Integral Scientific Institute

18484 Preston Road
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Dallas, TX 75252

August 21, 2015

Mr. Leo Drozdoff
Chairman, Nevada Drought Forum Board
Via contact: Andrea Sanchez-Turner (asanchez@dcnr.nv.gov)

Dear Chairman Drozdoff:

Integral Scientific Institute (ISI) is a nonprofit organization with a mission of designing cost-effective and environmentally responsible solutions to complex problems like droughts. Saïd Majdi and Dr. Thomas Manaugh, directors at ISI, recently received an award from MIT for a proposal that was designed to deal with a long-term threat of water scarcity in Nevada.

The proposal and a follow-up proposal can be viewed on the MIT Climate CoLab website at http://climatecolab.org/web/guest/plans/-/plans/contestId/1300208/planId/1309211 ("Stop Groundwater Plan – Save $8 Billion") and http://climatecolab.org/web/guest/plans/-/plans/contestId/1301501/planId/1319613 ("Saving Hoover Dam"). They are also submitted here as Attachments A and B, respectively.

In brief, the proposals describe a system that could be put in place by Nevada and California to provide desalinated water from the Pacific Ocean to Californians in exchange for California foregoing a small part of its water allotment from the Colorado River in favor of Nevada. No permanent transfer of water rights would be required of California, and California would benefit from getting a reliable supply of water of higher quality than it presently gets by transporting water from the Colorado River across several mountain ranges. Reducing dependence on the present transportation scheme would allow California to save energy, reduce emissions, and avoid water loss due to evaporation, leakage, and seepage.

Nevada, on the other hand, would benefit from increased water security. Legal challenges may permanently block a plan by Southern Nevada to pump groundwater from Eastern Nevada. It would be provident for Nevada to consider exploring how our desalination plan could be a positive, long-term alternative to the challenged groundwater pumping plan.

Sincerely,

Saïd Majdi
Executive Director
said.majdi@integralscientific.org

Enclosures: Attachment A – Save 8 Billion.pdf
Attachment B – Saving Hoover Dam.pdf

Stop Groundwater Plan – Save $8 Billion

By

Saïd Majdi and Thomas Manaugh

Integral Scientific Institute

Submitted to

The 2014 MIT Climate CoLab Contest

Adaptation Category

July 14, 2015

About the Authors

Saïd Majdi – said.majdi@integralscientific.org

Saïd Majdi received his MS in electrical engineering from the Paris Institute of Technology in Paris, France, with dual specialization in telecommunications and control engineering. He has 30 years of experience in electronic product development and large-scale system design, development, integration and modernization. For the last 20 years, he has focused on advising transportation authorities and operators on ways to achieve operational efficiency through the implementation of cost-effective, climate-friendly Intelligent Transportation Systems (ITS) solutions. In 2014 he co-authored an award-winning entry in a contest sponsored by MIT – an international contest that drew entries from 600 contestants who submitted proposals for projects about coping with climate change.

Thomas Manaugh – tom.manaugh@integralscientific.org

Thomas Manaugh, PhD, majored in psychology and minored in chemistry and biology as an undergraduate at the University of California at Berkeley. He earned his doctorate in medical psychology with a minor in anatomy from the Oregon Health Sciences University. Post-graduate education has focused on course work (math, physics, and computer science) that facilitated his work as (a) an educator of college students, (b) a consultant to companies selling environmentally responsible products and equipment, and (c) an inventor who has been awarded three patents, including two dealing with production of green energy. He is currently working on two patent applications for devices that facilitate environmentally responsible processes in the production of desalinated water. He has been a member of several national organizations whose mission has been to protect the environment. In 2014 he co-authored an award-winning entry in a contest sponsored by MIT – an international contest that drew entries from 600 contestants who submitted proposals for projects about coping with climate change.

About ISI – integralscientific.org

The Integral Scientific Institute (ISI) is a tax-exempt 501 (c) 3 nonprofit that was organized to develop a unique, coherent paradigm of study and action that focuses on interrelationships between water resources, food production, energy security, transportation efficiency, and climate policy. Achieving an integral understanding of the water-food-energy-transportation-climate nexus is crucial if we are to take responsible actions toward making our social and economic activities compatible with having a sustainable natural environment.

About the Format

The content of this document follows the formatting requirements of the MIT Climate CoLab Contest. The original contest entry can be accessed at http://climatecolab.org/web/guest/plans/-/plans/contestId/1300208/planId/1309211.

Pitch

Systems thinking leads to a regional desalination plan to replace a narrowly conceived, costly and destructive groundwater pumping plan.

Description

Summary

Water scarcity is a huge problem that grows more serious every day because of unrelenting droughts caused by climate change. We propose a solution to a particular problem of water scarcity in Las Vegas, Nevada, that can serve as an example of two important guidelines that should be applied elsewhere in the U.S. and around the world:

1. Reject short-term, local solutions that are unnecessarily costly and environmentally destructive.
2. Look for regional, system-wide long-term solutions that are less costly, provide benefits to other water users in a region, and are environmentally responsible.

In this case, we propose rejection of an existing groundwater pumping plan for Las Vegas that (a) is very expensive ($15.45 billion), (b) would call for the biggest groundwater pumping project in the history of the United States, and (c) would cause severe long-term impact on water resources, threats to protected species, and permanent damage to the ecosystem.

Our alternative desalination plan, based on systems thinking, is much less expensive and more environmentally responsible. It involves offering Las Vegas a greater share of water from the Colorado River system in exchange for its providing supplies of desalinated water to Los Angeles. It could also save rate-payers and taxpayers in Nevada about $8 billion.

Many civic and environmental groups stand in opposition to the groundwater plan to bring water to Las Vegas from wells 263 miles away in eastern Nevada. Part of our proposal involves carrying out a public education and advocacy campaign to promote the desalination plan as a replacement for the groundwater plan.

