California Public Utilities Commission

POLICY AND PLANNING DIVISION

Rethinking the Water Energy Nexus:
Moving toward Portfolio Management of the Nexus

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I. Summary

The Water Energy Nexus ("Nexus") is the interaction between water services and energy services where energy services rely on reliable access to water and water delivery services depend on access to energy. This co-dependency is referred to as the Water Energy Nexus.

Although the Nexus is well known throughout the energy and water sectors and frequently cited by the media and non-governmental organizations ("NGOs"), the Nexus as a whole is not actually well understood.

In 2005 a California Energy Commission ("CEC") study found that 19% of energy in California was used to provide water related services. While the finding is dramatic it is not clear what this means about the California water and energy economy. Does this imply that water delivery systems are energy inefficient and that energy has not been viewed as an important consideration in the water economy? While it may certainly be true that water systems are technically inefficient, it is not the only factor driving the 19% relationship in the Nexus. The fundamental economic value of water is also a key element of the Nexus. In California with an arid climate and mountain ranges separating water sources from water users the energy costs of water are inherently high. So part of this 19% factor may simply represent how hard it is to supply and convey water in an arid and mountainous state.

In order to promote the development of water and energy systems that are both technically efficient and economically efficient, it is important to understand how much of the 19% factor is due to the technical efficiencies of the water and energy systems and how much is simply an economic choice to tradeoff energy for water security? To date most efforts to quantify the Nexus have implicitly focused on technical efficiencies and metrics of the systems. The embedded energy in water and embedded water in energy are two such metrics used to quantify the Nexus.

This paper discusses embedded metrics. We also discuss the economic incentives of end-users, energy and water utilities and how water utilities tradeoff energy for water and how energy utilities trade water for energy.

We find that, from a policy perspective, the embedded metrics by themselves have several shortcomings that make them weak policy tools. They invite us to conclude that saving water will result in the savings of some specific and measureable quantity of energy. And that saving energy likewise will reduce water consumption by some specific and measurable amount. While such inferences may be useful as general indicators, we cannot count on them in any specific application, at any specific location, or at any specific point in time. As a general matter, embedded metrics do not reveal information about the technical efficiency of a system; rather they more closely reflect the climatic, geographic and hydrological conditions under which water and energy are managed. Furthermore, embedded metrics do not recognize that the tradeoffs of energy for water and water for energy are in themselves valuable economic activities and that there are times when increasing the amount of embedded energy can be valuable.

The key issue for improving the overall efficiency of the Nexus, both technical and economic efficiency, is not simply minimizing the quantity of energy and/or water used to provide water and energy services.

The challenge is more closely defined as managing the water-energy portfolio – balancing the technical constraints with the economic value of water and energy services. A portfolio management approach does not strictly rank potential opportunities, but rather balances the risks and opportunities of water and energy systems in order to achieve a broad set of objectives: such as preserving and extending the water supply, leveraging energy services to mitigate water scarcity, and reduce overall emissions. This may mean that in some cases we will use more energy to supply water and more water to supply energy.

II. Water and Energy: Can we manage these resources together?

The existence of the Nexus is well known and well documented. In 2005 the California Energy Commission (CEC 2005) published a report that established the now commonly quoted statistic that 19% of California electricity is used to provide water related services in California. In 2095 a United States Geologic Survey (USGS 2009) report found that 39% of freshwater withdrawals in the US were used to produce electricity in thermoelectric power plants. Notably, the USGS report found that in California, however, less than 1% of freshwater withdrawals are for thermoelectric cooling. While both of these findings established the magnitude of the connection between the water and energy

economies, there was a more significant message underlying these studies: that when we manage one of these resources we are really managing both.

The CEC report and many others in the mid 2000's were groundbreaking in many regards, but vacant in others. They established an understanding of an issue that had long been recognized, but not quantified. The issue was raised to national prominence by a 2006 Department Of Energy Report to Congress (DOE 2006) that cemented the Nexus as an important consideration in energy and water policymaking. Since that time there have been several more studies that have followed those early ones, refining the methods, and expanding the data used to estimate the strength of the water energy relationship. The embedded energy in water, perhaps the most recognized factor, is a metrics of the amount of energy used to convey, pump, treat, and distribute water to end-users. The complement to this metric is the embedded water in energy metric, which accounts for all water used to produce and distribute commoditized energy.

