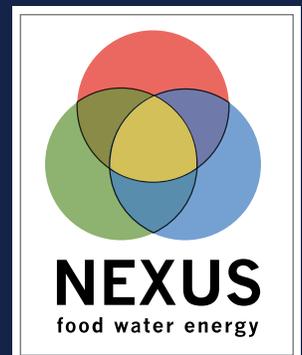




Food, Water and Energy: KNOW THE NEXUS



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Food, Water and Energy: Know the Nexus

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Foreword

» **Scott Cullen, Executive Director of GRACE Communications Foundation**

OUR CONSUMPTION OF FOOD, WATER AND ENERGY — directly or indirectly — impacts ecosystems and natural resources that society depends on for its survival. Recent events like droughts, oil spills and increasing food prices tell us that we can no longer view our food, water and energy systems in isolation. Instead, we all must understand how and where these three systems intersect — the *nexus*.

Consider:

- » Energy is required to treat wastewater and transport drinking water;
- » Water is required to make electricity and produce transportation fuels;
- » Energy and water are required to grow food;
- » An increasing portion of certain crops is being used for fuel instead of food; and
- » Water quality can be adversely impacted by food and energy production.

The use and management of one of these resources can impact the others, so it is necessary to take a nexus approach to all three. This means gaining a better understanding of how these three systems interconnect, then acting to ensure food, water and energy security and sustainability for the future. With the world facing dynamic shifts stemming from an ever-growing population, climate change and globalization, moving forward with a nexus approach is no simple task. As this paper demonstrates, doing so will require the combined efforts of individuals, businesses and governments.

The nexus concept may seem academic at first, but the real-world implications can be dramatic. Take, for example, the record-breaking heat and drought conditions across the United States during the summer of 2012. A significant portion of corn crops withered from lack of rainfall, affecting food and livestock feed supplies and prices as well as corn ethanol production. Numerous power plants had to scale back operations or even shut down, because the water temperatures of many rivers, lakes and estuaries had increased to the point where their waters could not be used for cooling. In the Midwest, household, municipal and farm wells had to be extended deeper into rapidly depleting aquifers to make up for the lack of rainfall, draining groundwater supplies and demanding more electricity to run the pumps.

When the nexus becomes unbalanced, there are clear consequences for public health, our economy and the environment. These imbalances are often expressed through habitat loss, poorer water quality and limited food, water and energy resources for humans.

Intended for advocates, community leaders and decision-makers in the United States, this issue paper defines the nexus and its components. The paper also illustrates how Americans are beginning to address its many challenges — in both positive and negative ways — and provides suggestions for filling in gaps in both our understanding and our management of the three systems. I hope that you will see the food, water and energy nexus not as an impossible riddle, but rather as a new way of thinking about the systems we depend on and how we can best manage and plan for a more sustainable future. We hope to stimulate a much broader conversation to help knock down the silo approach of isolated resource management because what we do every day affects the nexus and the nexus, in turn, affects our everyday life.

Introduction

THINK OF A SIMPLE SLICE OF PIZZA.

At first glance, it seems pretty basic — dough, tomato sauce and cheese — but look closer and you'll find that those three ingredients have a rich story to tell.

As you deconstruct your slice of pizza, consider the water and energy required to make it. You need to add water to the flour and yeast to make the dough, but what about the water used to grow the wheat that's milled into flour that makes up the dough that gets baked into your pizza? Or what about the water needed to produce the gooey mozzarella? You don't see this "hidden water" in your slice of pizza, but it's there.

Through a series of studies, the Water Footprint Network (WFN) broke down the water footprint of a margherita pizza (one topped with tomato, mozzarella and basil).¹ A water footprint looks at the direct and virtual water used to produce an item. **The WFN found that to make a single pizza requires 333 gallons (1,260 liters) of water, enough to fill almost ten bathtubs!**



Producing one calorie of food requires about one liter of water. That means you "eat" more water than you drink.²

Now think of the energy going into your pizza. There's the direct energy that goes into warming the pie, but there's also the virtual energy that goes into farming the crops (think tractors and fossil fuels required to produce fertilizers and pesticides), processing and distributing the ingredients and even the energy that was required to manufacture the pizza oven.

You may not have realized it, but just for a \$10 plain cheese pie, you rely on a global distribution network, industrial agriculture, fossil fuels and a *lot* of water.

In fact, water, energy and food are interrelated: you need water and energy to produce food; you need energy to treat and move water, and you need water to cool power plants and to produce natural gas and oil. The more you probe these networks, the more complex they become.

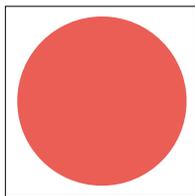
The next time you grab a slice of pizza you'll know more about all that's required for each tasty bite, but what about all the other things you consume? Do they also add up to a lot of food, water and energy? And how does your consumption of food, water and energy directly or indirectly impact our natural resources and ecosystems?

Let's take a broader look as we further explore the nexus.

Overview: Food, Water and Energy Systems

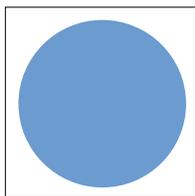
YOU'VE HAD A TASTE OF HOW THESE SYSTEMS — food, water and energy — are connected, but how does the “nexus” of these systems work on a larger scale, such as in your community or at the national level? To answer this, it's helpful to understand what we mean when we talk about food, water and energy systems in the United States. It's also important to understand how these systems and their interactions impact our environment.

» The Systems



Food System

A food system encompasses the activities, resources and people involved in bringing food from the farm to the table, including but not limited to the following:³ Growing and harvesting crops; Breeding, housing, feeding and slaughtering animals for food; Catching and harvesting aquatic plants and animals for food; Processing raw plant and animal materials into retail products; Transporting feed, animals, produce and other goods; Storing and selling products at retail outlets; Preparing and eating food; and the land, labor, soil, energy, animals, seeds and other resources involved in making the aforementioned activities possible.



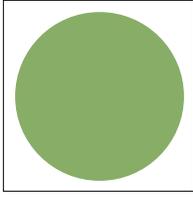
Water System

A water system supplies water for human consumption and treats wastewater to protect public and ecological health. But the fundamental way to view a water system is as a watershed, or an area of land in which all the water under it or that drains off of it goes into the same place.⁴ A watershed can be any shape and size and can cross political boundaries. According to the EPA, there are 2,110 watersheds in the continental United States.⁵ Unfortunately, water doesn't always exist when and where people need it. In order to meet the needs of individuals and communities, water is moved within and between watersheds. In essence, we alter water systems so we can fulfill our agricultural, municipal, commercial, industrial and energy production needs.