Category of the action

Mitigation/Adaptation, Changing public attitudes about climate change.

What actions do you propose?

Introduction

The category for this entry is "Adaptation/Mitigation, Changing public attitudes about climate change." Therefore, proposed actions here include presenting the public and public officials with reasons to reject a highly flawed existing plan. The proposed actions also include presenting a better plan to replace the existing plan. The existing plan is called here the "Groundwater Plan," and the replacement plan is called the "Desalination Plan."

The Groundwater Plan

The Groundwater Plan (1) was first proposed in 1989 as a way of increasing water supply to Las Vegas. The plan currently involves transporting water by using a 263 mile-long pipeline originating in eastern Nevada. If completed, it would:

- Be the biggest groundwater pumping project ever built in the United States.
- Pump and transport up to 176,655 acre-feet of groundwater a year to Las Vegas from five valleys in eastern Nevada.
- Require construction of more than 4,000 acres of power lines, well pads and access roads.

The potential economic, social and environmental effects of this massive and unprecedented groundwater mining and export project are of great local, state, regional and national significance.

The Groundwater Plan has generated widespread opposition (2), including concerns expressed by White Pine County, Nevada; the Great Basin Water Network; the Sierra Club; the Central Nevada Regional Water Authority; the Confederated Tribes Of The Goshute Reservation; the Ely Shoshone Tribe; the Duckwater Shoshone Tribe; the Baker, Nevada Water And Sewer General Improvement District; Utah Physicians For A Healthy Environment; the Utah Rivers Council; Utah Audubon Council; the League Of Women Voters Of Salt Lake, Utah; the Center for Biological Diversity; the Army Corps of Engineers; and the U.S. Environmental Protection Agency.

Among the concerns expressed are:

1. Very high cost to rate-payers and taxpayers. The Bureau of Land Management estimates the project will take 38 years for full completion and cost more than $15.45 billion.
2. Pumping more groundwater than the target area contains.
3. Violation of the National Environmental Policy Act by authorizing groundwater development by the Southern Nevada Water Authority's Clark, Lincoln, and White Pine Counties.
4. Devastating hydrological, biological, agricultural, and socioeconomic impacts across vast areas of eastern Nevada and western Utah.
5. Indirect harm to 130,000 acres of wildlife habitat, possibly causing several hundred springs to dry up and killing off several threatened species.
6. Severe long-term impact on water resources, requiring additional analysis of impact on wetlands.
7. Subsidence caused by heavy pumping of groundwater, where ground sinks into holes once filled by water.
8. Eventual exhaustion of groundwater resources tapped by wells drilled because groundwater is not a renewable resource unless it is recharged at a rate at least equal to that of what is pumped out.

9. Large amounts of greenhouse gases will be emitted from the natural gas power plant that supplies electricity for pumping and transporting groundwater.

The Desalination Plan

The Desalination Plan is an alternative to the Groundwater Plan. Its acceptance will require taking actions to change public attitudes about meeting the needs of Las Vegas in a cost-effective and environmentally responsible way. The plan will gain greater public exposure and acceptance if this entry enters into the final round of consideration in the CoLab contest.

If water shortages continue to develop the way scientists predict (3), Las Vegas will be forced to adopt some plan for mitigation. It will be important that the Desalination Plan should be well documented to be a robust and practical alternative to the flawed Groundwater Plan.

Desalination is a mature technology (4) that can be readily applied. At the start of 2012, approximately 16,000 desalination plants in more than 120 countries were operating at a total installed production capacity of 19 billion gallons per day (5). With desalination, we can tap into the world's most abundant water resource—the ocean.

Instead of using a go-it-alone, Nevada-only approach as is the case with the Groundwater Plan, the Desalination Plan will benefit from a systems approach. Las Vegas will benefit economically by making use of significant resources in the present system whereby Las Vegas already gets 90% of its water. That present system is the system for allotting and controlling the use of Colorado River water, as administered by the Bureau of Reclamation of the U.S. Department of the Interior.

The economic viability of the Desalination Plan will be analyzed in detail to document how the plan can be implemented at a reasonable cost. That cost is presently estimated to be $7.4 billion for a robust system to insure against water shortages for Las Vegas; see "Costs" section below. That estimated cost is significantly lower than the estimated cost of the Groundwater Plan.

The $7.4 million figure includes a "miscellaneous costs" figure of $1 billion. Part of that money will be needed to identify and secure sites for the proposed desalination plant(s). Siting is always a difficult problem because many competing and inescapable concerns about effects on local residents, economic benefits versus disruptions, aesthetics, disruption of transportation corridors, environmental impacts, etc.

Desalination plants are already built on the Pacific Coast, and adding one or more new plants, as needed, will not be a daunting task to either build or pay for. A thorough study of the history of past siting processes will be part of what is carried out during the earliest parts of Stage 1. That will allow us to establish the feasibility of the Desalination Plan based on other efforts in the recent past. Already, 15 to 20 new desalination plants are planned for California by 2030 (6).

Desalination plants will be powered by renewable energy resources. The Desalination Plan will call for the addition to the system of one or more concentrating solar power (CSP) plants. Such plants are already operating successfully within a service area that includes Los Angeles and other coastal cities. Here, again, hard data and analysis will show that adding one or more CSP plants to the system would not be a daunting task to build or to pay for.

A possible location for a CSP facility would be near the present site of the Ivanpah CSP facility in the southern California Mojave Desert that already supplies power to southern California via grid connections – the same grid that already powers desalination plants on the California coast. The Department of the Interior is engaged in identifying the best locations for large renewable energy projects – close to transmission lines and having fewer threatened species than other locations. In California, government agencies and environmental groups are working to identify large tracts in the Mojave Desert suitable for solar plants (7).

If this entry earns a Climate CoLab cash prize, all proceeds will go toward achieving the goals of actions described in Stages 1, 2, and 3.