However, what was and remains less well understood is how policy makers should respond to these findings. Does the use of 19% of electricity to provide water services represent an economically efficient use of that energy? Or does this imply that the institutions, service providers and consumers are not fully aware of the full energy costs and are using water and energy in technically inefficient ways? If it is the latter, can we manage these resources in a better way? Can the water and energy resources be more effectively managed when we think about them together, as a Nexus, as opposed to simply managing each resource independently?

California currently has a well-established set of policy and regulatory criteria for managing the development of energy and water resources independent of each other. In the energy sector the "loading order" is a policy that specifies priorities for both demand side and supply side projects. The demand side projects, energy efficiency and demand response, are assigned the highest priority in the order followed by renewables and clean fossil projects on the supply side. It is important to understand that while this is called a loading order there is no strict requirement that all energy efficiency measures be exhausted before moving through the order. The loading order establishes a priority for making judgments based on the cost effectiveness of each programs. These programs must then be balanced to address the current needs of providing energy services, with long-term goals of providing it efficiently. Within the context of the loading order it is possible and reasonable to

include both clean fossil and energy efficiency in a yearly set of projects. The loading order in practice is a guideline for portfolio management that establishes criteria for weighting and accounting for the uncertainty in demand side programs and supply side projects.

In addition to the loading order there are also target-based policies in the energy sector. The 33% Renewables Portfolio Standard ("RPS") requires 33% of electricity to be generated from renewables by 2020. The California Global Warming Solutions Act (AB32) also established a cap and trade system that has established a price on carbon emissions and in essence tightens emission constrains on energy consumption.

In the water sector there are a number of policy mechanisms similar to the energy sector for evaluating and prioritizing programs. The California Urban Water Conservation Council ("CUWCC") developed Best Management Practices ("BMPs") for water utilities, which established a set of foundational and programmatic guidelines that water service providers should adopt and follow. Originally the BMPs were a voluntary set of principles that signatories to the BMP Memorandum Of Understanding ("MOU") were encouraged to follow. The BMPs, however, have been elevated by the adoption of AB1420, which requires that urban water service providers implement BMPs as a condition of receiving grant funding from the Department of Water Resources ("DWR") and other state water agencies. . SBX7-7 the so called "20 by 2020" bill is more recent legislation that requires a 20% reduction in urban water use by the year 2020. This legislation also requires the development of water use measurement criteria in order to establish a baseline against which the 20% reductions can be evaluated.

In the Water Energy Nexus, however, policy objectives have not been clearly defined. Part of the reason for this may be that there already exist an extensive list of programs in the energy and water sectors that address efficiency and conservation. But what has not been clearly addressed and remains unknown is what, if any, additional benefit can be found if we develop policy that is driven by a comprehensive Water Energy Nexus policy. We know that saving energy saves water and saving water saves energy. But is it simply enough to focus efforts directly on saving energy and directly on saving water through existing energy and water programs? Or are we undervaluing water and energy savings and can accounting for embedded water and embedded energy discover hidden savings?

A. The Water Sector: Energy for Water

The components of the water lifecycle in California are not much different than other states, however, the magnitude of projects here are California sized. Conveyance of water stands out as the epitome of the system and distinguishes how Californians view water supply. The California aqueduct alone stretches more than 700 miles and spans much of the state and traverses mountain ranges and deserts. The complete water value chain consists of many other elements including: supply acquisition, groundwater management, surface water conveyance, water and wastewater treatment, distribution, and discharge. The energy intensity in each part of the chain depends on a number of factors and has a wide range of values. But the two main drivers of energy intensity are the amount of water pumped and input water quality of water subject to treatment. (Figure 1)

	Range of Energy Intensity kWh/MG	
Water-Use Cycle Segments	**Low**	**High**
Water Supply and Conveyance	0	14,000
Water Treatment	100	16,000
Water Distribution	700	1,200
Wastewater Collection and Treatment	1,100	4,600
Wastewater Discharge	0	400
Recycled Water Treatment and Distribution	400	1,200

Figure 1**:** Energy intensity of water in kilowatt hours per million gallons: Source CEC 2005

The wide range in energy intensity is dramatic and is driven primarily by the regional difference in water quality and access to sources of water, e.g. water stressed regions may rely on lower quality water sources and consequently may require more energy intensive water treatment. It is the highly variable nature of our topology, hydrology, and climate that drives the high level of variability in energy intensities.

Recently there have been efforts to include the energy intensity of water as a basis of policy and establish "embedded energy" metrics as an indicator of the potential energy savings in the water sector.[1] While these metrics are intuitive and perhaps compelling, by themselves they have a number of shortcomings that render their usefulness as policy tools weak and casts doubt on the veracity of decisions drawn using them.