What is the NEXUS?

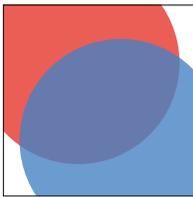
Food, water and energy systems are interconnected. The NEXUS is how and where these three systems intersect. Because actions related to one system can impact one or both of the other systems, it is necessary to take a NEXUS APPROACH.



Energy System

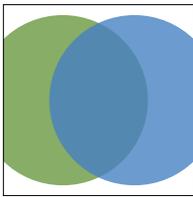
For the purposes of this paper, **an energy system includes the steps required to generate, transmit and distribute electricity, as well as the steps required to produce and distribute transportation fuels.** Electricity is typically generated at a power plant running on fossil fuel combustion — such as burning coal or natural gas — or nuclear fission.⁶ It is also generated by harnessing energy from flowing water, wind, sunlight and the earth's heat. Transportation fuels are also part of an energy system, which includes the production, refinement and distribution of oil and natural gas, as well as the production and processing of feed stocks (such as corn used to produce ethanol) for biofuels.

» Interactions Between Systems



Food and Water

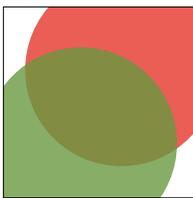
The water required for food production and processing is immense. Irrigating crops accounts for about 30 percent of all of the water withdrawals in the United States.⁷ Irrigation competes with other water uses such as power plant cooling, municipal drinking water and fossil fuel production. When parts of the country face drought, water sources can become strained, creating problems for farmers who rely on irrigation for their crops. This is especially troublesome for irrigators when restrictions are placed on water use by local and regional authorities. In addition, food production can significantly impact the quality of water bodies through agricultural runoff polluted with fertilizers, pesticides and manure from farms, fields and feedlots.



Water and Energy

Large amounts of water are required for conventional power production, primarily for cooling.⁸ **In fact, nearly half of all water withdrawals — both freshwater and ocean water — in the United States are used for thermoelectric power plant cooling.**⁹ Hundreds of large-scale power plants across the country are highly dependent on water resources, withdrawing 58 billion gallons of water from the ocean and 143 billion gallons of freshwater each day — more than any other water use category, including irrigation and public water supplies.¹⁰ For this reason, most power plants are located near rivers, lakes or the sea.

Power plants can be impacted by drought when surface water levels drop, leaving them without access to cooling water and forcing the plants to reduce their operations, sometimes even shutting them down altogether. During drier, warmer periods, the temperature of the water bodies that power plants draw from can rise too high to effectively cool the plants, or the water that runs through the plants can be warmed to such an excessive degree that it can harm the water body's ecology. The electric power industry is well aware of water issues. A recent Electric Power Research Institute survey of electric utility executives found that two-thirds of those polled reported “great” or “very great” concern about water, and expected those challenges to grow over the next decade.¹¹



Food and Energy

Agriculture and energy have always been connected, but modern technology and industrialization have significantly increased energy requirements for agricultural and food production. Energy inputs to agriculture include:

» **Fertilizer Production**

Industrial farms use synthetic fertilizers, which require fossil fuel inputs (primarily natural gas) to be produced. Other fertilizing agents (e.g., potassium and phosphorus) use energy as they are mined and transported.

» **Water Consumption**

Most forms of agriculture are water-intensive. As stated earlier, pumping and moving large volumes of irrigation water requires energy.

» **Farm Equipment**

Modern agriculture relies upon machinery that runs on gasoline and diesel fuel (e.g., tractors and combines), and equipment that uses electricity (e.g., lights, pumps, fans, etc.).

» **Processing, Packaging & Transportation**

Most of the food produced today is processed and packaged, increasing its energy and water footprints.

» **Transportation**

Because the food industry has been consolidated — fewer companies now control production — food is often transported long distances from a select few locations, requiring additional energy to power planes, trains, cars and trucks.

» **Industrial Livestock Farms & Energy**

Most meat, eggs and dairy products are now derived from livestock raised in industrial “concentrated animal feeding operations,” or “CAFOs”. Commonly referred to by critics as “factory farms,” these facilities raise thousands of animals in confined conditions without access to pasture. Such farms require tremendous quantities of feed produced by industrial crop farms using the energy-intensive processes described above.^{13,14}

Clearly, the relationship between food, water and energy is a complex one. To illustrate this, we’ve chosen three issues that demonstrate this nexus.

**WATER WITHDRAWAL
VS.
WATER CONSUMPTION**

Water withdrawal is when “water is diverted or withdrawn from a surface water or groundwater source” and then returned. **Consumptive water use**, on the other hand, is “water use that permanently withdraws water from its source; water that is no longer available because it has evaporated, been transpired by plants, incorporated into products or crops, consumed by people or livestock, or otherwise removed from the immediate water environment.”¹²

The Nexus in Focus

» Issue One: Sacramento-San Joaquin Delta

Photo: California Department of Water Resources



CALIFORNIA IS A LARGE STATE with a variety of climates, geographies, and population centers. In the early twentieth century, water and energy were primary ingredients for jumpstarting the state's economy, especially in the southern part of the state. Unfortunately, where food, water and energy are concerned, climate, geography and population don't line up in the Golden State. Some of the state's largest population

centers are in the arid, southern coast, which requires water to be conveyed from the wetter, northern parts of the state — and from the Colorado River. Moving and treating all that water takes almost 20 percent of the state's electricity.¹⁵ In addition, California has competing interests for the state's water resources: As a major agricultural producer, farms need water for irrigation while continually growing metropolitan areas need drinking water.