<u>Stage 1</u>

The authors' submission of an entry in this CoLab contest constituted the earliest step of Stage 1 activity, presenting to the public the Desalination Plan as a feasible alternative to the Groundwater Plan.

Other steps in Stage 1 include the following:

- Develop detailed arguments in favor of the Desalination Plan over the Groundwater Plan. Those arguments will be refined in consultation with civic and environmental groups that already are opposed to the Groundwater Plan for the reasons that were listed above.
- Document how technological issues related to desalination and CSP projects in the U.S. and around the world have been addressed. All relevant problems in providing infrastructure to support desalination and CSP installations should be considered and a history of successful solutions documented.
- Document how siting issues, including costs, were successfully addressed in California in the siting of facilities like the Carlsbad desalination plant and the Ivanpah CSP plant.
- Form a Special Advisory Committee made up of experts from various agencies, institutions of higher learning, and professional organizations like the National Research Council and the American Water Works Association. This committee will be appointed and approved by the concerned parties to address the following areas of potential concern as they relate to the Desalination Plan: technical, economic, social, environmental, and legal and institutional.
- Request the Department of the Interior to facilitate extension of present activities to include consideration of how desalination of Pacific Ocean water could help overcome water scarcity problems in Nevada and other western states. The Department has recently reported (8) success in executing a cooperative agreement for a pilot project to conserve water for the Colorado River system. The agreement was signed on July 30, 2014, by the Department of the Interior and municipal water suppliers from Colorado, Arizona, Nevada, and California. That historic agreement demonstrates states' willingness to work together to overcome water scarcity problems. Clearly, the new agreement should encompass consideration of actions like implementation of the Desalination Plan that

would reduce loss of water by evaporation as it is transported from Lake Mead to Los Angeles. Not transporting some of the usual allotment going to Los Angeles would conserve some water that would otherwise be lost to evaporation as it is transported through various canals and reservoirs. Additionally, energy would be saved with not so much water being pumped over various mountain ranges that traverse the canal that brings Colorado River water to Los Angeles.

- Prepare an analysis of what it would take to amend relevant laws and agreements regarding the use of the Colorado River.

Stage 2

A campaign should be mounted to inform public officials and the public about the Desalination Plan and how it could serve the interests of all participants who depend on water from the Colorado River. The civic and environmental groups, mentioned above, that are in opposition to the Groundwater Plan would be natural allies in getting both official and public support for the Desalination Plan.

The campaign will present these arguments:

1. It makes basic sense to seek other sources of water if the current source being relied on is becoming depleted because of the effects of drought.
2. Desalination is already being implemented successfully in California as well as thousands of locations around the world.
3. Pairing construction of a new desalination plant(s) with a new CSP plant would be an environmentally responsible way to augment the system of water allotment from the Colorado River.
4. California will benefit economically from the construction and operation of the proposed desalination and CSP plants.

Stage 3

Actual building of the plants needed to implement the Desalination Plan will take several years. Even so, the full implementation of the plan should take many fewer years than the 38 years suggested as needed for the full implementation of the Groundwater Plan.

Who will take these actions?

Because strong opposition to the Groundwater Plan already exists among civic and environmental groups in Nevada, it will be important to contact those groups to enlist their support. Those groups, if they agree with the alternative plan, will take the plan to the wider public and to public officials. Officials will have good reason to consider the replacement plan as water scarcity becomes ever more threatening and the Groundwater Plan becomes mired in controversy and lengthy lawsuits. (2)

For Los Angeles to forego a portion of its allotment of Colorado River water in exchange for supplies of local desalinated water, it will be important for several stakeholder groups in

California to understand that the Desalination Plan will provide a *more* reliable source of water to Los Angeles than it would otherwise have in an era of unrelenting drought. Those stakeholder groups include:

1. Public citizens who are consumers of water, rate-payers, and taxpayers. They have strong interests in seeing that water supplies are clean, reliable, and affordable.
2. Municipal water officials who will need to be assured supplies of desalinated water will enter their local water system so as not to disrupt ongoing service.
3. Agricultural business interests who will need to understand that delivery of some desalinated water to municipal Los Angeles will not disrupt their ongoing access to Colorado River water.
4. Industrial water users will need to understand that their access to water supplies will not be made less reliable or more costly.

Given the legal aspects of water rights, state legislatures and the federal government will have a role to play to guarantee a smooth and expeditious implementation of the Desalination Plan. The U.S. Department of the Interior may use the example of the Desalination Plan in recommending similar plans in other regions where cost-effective and environmentally responsible solutions to water scarcity are needed.

Where will these actions be taken?

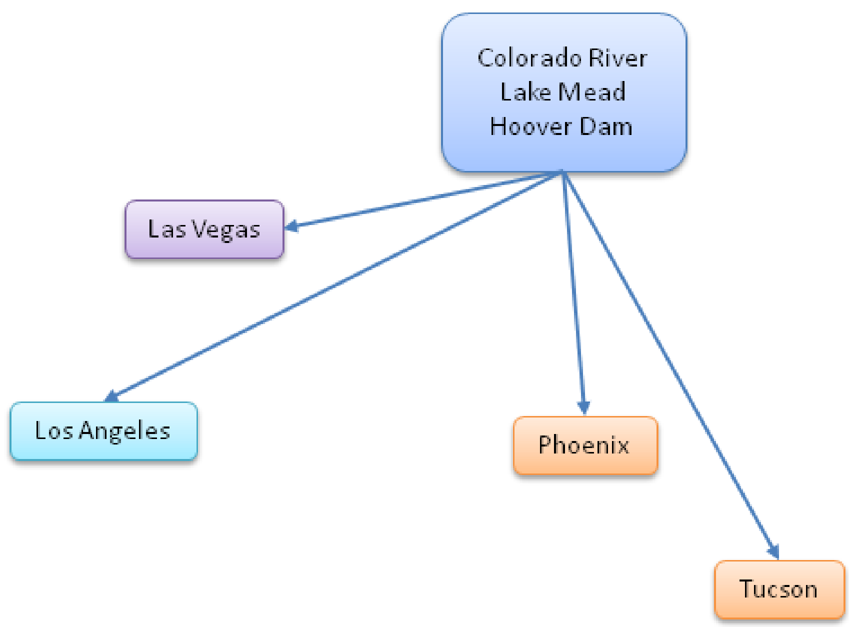

Figure 1 – Current Regional Water Distribution to Selected Cities

Figure 1 schematically shows the existing system for distributing water from the lower section of the Colorado River to selected cities in Nevada, California, and Arizona. System components include:

1. Hoover Dam that dams the Colorado River to form Lake Mead reservoir.
2. Population centers of Las Vegas, Tucson, Phoenix, and Los Angeles that receive water from Lake Mead. Allocations are monitored and controlled by the Bureau of Reclamation of the U.S. Department of the Interior.
3. Lines that represent existing infrastructure of pipes, canals, siphons, reservoirs, and aqueducts that link Lake Mead to population centers.

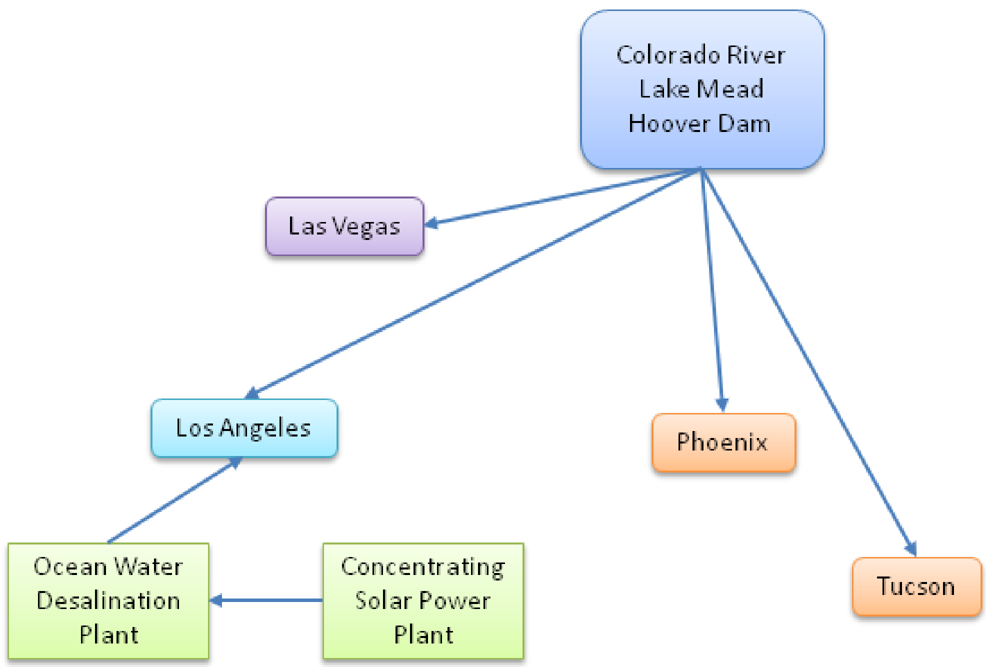

Figure 2 – Regional Water Distribution under the Proposed Desalination Plan

Figure 2 shows the same components as Figure 1 with the addition of:

1. A desalination plant on the Pacific Ocean coast that is proposed to augment water supply to Los Angeles.
2. Located in desert areas of California, a concentrating solar power plant is proposed to supply power to the desalination plant.

Supplying desalinated water to Los Angeles will allow a portion of the water allotted from the Colorado River to Los Angeles to be allotted to Las Vegas and, possibly, also to Tucson and Phoenix. Los Angeles will be compensated for a lower allotment by getting a reliable supply of desalinated water.

Acceptance of the Desalination Plan will be increased if stakeholders feel confident siting of desalination and CSP plants will be technically feasible, economically beneficial to chosen locales, and environmentally and socially acceptable. Sites will be determined by assessing multiple criteria, some of which apply to both types of plant. Table 1 shows main selection criteria that can be used to produce an initial list of site candidates (9,10).

	Main Site Selection Criteria	Desalination Plant	CSP Plant
1	Land size appropriate for required production capacity	√	√
2	Topography	√	√
3	Outside built and inhabited areas	√	√
4	Outside environmentally sensitive areas	√	√
5	Close to a consistently good quality seawater source	√	
6	Close to an appropriate brine discharge area	√	
7	Direct sunlight		√
8	Solar irradiation above a minimum level		√
9	Close to an electric power interconnection	√	√
10	Close to a water supply system	√	√
11	Close to a proper roadway network	√	√
12	Meets local and environmental laws and restrictions	√	√

Table 1 – Main Site Selection Criteria for the Desalination and CSP Plants

A cost-effective method for candidate site identification uses geographic information systems (GIS), followed by field visits. A GIS-based multi-criteria decision analysis (GIS-MCDA) could enhance confidence in the outcome of the selection process. (11,12)

What are other key benefits?

If the Climate CoLab judges find this entry worthy, stakeholders in Nevada will take notice and be encouraged to seriously question the advisability of adopting the Nevada-only Groundwater Plan – a plan that wastes billions of dollars on a project that is environmentally destructive and will eventually fail when groundwater resources become depleted.

By contrast, the Desalination Plan makes cost-effective and environmentally responsible use of an existing system. Additional water resources from desalination will make Los Angeles' water supply less threatened by on-going drought.

Lessons learned from using systems thinking and regional cooperation could benefit Tucson, Phoenix and other cities around the world.