[1] ACEEE (2011) white paper and GEI (2012) white paper

The key weaknesses of the embedded energy metrics for policy are that it:

1. Does not recognize that energy is used to mitigate water scarcity. In arid regions, energy is used to convey water from regions where it is abundant. Energy is used to store water underground during rainy seasons and pumped out in dry seasons. Water stressed regions of the state, as a matter of geography and climate, will invariable have significantly higher embedded energy costs than water abundant regions, and as a matter of policy may determine that using more energy to supply water is an effective risk reduction strategy.

2. Conflates embedded energy with the energy efficiency of water delivery systems. The amount of embedded energy in water is highly variable and is dependent on geographic and water quality factors that are completely independent of the energy efficiency of the system. For example a gravity feed water system with poor energy management practices may have a delivered embedded energy content of 0 kWh/MG, while systems that rely on water pumped over the Tehachapi mountain range but follow best energy management practices will have embedded energy content of 14000 kWh/MG or more.

3. Does not delineate which resource – energy or water - is being managed inefficiently. A system with a high level of embedded energy content can result from either poor water management (e.g. high or unknown leak loss rate) or poor energy management or any combination of the two. Embedded energy based accounting blurs these differences.

4. Embedded energy accounting could be considered arbitrary. Because the energy intensity requirements of some regions are naturally higher or lower than others, the inclusion or exclusion of a region or system can significantly skew an embedded energy measurement.

Issues 2, 3 and 4 are essentially accounting issues and can be addressed by developing ever more complex and convoluted accounting methods and improving cost effectiveness criteria. These methods would also need to develop a detailed inventory of the technologies deployed throughout the water value chain as well as an understanding of the operating procedures of the managing institutions. While these methods can be developed it is not clear if this will reveal any new savings that could not be found simply by assessing the energy efficiency of individual systems components.

Issue number 1, is a more challenging problem that in some ways may also be the largest opportunity to improve the economic efficiency of the Nexus– as this issue more directly reflect the economic value of the tradeoffs between water and energy. Increasingly, the marginal technologies in the water

sector are also more energy intensive, such as pressurized irrigation systems, recharging groundwater resources, or reverse osmosis systems. The choice to invest in these new technologies implicitly is a choice to tradeoff higher energy intensity in order to extend the water supply. This certainly raises the concern that the water supply could become more energy intensive.

B. The Energy Sector: Water for Electricity

While 39% of US freshwater withdrawals are for thermoelectric production in the US, in California, where we have easy access to over 800 miles of ocean coastline and a diverse inland waterway, less than 1% of freshwater withdrawals were for thermoelectric plants (USGS 2005), and the bulk of power plant cooling comes from saline water sources. Unlike other regions of the country, securing cooling water has yet to become a major concern in California. This likely accounts for the reason that there has not been as much focus on water use by the energy sector in the context of the Nexus and why the embedded water in energy metrics has not been greatly discussed. However this does not mean that water is not a concern – in California water quality is the driving feature.

One of the current water quality policy issues surrounds Once-Through-Cooling systems ("OTC") at thermoelectric power plants. The State Water Board ("SWB") has adopted rules that require OTC systems be replaced by less water intensive cooling systems. These new rules were put in place because the extraction of large volumes of water and the return of significantly warmer water to cold water sources by OTC systems has had a major impact on the ocean habitat and fisheries. While these changes in water use help to preserve the ocean habitat and fisheries, it comes at the cost of lower plant energy efficiency, increased rate of GHG emissions, and increased costs to operate these plants.

Water intensity in power plants is mainly driven by the choice of the cooling technology. There are three basic types of cooling technology used at thermal electric plants: Once-Through-Cooling, recirculation or wet cooling, and dry cooling. Once-Through-Cooling as the name implies only passes through the cooling systems once and achieves cooling through thermal conduction in a condenser. After having passed through the condenser, the cooling water is returned to its source at a higher temperature. These plants typically withdraw large amounts of water but consume a very small percentage of that water. Wet cooling systems conversely re-circulate water through the cooling systems many times and achieve cooling through an evaporative process. These systems have lower withdrawal rates but can actually consume more water as more and more water evaporates. Dry cooling is the least water intensive from both withdrawal and a consumption standpoint but is also the

least energy efficient. It re-circulates water through a closed loop system and achieves cooling through convection as electrically driven fans blow air over cooling fins.