With so many competing interests, conflicts emerge. Unfortunately, the source of much of the state's water, the Sacramento-San Joaquin Delta, is struggling to maintain its ecological integrity while supplying water to meet demand.¹⁶ Formed by the intersection of the two rivers of the same names, the Delta is the largest estuary in the western United States and empties into the San Francisco Bay. The delta provides 27 million people — two thirds of the state's population — with drinking water, while irrigating three million acres of land.¹⁷

Water from the Delta supplies California's extensive agriculture industry. The Westlands Water District, which encompasses 600,000 acres of irrigated land producing over 60 varieties of crops, is one of the big players in the fight to win water resources.^{18,19} This struggle pits farmers in the region against environmentalists and wildlife and water agencies, all of which seek to limit the water available for irrigation to protect indigenous species of fish in the Delta.^{20,21} The Chinook salmon fishery, for example, was an important commercial fishery until the 1950s, when fish

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stocks began to drop.²² The decline in population was so great that the fishery has had to close in recent seasons.²³ Fishermen blame the collapse of the Chinook salmon fishery on water being pumped out of the Delta, but it’s likely that other factors like habitat loss and pollution contributed as well.²⁴

To accommodate these competing interests and manage water resources in a more sustainable way, a plethora of agencies and regulatory bodies have been established. Both state and federal authorities are involved in oversight of resources that move water around the state. In order to streamline the bureaucracy, a plan stemming from a 2009 law signed by Governor Arnold Schwarzenegger (and the stewardship council that formed out of the legislation) takes a major step forward in redefining the Delta and its water use for people and crops while maintaining critical fish habitat.

The Delta Stewardship Council was set up “to provide for a more reliable water supply for the state, to protect and enhance the quality of water supply from the Delta, and to establish a governance structure that will direct efforts across state agencies to develop a legally enforceable Delta Plan.”^{25,26} The comprehensive management plan — a final draft version of which was submitted to the board in May 2012²⁷ — will be revised every five years to adjust for changing conditions, including population growth and climate change, among others.

Another tool for balancing the needs of water users with the ecological health of the Delta has been the Endangered Species Act. The Delta Smelt, an endangered fish species at the base of the food chain, has been threatened by water diversions that left too little water in the Delta for the smelt population to thrive. To meet ecological goals, “The Bay Delta Conservation Plan” (BDGP) is being prepared by a group of local water agencies, environmental and conservation organizations, state and federal agencies and other interest groups.”²⁸ This long-term conservation strategy, slated to be released in 2013, will be implemented over the next fifty years and will dictate how endangered species permits will be issued for water projects. Part of the plan involves two 37-mile-long tunnels to bring water directly from the Sacramento River to the existing pumps, bypassing the Delta and, thus, keeping fish away from the pumping facilities.²⁹ Whether these plans prove to be effective in better managing the Delta region (and better protecting the Delta Smelt) remains to be seen. Likewise, only time will tell if these plans will help reduce the tension between food, water and energy systems. Water pumping will still be a major consumer of electricity and agriculture will still be a major consumer of water, requiring vigilant management of the state’s scarce water resources.

As water economist David Zetland notes, “Nature makes a drought, people make scarcity.”³⁰ Droughts will undoubtedly occur during the timeline of the plans. Hopefully, officials will wisely maintain the Delta’s ecosystem while sustainably managing demands for water and energy in California. The importance goes beyond the state — if you’ve ever had a glass of California wine, some Blue Diamond almonds or any number of other products produced in the valley, then you too are a consumer of the Delta’s water.³¹

» Issue Two: Food Waste

BETWEEN ONE-QUARTER AND ONE-HALF of the more than 590 billion pounds of food produced each year in the United States is squandered.³² Using this range, food writer and food waste expert Jonathan Bloom estimates that, every day America wastes enough food to fill the Rose Bowl — the 90,000-seat football stadium in Pasadena, California — and sometimes as much as two stadiums full.³³ Approximately \$165 billion is spent each year on producing food that is ultimately wasted.³⁴



Photo: Shutterstock

As in other industrialized nations, a large portion of that waste occurs in households.³⁵ The average American throws away 20 pounds of food each month or about two-thirds of a pound per person per day.³⁶ Fresh products like fish, eggs, milk, fruits and vegetables make up most of household food waste.³⁷

Per capita food waste in the U.S. has increased by 50 percent since 1974.³⁸ In 2010, discarded food represented the single largest component of the municipal solid waste stream reaching landfills and incinerators; less than 3 percent of that waste was recovered and recycled as compost.³⁹ This component of garbage represents a significant cost to local governments (and ultimately taxpayers who already paid for it once as consumers), which is why many municipalities like the City of Santa Monica, California and Charleston County, South Carolina are adopting food waste collection and composting programs.^{40,41}

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What are the Root Causes of Food Waste?

On the consumer end, much household waste is due to food spoilage, overcooking, plate waste and over-purchasing. According to new research commissioned by WRAP (an advocacy group established to implement and market recycling in the U.K.), about two-thirds of annual household waste in the U.K. is due to food not being used in time, whereas the other one-third is caused by people cooking or serving too much.^{42,43} Some waste can be driven by consumer misinterpretation or confusion over “use-by” and “best-by” dates — which are based on manufacturer suggestions for peak quality — that lead people to throw out food for fear that it is spoiled, when in fact it still is safe to eat.⁴⁴

On the production side, crops are sometimes left unharvested or unsold because their appearance does not meet strict quality standards required by many supermarkets and expected by consumers. Adding to the problem, most stores discard food products as soon as they are past their “sell-by” dates. These dates tell the store how long to display the



product for sale. Stores end up using these “sell-by” dates to help determine when to remove goods from shelves and restock with new product, but quite often these products still have shelf life left.⁴⁵ There is also the potential that food can be stored or packaged improperly or mishandled during transport. Restaurants contribute to the problem with supersized portions, sprawling menus and inadequate training for food handlers about minimizing food waste.

Given the water- and energy-intensive nature of growing, processing, packaging, warehousing, transporting and preparing food, it follows that wasted food means wasted water, energy and agricultural resources.⁴⁶ This is problematic at a time when, as stated in this report’s Foreword, all three are under increased strain from a growing population, climate change and other factors.

A considerable amount of energy and water are associated with discarded food. Approximately 2.5 percent of the U.S. energy budget is “thrown away” annually as food waste.⁴⁷ This is equivalent to

the energy contained in hundreds of millions of barrels of oil. In addition, about 25 percent of all freshwater consumed annually in the U.S. is associated with discarded food; globally such waste consumes as much water as in Lake Erie.^{48,49}

Food waste has significant ecological consequences. If we did a better job of meeting demand by capturing food that currently gets discarded, a significant amount of land conversion from forests, grasslands and wetlands to agriculture might be avoided and, subsequently, we could potentially reduce our adverse impact on biodiversity.⁵⁰ We could also decrease pesticide and fertilizer runoff and their negative ecological and water quality impacts if fewer total acres of farming are required. At the disposal end, nearly all food waste ends up in landfills, allowing it to decompose and release methane, a greenhouse gas that traps 21 times more heat than carbon dioxide.⁵¹

