with the help of a small group of visionary investors. My intention was to try and develop a chemical engineering method using industrial crystallization practices that would result in a new method for the large scale, inexpensive, more environmentally friendly, desalination of seawater. In this effort, I have become acquainted with the broad range of desalination and water treatment issues, with researchers improving existing technologies and with the development of new technologies.

I have over 250 scientific publications, with many in the field of gas hydrate, which is the industrial mineral we have identified to be used in the chemical engineering/industrial crystallization process that we believe has an excellent chance to become a new method for large scale, inexpensive seawater desalination. I am involved in the field of gas hydrate in a number of areas including the recovery of natural gas from oceanic and permafrost hydrate, industrial applications of gas hydrates including two technologies for desalination, and the planetary science aspects of gas hydrate. My edited introductory book on gas hydrate is being used as a course textbook by universities not just in the United States but also across the world. An industry-standard book on the exploration and extraction aspects of hydrate natural gas is currently about to go into press for publication in the autumn. My company holds over 10 patents in the field of chemical engineering for desalination and has more applications under examination and in preparation to make applications.

The one thing that is no longer a matter of debate is that a national shortage of fresh water exists in the United States. To some extent, the problem is parallel to any couple, which has not saved or invested enough to allow them leisure in their retirement. Their problem is not understanding how to manage their money better, for no matter how they manage it, there will not be enough to confer what they want. Their problem is that they do not have enough money. Similarly, the world’s water problem can be mitigated somewhat by conservation and better water use but the widespread impending water shortage can only be fully resolved by finding new and inherently artificial sources of fresh water. The only available source of large quantities of fresh water potentially lies in the world’s oceans. But this fresh water must be removed from the seawater by a process called desalination. We must find both better and new ways to produce new fresh water.

Currently, desalination is targeted, mainly because of its high cost, at what could be called, ‘make-up water’. That is, desalinated water is now intended to bridge the gap between the amount of water that can be produced from existing natural fresh water sources and the actual demand. Our intention should be to be able to carry out seawater desalination at costs that make it competitive with natural fresh water sources. When this can be achieved, some, if not most of the water that is currently being extracted from natural sources, can be allowed to remain in the natural cycle. Our aim should be not only to produce adequate volumes of fresh water from seawater, but also to restore the environment as a natural outcome of achieving the technology required for this new paradigm.

There is a national shortage of water now and the problem is intensifying. In addition, where there is overuse of natural water sources this leads to environmental damage. It is therefore prudent to initiate a two-pronged attack on the problem of water shortage through desalination. Immediately, it is necessary to encourage existing desalination production. This can be achieved by providing incentive payments to producers (of any desalination technology) that would have the effect of reducing the cost of energy consumed for desalination. The aim should be, however, that new technology developments should achieve sufficient improvement in energy cost of desalination so that the new or sufficiently improved technology can be implemented without the energy incentive payments required for the existing technology. In other words, the incentivization should be fixed on the energy component of desalination and not on the cost of the desalinated water as a whole. Incentivisation of the energy cost should be regarded as a temporary measure required only to bridge the transition to more efficient desalination. While making incentive payments to lower the energy costs of conventional desalination, it is mandatory to also support research that would lead to enabling new technologies. Investing in research will broaden the technological base in a way that mitigating current production costs cannot. The promotion of innovation and research into new and more efficient technologies should be embedded into the Bill.

In order to make real progress on developing new and more efficient desalination technologies, research and development into new desalination technologies should be undertaken as a matter of urgency. Very little innovative research in new technologies is presently being funded. Commercial companies are making insufficient investment to move any new technologies. American industry has enough other issues that developing enabling new technologies is low on their priority list. Increasing research funding for breakthrough and new technologies has the potential to accelerate a solution. Unfortunately, much of the research and development is being spent on 'safe' development, which involves incremental improvements to existing technology, which is actually process optimization, not research. This is happening because of the natural, but unintended operation of research funding where only projects that achieve well-designated goals are regarded as fully successful. Funders have become very conservative because the achievement of the goals identified in proposals and statements of work are the basis of 'grading' of the program managers, even though the actual achievements may be very limited and the improvement small. Innovative research, where the fully identified solution is inherently unknown and where the actual framing of the research path itself depends on results produced during the course of the research, is almost unknown today. Therefore, where research is supported as the second prong of the attack on this water problem, it must be vectored toward speculative research and development or it will simply be consumed while producing no great result. Only increased-risk research and development can produce the great result of a downward step-function in the energy cost of desalination and the new fresh water provision paradigm.