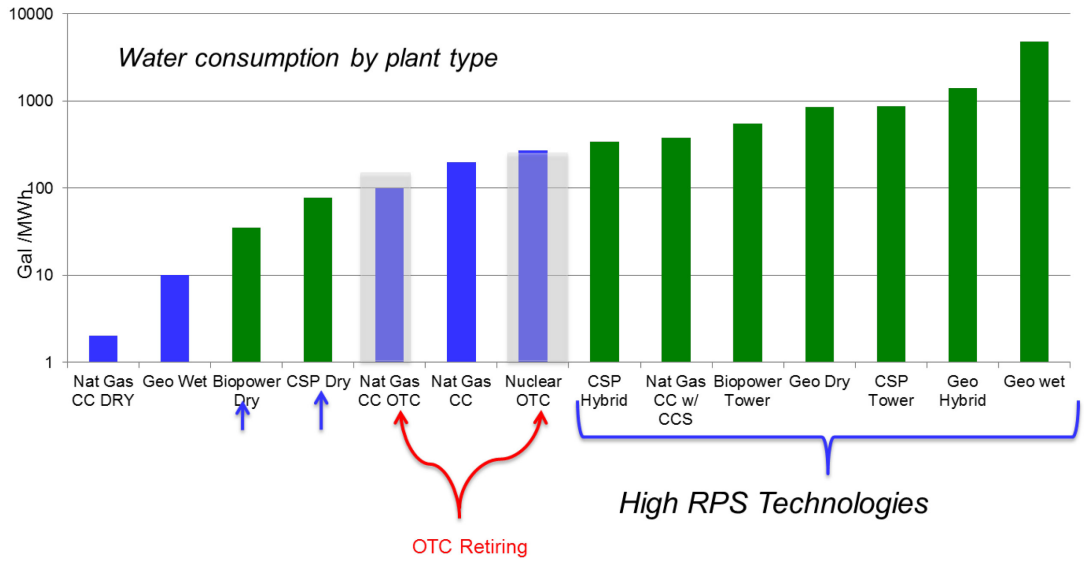

Figure 2**:** Water intensity of power plants: Source: NREL 2011

As mentioned the embedded water metrics has not been discussed broadly in the context of the Water Energy Nexus. There are three main reasons for this difference:

1. Embedded water use is typically concentrated at single points in the energy value chain: at generation plants. So the total lifecycle water intensity of generated electricity can be tied directly to its generating plant.

2. Water quantity only tells part of the water impact story; water quality is often the main concern.

3. Embedded water does not effectively distinguish or provided guidance about how to weight different parts of the water use cycle. i.e. water withdrawals taken from a source, water returned to the sources after having been used, and water consumed by the energy process.

Accounting for water use in the electricity sector is in principle more straightforward than accounting for energy use in the water sector. The water uses for electricity generation are clearly identified and the options are also clearly understood. The main challenge for the Nexus, however, is not merely accounting for water use but is one of assessing the value and impact of water in electricity generation. This includes the value of the water before it is withdrawn from the source water, the value in use by the electricity service provider, and the value of the degraded returned water. The choice of the technologies then comes down to the value of the energy saved vs. the value of the impact on the water resource. Since the primary water source for electricity are saline sources in California, which do not compete with the freshwater supply, the main tradeoff is simply cost, higher

GHG emission rates per KWh of generation, and the environmental impacts to the sources and returned water.

III. Water and Energy Institutions

Despite efforts to define metrics in the energy and water sectors, a well-established strategy for managing the Nexus has not emerged. Partially the issue is that the metrics themselves are not good indicators of inefficiencies in the Nexus. Rather these metrics more closely reflect choices made by operators within the Nexus, and the inherent financial and economic positions of the institutions that manage these resources.

Electric and water utilities typically operate under some sort of established regulatory framework. In the electricity sector three Investor Owned Utilities (IOUs) provide service to over 80% of the state, while municipal utilities provide the remaining 20%. The IOUs are publicly traded for profit companies that operate as regulated monopolies under the authority of the CPUC. For the IOUs the type and level of service is driven primarily by their ability to recover their costs. The cost recovery rates, which are determined publicly by the CPUC, are based on the level of investment made by the utilities and are independent or decoupled from the sales of electricity.

The cost of invested capital, typically equity financing, and other operational costs are considered in determining the final rates that consumers face. Decoupling the sales from the returns the IOU receive allows the CPUC to value energy efficiency investment at a rate higher than might otherwise occur and also aligns the utility incentive to provide energy efficient services, with its potential return form those investments.