Food waste is particularly egregious at a time when hunger is a growing problem and an increasing human rights issue. Nearly 20 percent of Americans have trouble putting food on the table, according to a recent USDA study.⁵² If we wasted just 5 percent less food, it would be enough to feed four million Americans⁵³; 15 percent less waste could feed 25 million Americans annually.⁵⁴

If we are wasting so much food, then the bottom line is that something isn’t working. According to Dana Gunders, Project Scientist with the Natural Resources Defense Council, “With such a hugely inefficient food system comes opportunity. Entrepreneurs and innovators who figure out how to tap into the huge reservoir of wasted food will find

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savings for themselves, their customers and the planet as a whole.”⁵⁵

The solution is a combination of radically reducing food waste at its source while ensuring that what gets wasted becomes a resource — not trash. One opportunity is to reconnect the whole supply chain from farm to table and table to farm by composting food waste and using it as fertilizer to grow crops.⁵⁶ Another opportunity is to connect home and community gardeners so that their excess harvest can be donated to the needy instead of allowing it to rot.⁵⁷ Significant reductions in food waste can often be achieved through simple changes in food purchasing, storage and preparation. Using “unavoidable” food waste as a resource involves diverting it from landfills and utilizing it to generate energy or create fertilizer from compost.

Increasing the efficiency of our food system is truly a triple-bottom-line solution. It offers the environmental benefits of efficient resource use, the financial benefits of cost savings and the social benefits of alleviating hunger through food donations. The complexity of the problem and the wide and varied set of potential remedies mean that everyone can be part of the solution.⁵⁸



» Issue Three: Browns Ferry Nuclear Plant

Photo: Nuclear Regulatory Commission



ABOUT A DOZEN MILES from the northern Alabama town of Athens, at the end of the appropriately named “Nuclear Plant Road,” sits the Browns Ferry Nuclear Plant. Hailed as the largest nuclear power plant in the world when it began operating in 1974, today Browns Ferry’s three nuclear reactors can churn out 3,400 megawatts (MW) of electricity, enough to power about two million homes.⁵⁹

Like most thermoelectric power plants, Browns Ferry needs an

ample supply of cooling water (about two billion gallons of water per day as of 2005), so the plant was built along the banks of Wheeler Reservoir, one of nine lakes created by the Tennessee Valley Authority (TVA) to turn the Tennessee River into a navigable waterway.⁶⁰

Nearly all nuclear power plants rely on cooling water drawn from a nearby river, lake or estuary to safely cool the steam used to turn turbines and generate electricity. Compared to fossil fuel power plants, nuclear power plants are particularly vulnerable because they require the largest water withdrawals per unit of electricity produced.⁶¹ Many older plants use a “once-through” cooling system, which withdraws a tremendous amount of water, uses it once (hence the name “once-through”) and immediately discharges it. A “closed-cycle” cooling system, on the other hand, withdraws far less water and recycles it through cooling towers.

The Browns Ferry plant relies on a hybrid system that uses both types of cooling; the type it uses at any one time depends on a number of factors, including water and air temperatures. However, Browns Ferry’s cooling towers as they exist today are limited, only able to reduce the temperature of about two-thirds of the cooling water that the plant uses.⁶² Instead, when the weather gets warm, the TVA uses its cooling towers to operate in what they call “helper mode,” where water is cooled just enough to keep the Browns Ferry plant humming.⁶³ Recent summers have highlighted the plant’s fragile dependence on water.

To protect the aquatic life within Wheeler Reservoir, the Browns Ferry plant operates under a state permit that prohibits it from raising the temperature of the reservoir above 90 degrees Fahrenheit downstream from the plant.⁶⁴ This limitation has forced Browns Ferry to reduce operations for periods of time. During 2007, for example, in the midst of an intense southeastern United

NUCLEAR POWER PLANTS ARE PARTICULARLY VULNERABLE BECAUSE THEY REQUIRE THE LARGEST WATER WITHDRAWALS PER UNIT OF ELECTRICITY PRODUCED.

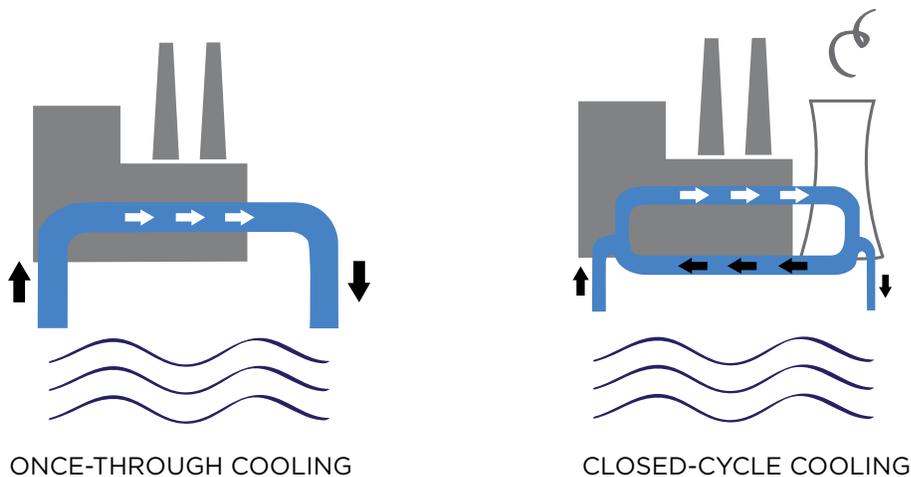
States drought, Wheeler Reservoir's water temperature got too high, forcing the plant to run at half-power.⁶⁵

For weeks during the heat waves of 2007, 2010 and 2011, the wide, shallow waters of the reservoir exceeded the 90 degree threshold.⁶⁶ The TVA had no choice but to drastically ramp down Browns Ferry's power output at exactly the time when air-conditioner-fed electricity demand was peaking. To meet demand, the TVA had to purchase electricity at a much higher cost. That cost was, in turn, passed on to consumers.