Combining use of power from renewable energy with desalination helps break a vicious cycle of negative environmental impact from using power derived from burning fossil fuels – a practice that contributed to the current water stress in the first place.

What are the proposal's costs?

Advocating for the Desalination Plan as a replacement for the existing plan will cost a relatively small amount in Stage 1 and Stage 2, when details of the plan will be disseminated to stakeholders in Nevada, California, Arizona, and Washington, DC. Whatever costs might be incurred for Stages 1 and 2 for public education and advocacy would only be about the size of a rounding error for costs associated with Stage 3, implementing the Desalination Plan.

Stage 3 estimates are based on costs known for existing desalination plants (13) and existing CSP plants (14), as follow:

1. $4 billion - Desalination plant(s) capable of producing a total of 200 million gallons of water per day.
2. $2.4 billion - CSP plant(s) capable of providing a total of 3 million kWh per day, sufficient to power the desalination plant(s).
3. $1 billion - Miscellaneous costs.

The total cost of $7.4 billion for the Desalination Plan is less than half of the cost of the Groundwater Plan.

Time line

<u>Short Term</u>

Stage 1 of advocating for the Desalination Plan started today with the submission of this entry in the Climate CoLab contest. Assuming some favorable feedback from judges, Stage 1 will continue for the next several months as we refine our proposal to replace the Groundwater Plan. Stage 2 will commence before the end of 2014, when we start to contact stakeholders in Nevada, California, Arizona, and Washington, DC. Stage 2 will continue until either construction is firmly underway on the Groundwater Plan, or it has been firmly rejected in favor of the Desalination Plan.

Medium Term and Long Term

Stage 3 will commence with the beginning of construction and will continue until the Desalination Plan is fully operational.

Related proposals

Adaptation to Climate Change

Improve Resilience through decentralising constructed wetlands for sewage

Global Plan

Strategically Transitioning To Global Adaptation!

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Saving Hoover Dam

By

Saïd Majdi and Thomas Manaugh

Integral Scientific Institute

Submitted to

The 2015 MIT Climate CoLab Contest

Energy-Water Nexus Category

July 14, 2015

About the Authors

Saïd Majdi – said.majdi@integralscientific.org

Saïd Majdi received his MS in electrical engineering from the Paris Institute of Technology in Paris, France, with dual specialization in telecommunications and control engineering. He has 30 years of experience in electronic product development and large-scale system design, development, integration and modernization. For the last 20 years, he has focused on advising transportation authorities and operators on ways to achieve operational efficiency through the implementation of cost-effective, climate-friendly Intelligent Transportation Systems (ITS) solutions. In 2014 he co-authored an award-winning entry in a contest sponsored by MIT – an international contest that drew entries from 600 contestants who submitted proposals for projects about coping with climate change.

Thomas Manaugh – tom.manaugh@integralscientific.org

Thomas Manaugh, PhD, majored in psychology and minored in chemistry and biology as an undergraduate at the University of California at Berkeley. He earned his doctorate in medical psychology with a minor in anatomy from the Oregon Health Sciences University. Post-graduate education has focused on course work (math, physics, and computer science) that facilitated his work as (a) an educator of college students, (b) a consultant to companies selling environmentally responsible products and equipment, and (c) an inventor who has been awarded three patents, including two dealing with production of green energy. He is currently working on two patent applications for devices that facilitate environmentally responsible processes in the production of desalinated water. He has been a member of several national organizations whose mission has been to protect the environment. In 2014 he co-authored an award-winning entry in a contest sponsored by MIT – an international contest that drew entries from 600 contestants who submitted proposals for projects about coping with climate change.

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Pitch

Systems thinking leads to a plan to keep Hoover Dam as viable source of clean water and energy.

Description

Summary

Hoover Dam, built during the Great Depression, should be preserved as (a) a powerful and lasting historic symbol of resilience and determination of Americans and (b) a sustainable source of clean hydroelectric power and water. Unfortunately, Hoover Dam's capacity to generate and transmit electricity has been reduced because drought has reduced water that is available to turn its turbines.

To bolster the viability of the Hoover Dam system as a source of clean energy and water and to tap underutilized transmission capacity, we propose installing a floating solar photovoltaic (PV) farm on Lake Mead, Hoover Dam's reservoir, to generate electric power. These floating platforms, covered with solar PV panels, would provide shade for lake water, thus reducing loss of water from evaporation. Less evaporation means more water available both for generating electricity and for meeting water demand from consumers and businesses in Arizona, California, and Nevada.

Energy from this floating solar PV farm could be used for a large variety of purposes. We propose to use this green and renewable power source to power desalination plants on the California Coast to support a water exchange program between Nevada and California. Thus, this proposed project uses systems thinking to identify novel and cooperative ways to put underutilized resources to work to produce clean energy and water.

What actions do you propose?

In proposing actions to deal with water scarcity in the Western United States, we recognize Hoover Dam as a nexus of water and energy, and an historic icon that testifies to the industry, bold vision, and resilience of Americans. It was miraculously constructed in a few short years during the middle of the Great Depression. Americans are deeply proud of what Hoover Dam represents.

However, if Hoover Dam were not already built, would it be a project that would get approved for construction today? Unfortunately, the answer is probably "No" because water flow in the Colorado River is too low to allow the dam to sustain full capacity of hydroelectric power generation. It now operates at far below its expected output if Lake Mead were at full height.