The municipal rates are determined by the municipal boards themselves and employ different method to recovery costs. More often they use a cost plus approach to determine at least a portion of the rates; municipal utilities, however, are also moving to decouple their cost recovery strategies from sales. Municipal utilities also enjoy other advantages in financing such as lower cost of capital, through debt as opposed to equity financing for example, that IOUs cannot access. Municipal utilities also have other types of

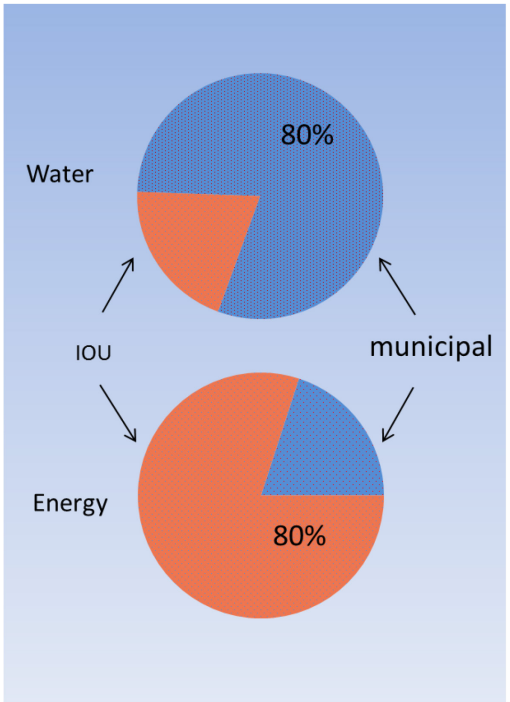

Figure 3: Water and Energy Utilities

advantages such as prioritized access to federally managed sources of cheap energy.

In the water sector, the mix of IOUs to municipal utilities is reversed. Municipal water service providers dominate the urban water service accounting for about 80% of the service connections, with IOUs only counting for about 20% of the service. The municipal water utilities also enjoy some of the same financial cost recovery and other financial advantages such as debt financing as in the energy sector. In addition municipal water utilities are also more reliant on sales for cost recovery. Another common cost recovery strategy of municipal water utilities is connection charges, a one-time fee associated with a new service connection. One of the consequences of this financing strategy is that it requires continuous growth in order to provide for the maintenance of existing infrastructure. This approach by necessity drives the need for even more supply and more growth.

In addition to the service providers there are also state actors that serve to manage and regulate the physical infrastructure and wholesale energy and water markets. On the electricity side, the California Independent System Operator ("CAISO") manages the grid and is responsible for assuring the daily functionality of the grid. In the water sector, a variety of (state and federally operated systems control and manage water flows across the state. The core mission for these controlling authorities, in both the energy and water sectors, is to provide reliable service across the state, essentially mitigating the supply risk of the individual utilities. This is a significant cost savings to utilities.

One of the underlying, though unstated, assumptions of the Nexus is that there should be some financial accounting mechanism that could account for the benefit to one sector due to savings in the other sector. For example a water utility saves some additional water and an energy utility receives a benefit of lower energy demand from the utility. There are currently a number of energy efficiency programs that finance energy efficient investments based on an estimate of the avoided cost to provide electric service. For the Nexus, a new avoided cost calculation would have to account for not only energy but also water savings. Additionally this new method would also have to somehow separate the value of water savings from the value of the energy savings in order to fairly attribute the cost and benefits to each sector. This accounting system currently does not exist.
Developing this kind of framework and bridge of the regulatory as well as the historical institutional divide is another and perhaps the largest challenge in the Nexus.

California, however, has taken steps to bring together representatives from both the energy and water sectors. The landmark climate action bill, AB 32, created the Climate Action Team (CAT) to coordinate emission reduction activities across agencies. This team subsequently formed a sub group, the Water Energy Team (WET-CAT), mandated to address the water energy Nexus issues and develop working relationships and plans of action to facilitate more coordination between the energy and water sectors.

IV. Water Energy Matrix: A Framework for Evaluating the Value of the Nexus

Since the CEC demonstrated that 19% of electricity is used for water related activities in the state of California, it has been assumed that this huge amount of energy reflects a huge hidden cost of water and also perhaps a hidden opportunity. Improved conservation metrics certainly will save both energy and water but this is not actually new. We always have had and continue to have the opportunity to make a choice to conserve water either by changing water use habits or by using water more efficiently by changing technologies, e.g. toilet replacement. We also currently have the opportunity to improve water system efficiency, by reducing leak lose rates and investing in energy efficient systems for example. And the value of those investments can be directly determined by estimating the value of the water savings and reduction in operating costs.