If not for the permit that limits how much higher Browns Ferry can raise the temperature of the Wheeler Reservoir, the consequences of the plant's "thermal pollution" would be significant. Fish and other aquatic life, whether in Wheeler Reservoir or any other water body, are highly sensitive to temperature changes. There is a great deal of scientific research explaining the impacts from thermal pollution from power plants, such as altering fish spawning, killing species through thermal shock and reducing dissolved oxygen levels.⁶⁷ Given that the reservoir and the rest of the Tennessee River is what the TVA calls a "major recreation and tourist center", the health of the waterway is important both biologically and economically.⁶⁸

To avoid future permit-driven shutdowns, the TVA has upgraded four of the six cooling towers at Browns Ferry, and added a large, new seventh tower. The plant's cooling system can now operate in closed-cycle mode for the first time in over two decades, allowing it to dissipate its massive amount of heat into the atmosphere instead of the reservoir. The cost of upgrading the Browns Ferry plant to make it less water-vulnerable is a cool \$160 million.⁶⁹ In the short-term, the investment is a sound one for the health of the Tennessee River and safe operation of the plant. In the long-term, the problem of more intense heat waves due to climate change may remain a challenge for Browns Ferry and other southeastern power plants. One study found the duration of Southeastern heat waves could expand by 60 to 80 more days every year.⁷⁰ Because power plants are more efficient when the temperature of the cooling water source is lower, even the effectiveness of a brand new cooling system in a future of lengthy temperature extremes is uncertain.

Once-Through vs. Closed-Cycle Cooling



A power plant with a closed-cycle cooling system cools steam with recirculated water — similar to how a car radiator works — as opposed to a once-through cooling system that continually withdraws water from a local water body. **Closed-cycle technology reduces power plant water intake by 95 to 98 percent.**

The Nexus in Action

WHILE THE FOOD, WATER AND ENERGY NEXUS may be a new concept for many of us, there are numerous examples of individuals, businesses and governments that already benefit from taking a nexus approach. Here are just four examples of people who, because they strongly believe in sustainability, are mindful of how these three systems interact.



CINDY RIDENOUR,
owner of Meadow Maid Foods, on how her family farm minimizes fossil fuel inputs, such as operating

farm equipment for hay production, by grazing beef cattle: “We estimate that their hay is probably just a couple percent of their total feed over their lifetime. And that’s the only fossil fuel input in these animals, from birth until the time we take them to slaughter.”

Photo: Courtesy of Cindy Ridenour



SAN ANTONIO WATER SYSTEM & CPS ENERGY,
on the interdependent relationship between water

and energy: “SAWS provides up to 50,000 acre-feet of highly-treated recycled water per year for CPS Energy, ensuring that the utility has the water needed to generate electricity for the foreseeable future while providing sufficient water flows for the downstream waterways.”

Photo: Courtesy of SAWS



WILL ALLEN,
founder of Growing Power, on vermiculture and aquaponics: “None of the stuff that we’re doing is new. We’ve always

grown food, we’ve always composted and we’ve always done aquaponics since ancient times . . . we’re taking those natural concepts and moving them into a building and doing the same thing.”

Photo: Courtesy of Will Allen



WAYNE KOECKERITZ,
owner of Food Waste Disposal, LLC, on recycling food waste: “Within this corn or tomato or

whatever it is, a number of BTUs were used to produce it. Let’s capture some of that energy rather than being incredibly wasteful with it.”

Photo: Courtesy of Wayne Koeckeritz

Food, Water and Energy Policy at the National Level

IN THE PREVIOUS ISSUES, much of the effort to address the food, water and energy nexus has taken place at the state or regional level. Given the wide-reaching implications of the nexus, it might be expected that the federal government would take a **nexus approach**. Unfortunately, as it turns out, the U.S. government has largely ignored the nexus, as indicated by legislation and policies that rarely account for interconnections in any combination among food, water or energy.



» Corn Ethanol: Not the Sustainable Answer

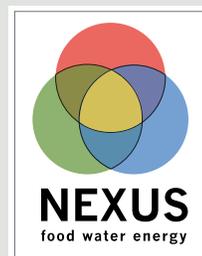
At one time, members of Congress and environmental organizations touted ethanol as a homegrown and environmentally-friendly alternative to oil, or another step towards energy security — but the claims did not play out.

Ethanol derived from corn is the most widely used biofuel in the United States, but the mandated amount of ethanol exceeds the supply, which is helping to drive up the price of corn. In 2010, nearly 40 percent of U.S. corn was converted into ethanol.⁷¹

Millions of acres of corn crops can have environmental effects made worse by the high demand created by the ethanol mandate. The fertilizers that are heavily applied to corn crops can run off of fields into waterways and cause overgrowth of algae in rivers and lakes. Algae blooms can consume much of the oxygen in the water creating “dead zones.” Within the Gulf of Mexico, the combined farm runoff emanating from the Mississippi River has resulted in the formation of a seasonal “dead zone” that averages 5,200 square miles.⁷² National studies and regional assessments of waterways in the Mississippi River Basin consistently point to chemical fertilizers and manure spread on fields as the main sources of nutrient pollution.⁷³

Different studies have produced differing figures, but corn-based ethanol has been shown to be less effective at lowering greenhouse gas emissions than other biofuels. For example, one complete life-cycle analysis calculated that corn-based ethanol reduces greenhouse gas emissions by only about 12 percent relative to gasoline.⁷⁴

Corn-based ethanol production takes a toll on water, energy and food resources and is not an environmentally friendly alternative to oil. To be greener, the production of ethanol and feedstocks used in that process should be sustainable with efficient water consumption. Such criteria should extend to imported biofuels and feedstocks, as well.



What is the NEXUS APPROACH?

At the heart of the NEXUS APPROACH

is a strong understanding of the interdependencies among these three systems and how to ensure food, water and energy security for an ever-growing population. This will require the work of individuals, businesses and government.



» The Energy-Water Roadmap: Delayed for Too Long

In 2005, a Congressional spending bill authorized \$500,000 to examine the “threat to national energy production resulting from limited water supplies.” The Department of Energy (DOE) immediately began this significant project by holding a series of meetings across the country.⁷⁵ Sandia Lab (part of the DOE) published the first report in 2006 which described the collision of energy generation needs and water supply: “Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water”.⁷⁶ The second report, intended to lay out further research and, most importantly, the development of real world solutions, has been stuck in bureaucratic limbo. So far, the DOE has rejected 22 drafts of this so-called “Roadmap Report” presented for publication.⁷⁷

In rejecting so many drafts of the Roadmap Report, the DOE — for reasons that remain unclear — does not seem ready to publicly release this study of the complex interconnections between the nation’s water and energy resources. Some in Congress, however, continue to push for more energy-water nexus coordination, as evidenced by the recent introduction of a bill that would direct the DOE’s Secretary of Energy to take water use under greater consideration in the department’s energy research.⁷⁸

**THE DOE HAS REJECTED
22 DRAFTS OF THIS
SO-CALLED “ROADMAP
REPORT” PRESENTED
FOR PUBLICATION.**



» Hydraulic Fracturing: Unknown Risks to Water

Hydraulic fracturing, also known as “fracking,” is a method of extracting oil and/or natural gas from rock formations thousands of feet below the surface of the Earth by injecting a mixture of chemicals, water and sand into the rock to fracture it in order to release the oil and natural gas trapped inside.