If Lake Mead were at full height, that would allow Hoover Dam's generators to generate closer to their "nameplate" (i.e., maximum sustainable) generation capacity. Operating 24 hours per day and 365 days per year, the generators could theoretically produce 18.2 terawatt-hours (TWh) annually. The closest to that theoretical maximum occurred in 1984 when 10.4 TWh were generated. An average in recent years has been 4.2 TWh. [1] Expected generation in 2015 is 3.7 TWh. [2]

If the height of Lake Mead continues to fall, output lower than 3.7 TWh can be predicted in coming years. There is no doubt that if electricity could be generated at the 1984 output level, when Lake Mead was at a high level, the clean and inexpensive electricity generated would be more than welcome on the electricity market. On the other hand, great disruption would occur if Lake Mead were to fall to such a low level that no electricity could be generated. One observer commented: "Hoover goes nowhere without taking down a significant piece of the economic and electric portfolio of California." Similar sentiments have been expressed by observers in Arizona and Nevada. [3]

Here, systems thinking is used to design a large, bold, and novel proposal for actions to help Hoover Dam continue to serve its historic function as an important source of both clean electricity and clean water for consumers in California, Arizona, and Nevada.

Water scarcity has become ever more dire in Southwestern United States and has led to the following actions:

1. Restrictions on water availability to consumers in California. [4]
2. A groundwater pumping plan in Nevada that is advancing toward realization in spite of opposition from environmental activists. [5]
3. Construction of new desalination facilities to make potable water from seawater taken from the Pacific Ocean. [6, 7]
4. Funding by the U.S. Bureau of Reclamation, Arizona, California, and Nevada of pilot studies aimed at identifying new ways to conserve water in the Colorado River system. [8]

The authors recently traveled to Nevada and California to talk to water officials and to citizens concerned about water scarcity in the southwest. [9] The impetus for that trip was a proposal developed by the authors into a 2014 MIT Climate CoLab entry, entitled "Stop Groundwater Plan – Save $8 Billion." [10] The 2014 entry, for which the authors received an award, proposed a plan called the Desalination Plan. Under that plan, California would accept locally produced desalinated water from the Pacific Ocean in exchange for foregoing some of its allotment of water from the Colorado River. That water from California's allotment would be directed to Las Vegas. In exchange, Nevada pays for the desalination plant and the solar power plant to power it—all at a price tag less than half the price tag of the Groundwater Plan.

The Groundwater Plan [11] was adopted by the Southern Nevada Water Authority (SNWA). It calls for constructing the largest groundwater pumping project in U.S. history. It will consist of pumping groundwater from the eastern region of Nevada and transporting it to Las Vegas over sections of pipeline that total 263 miles in length. Experts and concerned civic groups believe that the Groundwater Plan, if implemented, will be environmentally destructive and costly at a price tag that could exceed $15 Billion, according to some estimates.

It makes basic sense for California to accept desalinated water from a plant on its Pacific Ocean coast instead of Colorado River water that must be transported hundreds of miles from a location on the border between Arizona and California. The desalination approach would make California's water supply more secure and virtually increase its allotment from the Colorado River—transporting water over long distances requires energy and results in loss from evaporation (up to 20%), leakage and seepage. Moreover, desalination offers many direct and indirect benefits, including better quality water and reduced demand on groundwater resources. [12]

Based on that prior work, this proposal is designed to support and facilitate efforts to make clean water and energy available to citizens of western states in a way that (a) is cost-effective because it makes good use of underutilized resources, (b) is environmentally responsible, and (c) helps to avoid unintended consequences that typically result from solutions that increase supply to satisfy increasing demand. Specifically, we propose the following:

1. Solar photovoltaic (PV) panel arrays on floating platforms in Lake Mead will generate and deliver electricity through Hoover Dam's currently underutilized transmission network and to the grid that services Southern California. That same grid is used to deliver electricity needed by desalination plants on the California Coast. Thus, solar power from Lake Mead will benefit California by providing clean power that is used to produce clean water. Mounting solar panels on floating platforms is a proven technology that is being used in Japan and Brazil. [13, 14]
2. Shade from the installed solar panels will decrease evaporation, thus conserving water in the Colorado River system. Southern Nevada is dependent on the Colorado River for 90% of its potable water, so it especially will benefit from any conservation effort. All the three states of the Colorado River Lower Basin (Arizona, Nevada and California) will benefit if water is conserved in Lake Mead. If water in Lake Mead falls below a certain level, all three states will suffer a decrease in their water allotments. [15]
3. Water in Lake Mead will be available to keep solar panels at an optimal temperature for converting solar radiation to electricity in an efficient manner.

<u>Floating Solar PV Structure</u>

Figure 1 depicts an installed floating solar PV farm in Kato City, Hyogo Prefecture, Japan. At least two other floating solar PV farms have been installed in Japan with more floating solar PV farms in the planning phase.

Figure 2 shows a schematic diagram of floating modules with specification provided by the French manufacturer Ciel & Terre. The floating modules are connected to form a platform for mounting solar PV panels. The connected floating modules are engineered to withstand extreme physical stress, including typhoon conditions with winds up to 118 mph. They are made of high-density polyethylene (HDPE). This material is 100% recyclable, UV and corrosion resistant, and drinking-water compliant.

For safety reasons, the installation will include a security cordon and standard maritime traffic signage to alert and keep away nearby boat traffic.