Now with the insight from the Nexus, the new opportunity is to use information about the extent of the energy savings potential to make better choices about how to use water and when to invest in water technology. What we would like to know is how does the improved information about the Nexus and the energy content in water change how we prioritize programs? Should we spend more money on conservation programs rather than technology replacement programs? Or perhaps it is the reverse? Our efforts should be focused on assuring that our priorities are correctly aligned with the total potential savings from the Nexus.

To a water consumer, developing energy informed priorities is difficult, mainly due to the fact that embedded energy has little bearing on cold-water use. When you water your lawn it does not matter if the water was pumped over the Tehachapi and has high-energy content or if it was supplied though gravity feed system and has no energy content. For cold-water uses the only reflection of the energy

content would be in the cost of the water. Consumers could, however, make energy informed choices regarding their water use if the embedded energy were accurately reflected in the price of water. For hot-water uses it is more complex since the embedded energy is part of the value of the service and the consumer must make choice about how they want to use both water and energy. Individual decisions as well as policy decisions that involve a tradeoff of water and energy are inherently more difficult. The difficulty is in prioritizing the benefit of saving water vs. saving energy. For example there might be two different policy options - one program that might have expected savings of 1KWh / 10 gal and another program where 10 KWh / 1 gal are saved. Which one should be preferred? This type of problem is not one that can be solved merely with more data since it is inherently an economic choice about the value of water vs. the value of energy. To date there is no established policy or guidelines for evaluating this type of tradeoff.

A major opportunity in the Nexus is to classify those tradeoffs and clarify what constitutes an efficient and beneficial tradeoff between water and energy savings. This would allow us to develop policies that promote technologies that are consistent with those values.

While the previous discussion was focused on the water end-use, the Nexus is more extensive. It also includes activities that supply, convey, transmit and distribute both energy and water. This requires a more comprehensive framework and model of the economic incentives. In order to evaluate the options within the Nexus, LBNL (LBNL 2008) developed a useful framework for visualizing and evaluating the range of these types of economic interactions. The framework classifies water and energy activities based on their impact on water and energy supply and segments them into quadrants designated as either substitutes or complements. This framework defines a strategic matrix with either increasing or decreasing energy supply on one axis and increasing or decreasing water supply on the other axis. Because technologies within each quadrant are similarly aligned we could in principle rank new programs against others within the same quadrant: an apples-to-apples comparison so to speak.

The definition of the technologies within each quadrant depends on the types of uses. For certain uses, access to water is the main driver in developing a resource and energy plays a supporting role. For other uses it is the energy resource that is developed with water utilized to make energy production more efficient. In other cases simultaneous access to both energy and water is the goal

and both are seen as equally valuable resources. From an economic viewpoint we can classify these two resources as either substitutes or complements. The perverse nature of the Nexus is that sometimes water and energy are economic substitutes and sometimes they are complements.

Water and energy are complements when a decrease in price for one resource implies an increase in the demand for the other. Energy and water are complementary in end-uses such as water heating. As energy prices decreases the use of both energy and water will increase, for example since people may be more like to use more heated water.

Water and energy are substitutes when an increase in price for one resource implies an increase in the demand for the other. In water for example a rise in water scarcity will lead to an increase in ground water pumping or other energy intensive supply options. In the energy sector an increase in water prices leads to the adoption of more energy intensive cooling technologies. In these cases water and energy are traded for each other. While essentially a notional tool, the strategy map (Figure 4) allows for the comparison of different activities, programs and technologies and puts in context how a programmatic change might impact the entire Nexus. The matrix can cover a range of technologies in the Nexus value cycle from water and energy storage in hydro-plants, to water/energy conversions by both water and electric utilities, to final end-uses in multiple consumer segments.