Issues concerning hydraulic fracturing lie squarely at the center of the food, water and energy nexus. Similar to corn ethanol, the push for hydraulic fracturing is framed as a matter of energy security, yet both come with potentially significant costs to the security of our water resources. In the pursuit of natural gas locked far underground, the process requires 4.5 million gallons of water to drill and fracture a typical deep shale gas well.⁷⁹ Up to 1 million gallons of that hazardous water-sand-chemical mixture flows back up to the surface which, if mishandled, can pose a threat to nearby water resources. A 2011 study found that over the past few years, gas drillers have injected millions of gallons of fluids containing potentially toxic chemicals into the ground.⁸⁰

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The regulation of hydraulic fracturing is constantly evolving and remains primarily the responsibility of the states with little federal oversight. Through both the Safe Drinking Water Act and the Clean Water Act, the EPA can regulate how wastewater produced by hydraulic fracturing is disposed of and treated.⁸¹ However, the so-called “Halliburton Loophole”⁸² in the Energy Policy Act of 2005 prohibits

the EPA from regulating fracking fluids under the Safe Drinking Water Act, whereas in most other cases the law dictates what chemicals can be injected underground.⁸³ The Department of Interior initially planned to regulate the drilling technology on public and Indian lands, but withdrew their proposals just a few months after releasing them in 2012.

The oil and gas industry opposes federal regulations because it claims that states already regulate hydraulic fracturing. Nearly all states faced with potential fracking development are still creating their own regulations with varying degrees of stringency and uneven enforcement. Further, there is only an incomplete understanding of how fracking can impact air quality, water resources and public health in both the short- and long-term.⁸⁴ For example, there have been reports of unusual health symptoms in livestock and high concentrations of toxins in crops from farmers and ranchers located near oil and gas operations around the country.⁸⁵ With hydraulic fracturing drill sites being located in agricultural areas, there should be more research into the potential impacts on food safety for livestock and crops.

There are some efforts at the federal level to create more thorough oversight for hydraulic fracturing. For example, the FRAC Act was introduced in 2011 but remains in legislative limbo with a House subcommittee.⁸⁶ Additionally, the EPA is in the process of creating a report on the impacts of fracking on drinking water, which is not expected until 2014.⁸⁷ Meanwhile, natural gas wells continue to expand in number; drilling is expanding into states and regions unaccustomed to oil and gas operations and with limited understanding of the consequences.



» The Farm Bill and Industrial Farming: Ignoring the Nexus

The Farm Bill is a lengthy piece of legislation that comes up for renewal every five years. Contrary to its name, two-thirds of the bill is dedicated to food and nutrition program spending, with the final third dedicated primarily to commodity crops like corn and soybeans, as well as a small amount of conservation program spending.⁸⁸ The bill has traditionally been influenced by special interest groups working for large-scale farms and farm-state politicians.

Industrially-farmed commodity crops are primarily used as livestock feed, fuels, food products, oils and syrups.⁸⁹ Farming these crops in an industrial context requires application of fossil fuel-based fertilizers and pesticides which can run off of fields and into local waters. The heavy application of fertilizers and pesticides has made industrial agriculture one of the leading causes of water pollution in the United States.⁹⁰ Contaminated runoff can kill fish, degrade aquatic habitats and threaten drinking water supplies.

Raising livestock on industrial livestock farms requires enormous quantities of feed, which while growing requires large volumes of freshwater for irrigation.⁹¹ In addition, manure generated by the nation's livestock farms, estimated at 335 million dry tons in 2005⁹² — compared with just 7.6 million tons of human waste generated by publicly owned treatment works in the U.S. that year⁹³ — can contaminate water resources if manure lagoons overflow into nearby waters, seep into groundwater from unlined waste lagoons or flow off from solid waste disposal sites.⁹⁴

THE HEAVY APPLICATION OF FERTILIZERS AND PESTICIDES HAS MADE INDUSTRIAL AGRICULTURE ONE OF THE LEADING CAUSES OF WATER POLLUTION IN THE UNITED STATES.

Energy demand is also high for industrially-produced meat products. It typically takes three units of fossil fuel-based energy to produce one calorie of food energy for most U.S. agricultural products combined. That ratio soars as high as 35:1 for beef produced in feedlots.⁹⁵

Past farm bills have not addressed the food, water and energy nexus at the federal level. Some federal programs that do assist farms with pursuing energy efficiency, solar and wind installations, second-generation biofuels (i.e. not corn ethanol) and biomass production have recently been cut instead of increased.⁹⁶

Recent work by food and farm activists has resulted in efforts like the proposed Local Farms, Food and Jobs Act, aimed at increasing funding to small, organic farmers and providing underserved communities with greater access to local produce.⁹⁷ However, the provisions of the Act were largely not included in the newest Farm Bill. Until such reforms are made, and as long as the status quo remains with agribusiness interests, the Farm Bill will likely continue to subsidize large-scale, industrial farming, which has considerable implications for water and energy resources.



» Energy Subsidies: Fossil Fuels Cash In

Subsidies for the U.S. fossil fuel industry date back to 1916, when the newly developing oil industry was given a break on the then-new income tax.⁹⁸ This set a precedent, as tax breaks and federal financing grew tremendously for other energy sources like coal, large dams and nuclear fuels through the 1950's. After the 1973 oil embargo, the fossil fuel and nuclear energy industries received more subtle subsidies like exemptions from regulations, saving the industry money. For example, the Price-Anderson Act provides a subsidy for the nuclear power industry by limiting the amount of accident liability a nuclear power plant operator has to provide to \$375 million.⁹⁹ One study estimated that between 1950 and 2003, the federal government provided \$644 billion in incentives for energy development.¹⁰⁰ **Of that, the fossil fuel industry raked in \$470 billion, or nearly 75 percent.** Renewables, on the other hand, pulled in \$32.6 billion in incentives over that same period.¹⁰¹

The impact of subsidies on our energy portfolio is clear: as of 2011, 13 percent of the energy generated in the United States was derived from renewable sources, and two-thirds of that came from large hydroelectric projects that were once heavily supported with government funding.¹⁰²

FROM THE EXAMPLES NOTED ABOVE, it is clear that there is little effort by the U.S. federal government to address the food, water and energy nexus. However, as is often demonstrated with other policy issues, local and state governments and regional partnerships tend to pick up the slack, whether by proactive management or out of necessity.