Figure 1 – Floating Solar PV Farm in Kato City, Japan

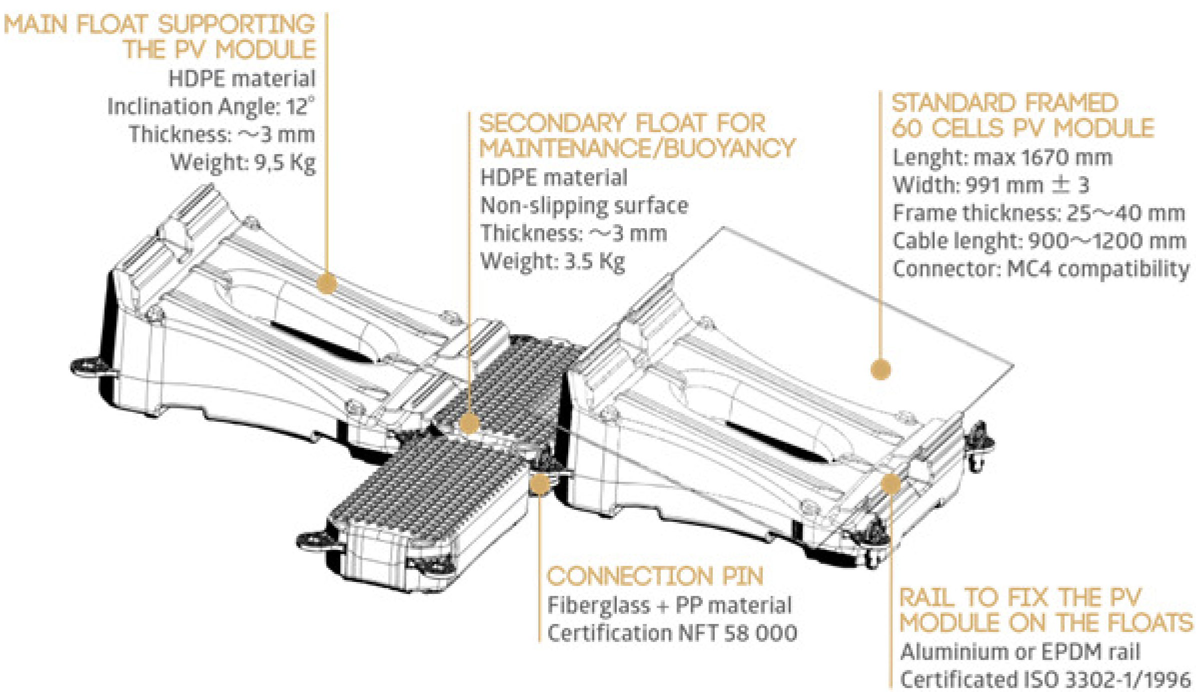

Figure 2 – Schematic Diagram of Floating Module (Courtesy Ciel & Terre)

Breaking the Vicious Cycle

Bringing clean water to the end user requires energy for extraction, conveyance, and treatment. Similarly, converting conventional energy into electric power results in water utilization and water consumption. So, an increase in water supply results in an increase in energy demand, which results in an increase in water demand, which in turn results in increased water scarcity, further leading to the need of greater water supply. This interrelationship between water and energy is illustrated in Figure 3, which depicts a causal loop diagram. When reading the diagram, keep in mind that an arrow links a cause to its resulting effect. A plus sign (+) on the arrow means that the cause and effect move in the same direction; i.e., an increase in the cause results in an increase in the effect and a decrease in the cause results in a decrease in the effect. A minus (-) sign on the arrow means the cause and effect move in opposite directions; i.e., an increase in the cause results in a decrease in the effect and a decrease in the cause results in an increase in the effect. While increasing water supply seems to fix the problem of water scarcity (small, balancing (B) feedback loop), there is an unintended consequence that results in increased water scarcity (large, reinforcing (R) feedback loop). In system dynamics, this phenomenon is typically called "fixes that can backfire". Our proposal breaks the reinforcing feedback loop by relying on a source of energy that requires no water, or minimal amounts of water, for its conversion into electric power. Thus, systems thinking leads to a solution that solves the problem of water scarcity without causing unintended negative consequences.

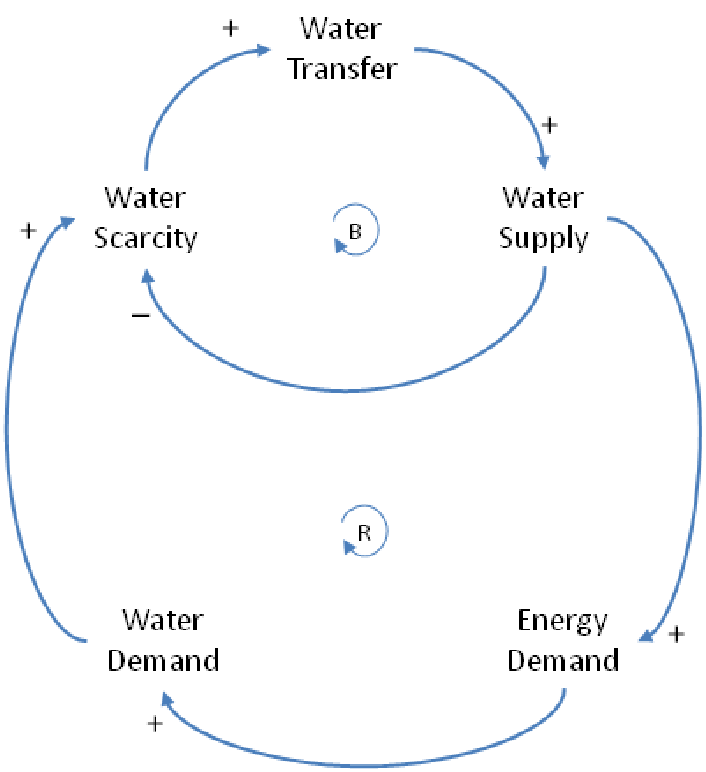

Figure 3 – Energy-Water Causal Loop Diagram

Who will take these actions?

Lake Mead is within the boundaries of the Lake Mead National Recreation Area, which is federal land under the jurisdiction of the National Park Service (NPS) of the U.S. Department of the Interior. The NPS would therefore be the governmental entity to make decisions and conduct the National Environmental Policy Act (NEPA) analysis (environmental impact statements, etc.) that would be necessary to site the floating solar PV farm. The Department of the Interior and its Bureau of Reclamation have a long history of efforts to deliver both water and energy to people, businesses and farms in the U.S.

Multi-jurisdictional projects pose great challenges. However, states in the Western U.S. have made a tremendous amount of progress toward establishing a unified front in dealing with the impact of climate change. One of the channels to facilitate such productive interaction is the Western Governors' Association (WGA). The WGA represents the Governors of 19 western states and 3 U.S.-flag islands who use the association for bipartisan policy development, information exchange and collective action to deal with critical issues in the Western U.S.