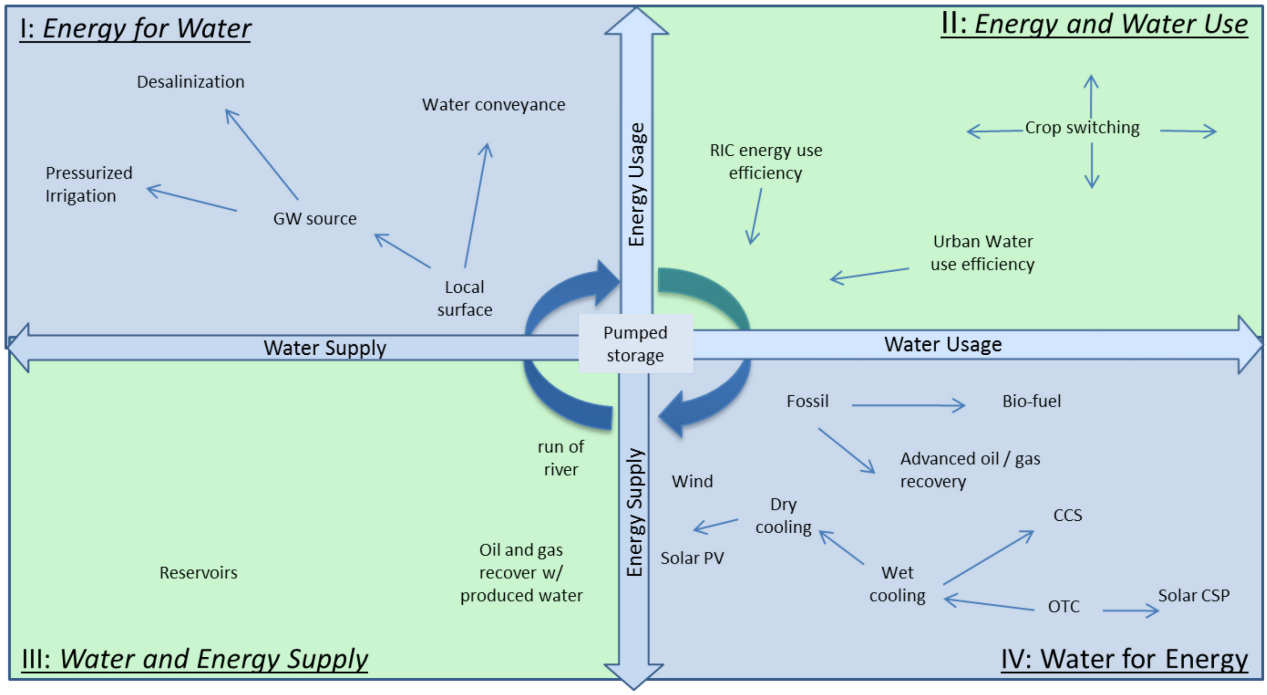

Figure 4: Framework for evaluating tradeoffs in the Nexus. Modified diagram from LBNL 2008

Part of the shortcomings of the embedded energy approach arises from the fact that the metric is only focused on one part of the Nexus; water end-uses. But the Nexus is actually broader than just energy in support of for water services. This approach provides a strategic framework where programs from different parts of the Nexus can be compared.

One of the insights from this framework is that there may be opportunities to coordinate efforts across the Nexus that might not be beneficial by themselves but together may provide greater overall benefit to a region. For instance conjunctive use programs coordinate surface and groundwater resources, balancing seasonal differences though the exchange of surface and groundwater resources. The result of this type of management may result in higher local energy intensity, reduced reliance on conveyed and highly energy intensity water but more water security.

As we move toward more renewables there may also be opportunities to co-develop renewable resources with conjunctive management, water recycling and water conservation programs. This may also be a benefit on the energy side since it my open the opportunity to develop resources that are valued based on the water sector reliability requirements rather than grid reliability requirements. This is a much more integrated form of demand response that can not only span hours but seasons. . Developing renewables close to major water pumps stations, and eliminating or reducing the transmission development needs, is another way that new energy projects could become viable and more cost effective.

V. Recommendations

The main goal of this white paper is to rethink how we should evaluate the Nexus and develop a roadmap that prepares us for the challenges that we might face.

We have found that a simple characterization of the Nexus with embedded metrics neither reflects the regional differences and constraints on water nor the economic value of tradeoffs between water and energy. We have also found that water sector institutions and energy sector institutions operate under different incentive structures and use different criteria to make judgments about the tradeoffs between using water and using energy. It is also clear that while tradeoffs between water and energy can be beneficial, there is no clear or consistent assessment or metric of the value of those tradeoffs.

More robust management of the Nexus should be mindful of these shortcomings and promote a technically efficient and resilient infrastructure given regional constraints while also recognizing that water and energy services are essential and should be available across the state.

To develop this type of cross sector and long-term Nexus management we have the following recommendations.