A significant example of this is the Great Lakes Commission's Energy Water Nexus Initiative to integrate decisions about the region's energy future and its water resources.¹⁰³ In addition, the Los Angeles Department of Water and Power is working with its customers to be more water and energy efficient with the expectation that climate change will increase the energy required to produce and treat the region's water supply; reducing demand will lessen the need to move more water in the future.¹⁰⁴ Another example is seen in Texas, where the 2011 drought led the state's Water Development Board to declare: "In serious drought conditions, Texas does not and will not have enough water to meet the needs of its people, and its businesses, and its agricultural enterprises."¹⁰⁵ The board clearly understands the effect of drought on food and energy resources in Texas, but how the current situation will affect future policies remains unclear.

Discussion

WE ALL KNOW THAT EVERYDAY PRODUCTS don't simply appear as-is on store shelves or our dinner plates, but what may not be obvious is how the complex interactions between food, water and energy systems play a part in delivering those products to us. While the term "nexus" has become a buzzword in some policy and corporate circles (like the internationally focused Bonn 2011 Nexus Conference held in preparation for the U.N.'s Rio+20 Conference), experts are still searching for a better understanding of the interactions involved in the nexus.¹⁰⁶ This nexus approach gives a wide-angle view of how people use natural resources.

As illustrated in this paper, food, water and energy resource management and policies are often conducted in silos focused on only one issue at a time, often at the exclusion of each other. When resources become scarce, this narrow focus becomes problematic. For instance, the 2008 food crisis was caused by several nexus factors including higher energy prices, lower crop yields because of worldwide drought, and increased production of biofuel crops that converted food crops like corn into ethanol. The lower overall food crop yield, especially for staples like grain, drove up global food prices and led to an acute food shortage in parts of Asia and Africa, areas that were already highly dependent on food imports.^{107,108}

A broad outline of what we know versus what we don't know about the nexus can help with the development of a general framework of understanding. (See the Stockholm Environment Institute's paper "Understanding the Nexus" for more.¹⁰⁹)

» The Nexus: What We Know — What We Don't Know

What we know:

- » Most modern societies rely upon intensive natural resource use.
- » The nexus is comprised of food, water and energy systems that rely upon each other to function and therefore greatly impact each other.
- » Freshwater resources cannot always meet the water demands of agriculture, energy generation, public drinking water and industry.

THE 2008 FOOD CRISIS WAS CAUSED BY SEVERAL NEXUS FACTORS INCLUDING HIGHER ENERGY PRICES, LOWER CROP YIELDS BECAUSE OF WORLDWIDE DROUGHT, AND INCREASED PRODUCTION OF BIOFUEL CROPS THAT CONVERTED FOOD CROPS LIKE CORN INTO ETHANOL.

**EVEN WITH
INCREASING DEMANDS
ON FOOD, WATER AND
ENERGY RESOURCES,
A NEXUS APPROACH
COULD INCREASE THE
SUSTAINABILITY OF
ALL THREE.**

- » As conventional fossil fuel reserves diminish, fuel becomes more costly in terms of price and environmental impact due to greater reliance on harder-to-reach unconventional sources accessed through deepwater oil drilling or hydraulic fracturing.

What we don't know:

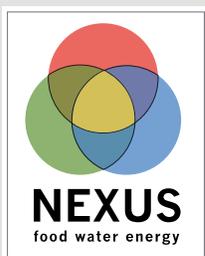
- » We have a poor understanding of where, when and how much water is used.
 - » We do not have a clear picture of the quantity and quality of the nation's groundwater.
 - » We are not effectively monitoring the condition — or coordinating the management — of food, water and energy systems.
 - » We have a poor understanding of the true economic costs of environmental degradation, such as pollution, habitat destruction and natural resource overuse because these costs are typically excluded from the price of goods and services.
- » We have not performed life cycle analyses of resource use for the vast majority of goods, services and industrial processes.

Because environmental, economic and political conditions are constantly changing, there are several factors that will most likely impact the nexus¹¹⁰ and threaten to throw it out of balance:

- » **POPULATION GROWTH** and urbanization in the United States and around the globe will generate greater demands on the food, water and energy systems and the natural resources that support them.
- » **CLIMATE CHANGE** models suggest that we will experience more extreme weather swings, or “drought and deluge” conditions.¹¹¹
- » **GLOBALIZATION** will increase competition for and demands on natural resources.

The nexus approach to evaluating food, water and energy systems is meant to ensure that natural resources are used efficiently and productively enough to be available for future generations. Even with increasing demands on food, water and energy resources, a nexus approach could increase the sustainability of all three.

As was shown with the Browns Ferry Nuclear Plant, most thermoelectric power plants in the United States rely upon



Our food, water and energy systems are inextricably linked and therefore must be managed and governed in an integrated manner to effectively meet the needs of an ever-growing world population. To advance the goal of integrated planning, policy and management, we must increase awareness about how these three systems intersect, and why greater coordination is necessary.

— Kyle Rabin, GRACE Communications Foundation

a ready supply of water for cooling. For the TVA and Browns Ferry operators, taking a nexus approach to power plant water use is unavoidable since plant operations are, essentially, at the mercy of rising water temperatures. Adding closed-cycle cooling towers will dramatically reduce the plant's hot-water discharges which will benefit aquatic life, the surrounding ecosystem and the sport and tourism industries. Nevertheless, the power plant's future generation capabilities could still face challenges because Wheeler Reservoir may experience more frequent and longer periods of elevated water temperatures due to climate change.

The California Sacramento-San Joaquin Delta illustrates the complexity of the nexus, especially when decisions have to be made about distribution of vital freshwater resources between competing users like agriculture and urban public water providers. This longstanding issue has forced a wide variety of interested parties to work within an intricate mix of governmental agencies and regulatory schemes. Getting the many players to agree to a plan is going to be difficult because, as yet, there is no single decision-making process or structure that adequately addresses the interests of all involved. This is why the anticipated Delta Plan is so significant: It could create an institution that will help make major changes that have been discussed for decades.