The authors of this proposal have created a nonprofit organization, Integral Scientific Institute, which is dedicated to the idea of identifying and advocating for environmentally responsible solutions to complicated social and economic problems. Following publication of this proposal, the authors will continue their advocacy for implementing an approach to problems like water scarcity where underutilized natural and renewable resources can be tapped to solve problems in ways that are both environmentally responsible and cost-effective. Thus, we are committed to presenting public officials and interested citizens with creative alternatives to costly and environmentally damaging ways of doing "business as usual." Clearly, alternatives are needed that involve more cooperation, more long-term planning, and better use of resources.

Where will these actions be taken?

The proposed project will be located on Lake Mead in the vicinity of Hoover Dam. Lake Mead acts as a reservoir for Hoover Dam. Nearby Las Vegas and Boulder City, Nevada, will serve as likely hubs for activities related to project construction and operation.

Lake Mead is a very large body of water, even though it currently holds only 37% of the volume of water it once had. It used to be the largest reservoir in the United States; now it is ranked fourth. It stretches for about 110 miles north and east from Hoover Dam to the point where it receives water from the Colorado River. Its surface area is 248 square miles when at full capacity. A small fraction—less than one square mile—of Lake Mead surface area would be required for the proposed project.

How will these actions have a high impact in addressing climate change?

This project will have very significant implications for coping with climate change. Here are the most salient:

1. It will be climate friendly. Use of solar PV panels will help to meet energy needs in the southwest with no significant release of greenhouse gases. It is estimated that reduction in use of fossil fuels to produce electricity will reduce CO2 emissions by 222,000 tons per year.
2. Providing clean energy to desalinate water in Southern California will be a benefit to California, which now is (a) in a severe drought and (b) producing significant amounts of greenhouse gases in association with transporting water from other areas of the state.
3. Because this project leads to less water evaporation and more use of desalinated water, all states in the southwest will benefit from reducing the demand for water from the Colorado River. Every state will suffer a diminished allotment of water from the Colorado River if Lake Mead water levels fall too low. [16]

What are other key benefits?

Some other key benefits are:

1. Underutilized resources for electric power transmission will be put to use.
2. Hoover Dam releases water to generate electricity even during times when demand for electricity is not at its highest. Because power from the floating solar farm will often be available to satisfy demand during non-peak-demand times, Hoover Dam will become better able to preserve water for release during peak demand times. Thus, Hoover Dam and the floating solar farm, working together, will save water for generating peaker power and thereby reduce the need for using peaker power plants that burn fossil fuels.
3. Project construction and operation will stimulate the economy in the area of Hoover Dam and Lake Mead.
4. Cooperation between states for implementing the project will serve as both (a) a benefit for coping with water scarcity in the southwest and (b) a model for cooperation among other states and nations as they attempt to cope with the impact of climate change.

What are the proposal's costs?

The proposed amount of water to be exchanged between Nevada and California is 200 million gallons per day (MGD). The desalination plant to be built in California will use reverse osmosis (RO) technology. Usually, producing 200 MGD requires 3 gigawatt-hours (GWh) per day of electricity. However, the integration of an energy recovery system will yield energy savings of 40%. So, the energy requirement for producing 200 MGD of potable water will only be 1.8 GWh per day.

Lake Mead receives 6.45 hours of average daily solar irradiance. This means that the floating solar PV farm needs to have a capacity of 279 megawatts (MW).

Installed cost for commercial solar PV projects is between \$3 and \$7 per watt. Considering that this is a very large project, with economies of scale and decreasing PV panel costs, the low end of \$3 per watt is a good estimate. This yields a total cost of \$837 million. Surcharges that are traditionally associated with work on water in off-shore projects do not apply in the case of this project. Indeed, none of the specialized equipment and additional effort required for off-shore installations is needed for deploying the floating solar PV farm on Lake Mead.

The cost of a similar installation in Japan for a 92-MW solar PV plant is $290 million (2015). Extrapolating, without taking into account economies of scale, yields $879 million for a 279-MW solar PV plant. So, $837 million is a reasonable estimate.

Therefore the proposed floating solar PV farm on Lake Mead will have the following specification:

1. 279 MW solar PV power plant
2. Generation capacity per year: 657,000 MWh
3. Generation capacity per day: 1,800 MWh
4. Area: 0.63 square mile
5. Water evaporation reduction capacity per year: 2,620 acre-feet or 854 million gallons (Evaporation rate at Lake Mead: 6.5 feet per year) [17]
6. CO2 reduction per year: 222,000 tons (370,000 tons if reduction from using the RO energy recovery system is included)
7. Cost: $837 million

Time line

The projected time needed to implement the proposed project is five years. That short suggested timeline is possible because the project might need relatively little lead time to implement a pilot project, secure funding, complete construction, and begin operations.

Favorable circumstances for allowing relatively quick implementation are as follows:

1. Conservation pilot studies are already being cooperatively funded by the U.S. Bureau of Reclamation in Nevada, California, and Arizona.
2. Bipartisan support would be achievable because the significant benefits from the project would inure both to the environment and to the state's economic interests.
3. Southern Nevada Water Authority has pushed forward on a groundwater pumping and transfer project that has been estimated to cost upward of $15 billion. That suggests that funding would be available to any well-conceived project that would enhance water security for Nevada and surrounding states.
4. Siting a project is usually a lengthy and contentious task. In this case, the proposed site is under the exclusive jurisdiction of the federal government, so siting could be expedited because fewer local, state, and regional agencies would be required to approve siting plans. Given that Hoover Dam is in danger of becoming obsolete because of its declining power-generating capacity, it is reasonable to hope that the federal government would act in an expeditious manner.

Related proposals

Saving water with ping-pong balls - Energy-Water Nexus

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