1. Develop guidelines for managing the portfolio of Water Energy Nexus

In both the water sector and energy sector there are formally agreed on principles (BMPs for water and the "loading order" for energy) that are used to help align and set priorities within the sector. These principles are well established and supported by legislation and regulatory rulings. In the Water Energy Nexus there is no such set of guiding principles. The diverse institutions in the Nexus could benefit from an established and agreed upon core set of principles and objectives for managing the Nexus. These common principles and objectives would not necessarily specify how any particular decision should be made; rather it would help to consistently and transparently set priorities across all stakeholder groups. This requires institutions and stakeholders in the Nexus understand and commit to these principles and objectives

These principles and objectives should be flexible and recognize that the fundamental nature of the Nexus is based on the fact that tradeoffs between water and energy are valuable. These principles and objectives should help clarify and find the balance between using more energy to provide more water and using more water to provide more energy. They should also help clarify the value of a new tradeoff given how much it mitigates energy and water related risks. These principles and objectives should also recognize that while the coordinated use is valuable, efficient use is equally as valuable and that embedded resource costs should be fully reflected in the prices of the delivered service. Some important considerations include

- Recognize regional constraints and fundamental water rights and needs.
- Establish a framework for evaluating tradeoffs between water use and energy use against the value of the mitigated risk
- Establish transparent price mechanisms that recognize that embedded energy in water is essentially a cost of providing water service.
- Monitor the impact that high energy intensity water systems have on statewide GHG emissions.

2. Develop a consistent water and energy data reporting standards.

With an understanding of the Nexus principles and objectives, it will be important to have robust data that can support and validate the progress for achieving those objectives. Currently this type of data is sporadically collected and even more rarely reported and shared. There is no current repository that decision-makers can utilize or a regular schedule of updates to water and energy data. Furthermore, as water systems deploy more energy intensive technologies, it will also be important to understand how water related energy demand is forecast to change. Developing reporting standards and assigning a responsible entity or entities to manage and enforce these standards will help to align efforts across all parts of the Nexus. Such reporting efforts may include.

- Require comprehensive water use reporting to CEC IPER
- Require comprehensive energy use reporting to DWR state plan
- Require energy efficiency savings to be included in water demand projections
- Require water conservation program savings in energy demand projections in the IEPR
- Include agricultural water irrigation metering
- Develop a consistent water and energy data standards.
    - Define when and by whom data should be collected.
    - Define engineering measurements standards and protocols

Consistent data collection and coordination will allow us to identify gaps and weakness, establish best practices, and develop programs to improve the overall efficiency of the Nexus.

3. Develop energy water partnerships between electric utilities and water utilities

Efficiency programs are typically focused on making technological changes that reduce use of a resource while conservation programs are focused on behavioral changes that reduce use of a resource. Electric utilities have robust energy efficiency programs and are adept at measuring the impact of these programs, water utilities have more robust and experience with water conservation programs. We also recommend that electricity utilities develop water sector focused EE programs and that water utilities develop energy sector specific programs:

- Development of best practices for efficiency programs for the water sector
- Development of best practices for conservation programs for the energy sector

The untapped value of the Nexus lies in our ability to align and manage the water energy tradeoffs consistently. In a diverse state like California this can be a challenge, particularly since some regions are more water stressed than others, and may value water more highly than energy. Nevertheless we are beginning to realize that we can manage the Nexus in a better way: one that preserves and secures water resources while also reducing GHG emissions and impacts to the environment.

VI. References

ACEEE (2011) "Addressing the Energy-Water Nexus: A Blueprint for Action and Policy Agenda."

DOE (2006) "Energy Demands on Water Resources" Report to Congress on the Interdependence of Energy and Water.

GAO (2012) "Energy Water Nexus: Coordinated Federal Approach Needed to better Manage Energy and Water Tradeoffs". GAO- 12-880.

CEC (2005) Klein, Gary, "California's Water – Energy Relationship." California Energy Commission CEC-700-2005-011-SF.

GEI (2012) Park, L., "California's Water Energy Nexus Pathways to Implementation" GEI 2012.

LBNL (2008) Dale, L., et al., "The Interaction of Water and Energy in California" LBNL 2008

NREL (2011) Macknick, J. Newmark, R., et al. "A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies" NREL/TP-6A20-50900, March 2011.

EPRI (2002) Powicki, C., "The Water Imperative," Electric Power Research Institute, EPRI Journal, July 2002.

USGS (2009) Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., "Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344", 2009 p 52.