Finally, the food waste issue illustrates how food and other consumer goods are at the heart of the nexus. Food production requires a lot of water and energy, so wasted food is also wasted water and energy. Food waste also comes at a significant cost to both the food industry and consumers. Clearly, reducing food waste has immense environmental and economic benefits. A rising awareness of how food is produced, as illustrated in the growth of the local and organic food market, could provide a big push towards a more efficient and healthier food system for both producers and consumers. A reevaluation of food waste as a potential energy and composting resource, rather than as trash, is a perfect example of planning that incorporates the nexus.



Conclusion

ADOPTING THE NEXUS APPROACH in a large-scale, system-wide manner may be challenging because we have a limited knowledge of how food, water and energy systems operate and interact. Government policy, especially at the federal level, must set the stage by improving data monitoring and gathering programs, knocking down the silo approach of isolated resource management and illuminating how these systems and processes overlap through reports and studies. Otherwise, a policy relevant to a single resource might actually end up having a negative impact on the rest of the food, water and energy system.¹¹² These steps must be combined with sensible policies and regulations that encourage cooperation between individual citizens, governments and businesses so that all decisions are seen as sustainable and legitimate.

A nexus approach provides more flexibility to confront complex challenges like natural resource depletion and climate change adaptation.¹¹³ Change can only happen if policy makers, business owners and consumers alike better understand these interconnections.^{114,115}

The nexus is part of *everyone's* life — from grocery shoppers to power plant managers to elected officials. With many challenges facing our strained food, water and energy systems in the United States, a shift in thinking is necessary to understand that what we do every day affects the nexus and the nexus, in turn, affects our everyday life.

PICK A SLICE: WHAT YOU CAN DO



If the scope of the nexus is too daunting and you feel there is nothing you can do to help, we suggest you “pick a slice.” There is an opportunity to contribute in ways that suit you best: join a watershed group; campaign for a local official that supports sustainable solutions (or even run yourself!); eat locally and lower down on the food chain; drive less and walk more. There are as many ways for you to make changes as there are issues and challenges to be found in the food, water and energy nexus.

It might even begin with your next slice of pizza.

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Appendix: Food, Water and Energy Nexus Resources

Organizations

INSTITUTE FOR AGRICULTURE AND TRADE POLICY:

IATP works locally and globally at the intersection of policy and practice to ensure fair and sustainable food, farm and trade systems. The Institute focuses on food, water and energy issues among others.

» www.iatp.org

JOHNS HOPKINS CENTER FOR A LIVABLE FUTURE:

The Center, based out of the Bloomberg School of Public Health, works to research and communicate the complex interrelationships among diet, food production, environment and human health.

» www.jhsph.edu/clf

PACIFIC INSTITUTE:

The Pacific Institute works to create a healthier planet and sustainable communities. The Institute focuses on four initiatives: International Water and Communities, Water Use in Business, Climate Impacts and Adaptation, and Integrity of Science.

» www.pacinst.org

RIVER NETWORK:

The River Network's "Rivers, Energy & Climate Program" is informing how the nation's energy choices not only impact climate, but also the availability of fresh water resources.

» www.rivernetwork.org/programs/saving-water-saving-energy

UNION OF CONCERNED SCIENTISTS:

UCS has numerous reports and infographics that explain how the energy-water connection can turn into a collision—with dangerous implications for both.

» www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/energy-and-water.html

THE WATER, ENERGY & FOOD SECURITY

RESOURCE PLATFORM:

Hosted by Germany's Federal Government, the Nexus Platform is an invaluable resource for nexus research and news.

» www.water-energy-food.org

WATER FOOTPRINT NETWORK:

The Water Footprint Network is advancing the concept of the "water footprint," an indicator of direct and indirect water use of consumers and producers.

» www.waterfootprint.org

WEBBER ENERGY GROUP:

The Webber Energy Group is Professor Michael Webber's research group at the University of Texas at Austin. The group's research can be organized into four broad topical areas: 1) The Energy-Water Nexus; 2) Dynamic Modeling of Complicated Energy Systems (including the smart grid); 3) Alternative Transportation Fuels (electricity, algae and natural gas); and 4) The Nexus of Food, Waste and Energy.

» www.webberenergygroup.com

Key Reports

CIRCLE OF BLUE's "Choke Point U.S.," series explores how energy demand is confronting water scarcity.

» www.circleofblue.org/waternews/featured-water-stories/choke-point-us

THE U.S. DEPARTMENT OF ENERGY'S SANDIA NATIONAL LABORATORY 2006 report, "Energy Demands on Water Resources Report to Congress on the Interdependency of Energy and Water," reviews the "threats to national energy production resulting from limited water supplies."

» www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf

THE WORLD ECONOMIC FORUM'S "Water Security: The Water-Food-Energy-Climate Security Nexus," documents how water is linked to economic growth across a nexus of issues and makes clear the water security challenge we face if a business as usual approach to water management is maintained.

» www.weforum.org/reports/water-security-water-energy-food-climate-nexus

THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS' report, "Energy Use in Organic Food Systems," analyzes energy use in organic agriculture, in comparison with conventional agriculture, and finds that organic agriculture uses less fossil fuel-based inputs and has a smaller carbon footprint than standard agricultural practices.

» www.fao.org/docs/eims/upload/233069/energy-use-oa.pdf

THE USGS report, "Estimated Use of Water in the U.S. in 2005," is the best source for estimates of water use by power plants, irrigation, livestock, public water supplies and other categories.

» pubs.usgs.gov/circ/1344/

THE NATURAL RESOURCES DEFENSE COUNCIL'S issue paper, "Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill," reveals how Americans are throwing out the equivalent of \$165 billion worth of food each year, along with 25 percent of all freshwater and huge amounts of unnecessary chemicals, energy and land.

» www.nrdc.org/food/wasted-food.asp

THE CONGRESSIONAL RESEARCH SERVICE'S report, "Energy Use in Agriculture: Background and Issues," provides baseline information on energy use by the U.S. agricultural sector and touches upon emerging issues and related legislation.

» www.nationalaglawcenter.org/assets/crs/RL32677.pdf

STOCKHOLM ENVIRONMENT INSTITUTE'S background paper, "Understanding the Nexus," for the Bonn2011 Conference on the Water, Energy and Food Security Nexus explains the nexus and presents initial evidence for how a nexus approach can enhance water, energy and food security.

» www.water-energy-food.org/en/whats_the_nexus/background.html

THE AMERICAN COUNCIL FOR AN ENERGY EFFICIENT ECONOMY'S report, "Roadmap to Energy in the Water and Wastewater Industry," compiles expert opinions on opportunities for energy efficiency in municipal water and wastewater.

» www.aceee.org/research-report/ie054