Each technology for desalination has its own particular inherent costs and benefits, inhibiting factors and opportunities. Because of this, the different technologies are usually compared through their cost structure. Of these, energy is the primary cost element, although construction costs can vary considerably for different technologies. Desalination technologies fall into two different categories; conventional and unconventional. Conventional technologies for seawater desalination today consist of thermal and membrane processes. These technologies are termed 'conventional' because they are regarded as working, industrially practiced technologies that have low risk. With respect to the difficulties commonly encountered in some of these conventional technology desalination installations, for instance the Tampa reverse osmosis facility, substantial risk factors remain even in what is considered conventional technology by industrial proponents. It must be pointed out that sequentially newer conventional technologies only become recognized as conventional after they are implemented in a number of commercial installations. The only way for a potential new desalination technology to emerge is for adequate research to be undertaken. There is no methodology for evaluating the likelihood of success of potential desalination technologies other than doing enough applied research and development to establish operating parameters and cost factors.

Of the conventional desalination techniques, thermal processes or distillation, for instance, is characteristically the most energy expensive because of the energy cost of boiling water. Modern multi-stage, multi-flash distillation technology is much more efficient than simple boiling, but it still is generally the most expensive method. Thermal methods are the oldest of the desalination technologies and their development has been carried the farthest. There is less potential for development in this technology than any other. Membrane filtration desalination methods, principally reverse osmosis, has its main energy requirement in pumping the source water to high pressures necessary to force it through the membrane filters. Improvements in membranes and membrane technology, and in energy recovery techniques, have vastly improved performance over the last ten or 15 years, but it is still relatively energy expensive. Unless there is some breakthrough in membrane technology that will vastly reduce the energy cost, there is again potentially very little gain to be expected, no matter how much R&D funding is applied. Development of conventional desalination technologies concerns the incremental improvement of existing technologies. As a technology matures, increasingly large investment in product improvement tends to increase performance in only smaller and smaller increments. Both of these conventional methods extract all or most of the water and produce considerable volumes of environmentally potentially harmful brine that has to be safely collected, transported and disposed of in an environmentally acceptable manner. This produced brine must be mixed with seawater.

Because of the limited scope for reaching the new desalination paradigm with further development of existing technology, focused research is required on new methods that have potential for seawater desalination. These methods are mainly in the fields of electrical and chemical engineering applications. A common attribute of electrical methods is that while they may work efficiently with brackish water, the currently practiced methods do not work efficiently with full-salinity seawater. Current developments in capacitive deionization, however, show promise for being able to desalinate seawater. Desalination through chemical engineering, where the formation of a crystalline substance incorporating water and rejecting salt from the crystallized material, is an attractive option.

Principal among the chemical engineering methods for seawater desalination is the use of gas hydrate in an industrial crystallization process. Gas hydrate is a solid crystalline material formed from a cage of water molecules hosting hydrate forming gas molecules within voids in the cages; the entire structure being stabilized by weak electrical bonding forces. It is a special type of clathrate, or inclusion compound. Common hydrate forming gases on Earth are the hydrocarbon gases (methane, ethane, propane, and butane), carbon dioxide, sulfur di- and trioxide, amongst others. At higher pressures and/or colder temperatures, virtually all gases will form hydrates. Although gas hydrate has often been regarded as a type of freeze desalination because of the apparent similarity of gas hydrate to water-ice, the differences between them are far more important. Water-ice (freeze desalination, which has limited scope for seawater desalination as part of an industrial process) is essentially isobaric and the control of temperature alone is available for freezing and melting the water. In contrast, the stability of gas hydrate can be controlled by varying both temperature and pressure. When gas hydrate forms, it is known for strongly rejecting dissolved solids (salts). Gas hydrate occurs commonly in nature, although not at pressure-temperature conditions where it can be easily observed. Natural gas hydrate, which is only now being recognized as potentially one of the major energy reserves of the planet, occurs in both oceanic marine sediments along continental margins and in permafrost regions. Understanding how natural gas hydrate forms has led to research to use gas hydrate as an industrial crystallization product for large scale, inexpensive desalination.

My company, MDS has initiated and carried out sustained research and development of gas hydrate industrial crystallization. MDS is now recognized as one of the leading gas hydrate research laboratories in the world, and the only one regularly growing large volumes of gas hydrate in short periods of time. We have designed, engineered, and fabricated unique experimental apparatus and are currently in what we believe are the last stages of perfecting the hydrate desalination method as an industrial technology. We have identified two different sub-technologies for hydrate formation that each have particular attributes for controlled hydrate formation and are pushing toward development of practical industrial processes. The main one of these is intended to produce very large volumes of fresh water very inexpensively, with very low energy costs.
The water matrix or buoyant hydrate separation process is intended to operate in the sea or in shafts nearby the sea using cold, relatively pure deep seawater. In this process, the hydrate is formed at depth where pressure is provided by the weight of water using natural gas that forms positively buoyant hydrate. No water is pumped to pressure and the cost for injecting the hydrate forming material can be very low where certain common supply conditions can be utilized. Once the hydrate is formed, under counter-flow conditions that hold the crystallizing hydrate in the deep hydrate formation region for a desired period of time, the hydrate is allowed to float upward under its own buoyancy. As it rises in the column or shaft, it passes with insignificant mixing from a region of seawater in the lower part of the shaft to a region of fresh water in the upper part of the shaft. Within this fresh water region, it naturally is subject to decreasing pressure as it rises and becomes unstable at a certain pressure and begins to dissociate. Dissociation is a process similar to melting where the structure at the margin of solid hydrate breaks down and releases the constituent gas and water. The gas and water naturally separate. The gas is drawn off for reuse or use elsewhere, such as in the generation of power, and the fresh water is available to be drawn off. Once the startup period for an apparatus is complete, the amount of water drawn off is directly related to the formation of hydrate. It is intended that very large volumes of hydrate be crystallized and that very large production of water take place. Because no artificial pressurization of water or thermal energy costs of the water are required, it is possible to economically remove only a small portion of fresh water from the whole of the seawater, which results in an environmentally friendly residual cooling water (the process of hydrate formation is exothermic and the water is naturally heated) that will require no mixing with seawater to make it tolerable for marine organisms.

In the course of the MDS research, considerable spin-off technology has emerged in the field of being able to carry out desalination using negatively buoyant gas hydrate and where the source water is too warm for hydrate to form spontaneously as it will in the colder water but whose bulk does not have to be refrigerated, in artificially pressurized apparatus, dewatering industrial process water effluent, such as the settling ponds of phosphate fertilizer factories, removing water from complex fluids such as water and ethylene glycol mixes, separating different gases, such as SOx from exhaust or natural gas, food processing, and the removal of water vapor from gas.

I regard it as likely that in the new desalination paradigm, different technologies can complement rather than replace existing technologies. This is known as a treatment train, the aim of which is to improve overall efficiency and performance. One of the main negative features of new technology development is that existing technology adherents inherently regard the development of new technologies as a threat their desalination technology. It is more likely, however, that bringing hydrate industrial crystallization to the desalination marketplace will actually stimulate the greater use of existing desalination technology, principally membranes or some other desalination methods suitable for brackish water. Future large scale, inexpensive desalination may involve the use of more than one technology, each removing salt within the operating conditions in which each offers best performance. For instance, thermodynamic and process modeling of a chemical engineering process for industrial crystallization using gas hydrate indicates that the process is most efficient at rendering salt from raw seawater of almost any oceanic salinity down to the level of lightly brackish water. Operated less efficiently (with respect to rate of water removal as a function of product salinity), the method may be capable of producing water of potable dissolved solids standards. Even at this level, however, the product water almost certainly will need polishing. When a conventional desalination technology such as reverse osmosis can operate within its most efficient energy/cost region to both polish and produce final product water as part of a multi-system approach, this should remove the need for incentive payments for energy.

MDS has identified Southern California as the first place that we would like to establish a major desalination facility. The deep, cold water necessary for the water matrix hydrate process to operate efficiently is available immediately off the narrow continental shelves of California, particularly southern California. There is no doubt that a market for competitively priced, new sources of fresh water exists. We are presently carrying out a site survey for an artificial island on the Coronado Bank off San Diego, which imports over 95% of its fresh water. And there is no doubt that if our production targets can be achieved that substantial reduction in water extraction for southern California may be achieved, with a consequent beneficial effect for the environment and for the water availability situation in the upstream basin of the Colorado River. Our intention is to develop a desalination installation based on our new technology that will not only provide for all the potable water for San Diego but to also allow San Diego to export desalinated water inland. Other sites for this MDS technology are also possible to the north along the coast.

In closing, I would like to add that government sponsorship of new desalination technologies and combinations of new or new and conventional technologies, is the one critical factor that may result in the establishment of a seawater desalination paradigm that has the potential to radically alter the present situation of an existing, and intensifying shortage of fresh water.