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Biofuel Policies: Robbing Peter to Pay Paul

Aaron Smith

Policies aimed at reducing carbon emissions from transportation have hit major obstacles in the past few years. In effect, these policies take money from petroleum producers and give it to renewable fuel producers, creating heated political and legal battles but little effect on consumers.

Also in this issue

2015 was the warmest year recorded on earth since at least 1880. Last year, the same statement was true about 2014. The four warmest recorded years since 1880 have occurred since 2010. Alarmed by the scientific consensus that fossil fuels are the main cause of this warming, many governments have enacted policies to promote alternative fuels and penalize fossil fuels.

California drivers are affected by three such policies, one federal and two implemented by the state government. The Federal government requires a certain quantity of biofuels to be used in the country (the Renewable Fuel Standard, or RFS). The California state government requires firms to purchase a certain number of credits for each gallon of fossil fuel they sell (the cap-and-trade program, or CAT). The state also requires firms to achieve prescribed carbon-intensity levels in the fuel delivered to consumers (the Low-Carbon Fuel Standard, or LCFS).

How Do the CAT Program, RFS, and LCFS Work?

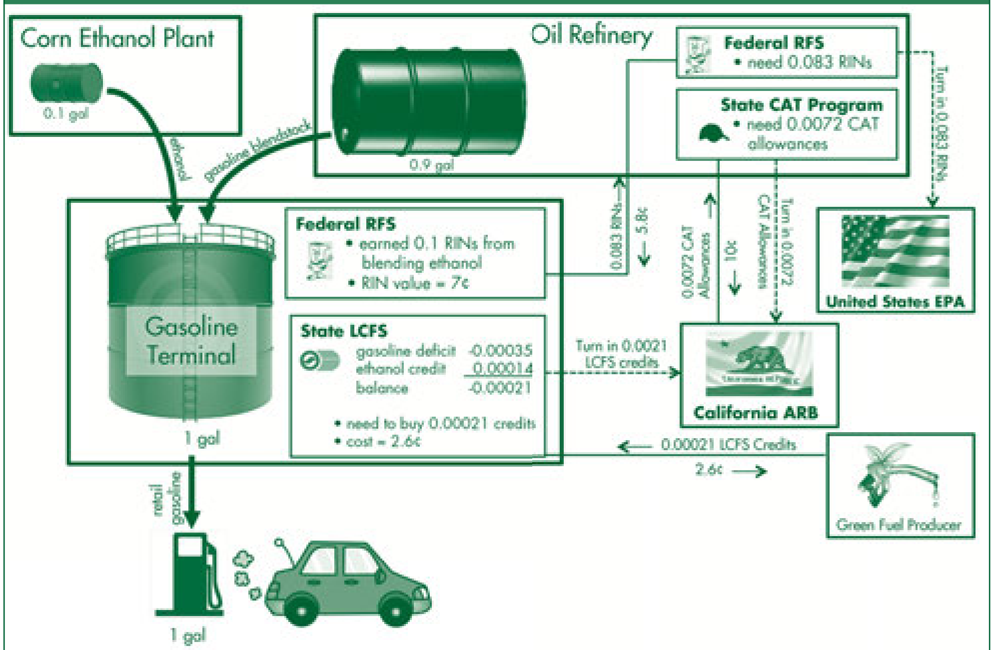
Figure 1 illustrates how the three policies affect a typical gallon of California gasoline. Essentially every gallon of gasoline in the United States is made up of 90% petroleum and 10% ethanol, which is a biofuel made almost exclusively from corn. Gasoline blendstock is produced at an oil refinery, and ethanol is produced at an ethanol plant. These products travel by pipeline, train, or truck to a gasoline terminal in a city near where the fuel will be consumed. The fuel is blended at the terminal and delivered by truck to a gas station.

The CAT program requires that polluting firms, such as electricity generators and producers of gasoline and diesel, purchase emissions allowances. To sell the 0.9 gallons of gasoline blendstock to the terminal, the oil refiner, is required to turn in 0.0072 CAT allowances to the state. The refiner can purchase these allowances from the state at one of the quarterly auctions (as shown in Figure 1), or from another firm that has allowances it doesn't need. Ethanol and other biofuels are exempt from the CAT program.

Since the beginning of 2015, the price of CAT allowances has averaged the equivalent of 10¢ per gallon of gasoline. This charge likely gets passed along to consumers, which creates an incentive to use less gasoline.

Rather than only penalizing fossil fuels, as in the CAT program, the RFS and LCFS aim to promote alternative fuels. Under the RFS, the oil refiner also has to turn in a certain quantity of RFS credits, known as RINs, per gallon of gasoline and diesel it produces. In 2016, it would require 0.083 RINs for the gasoline that goes into our consumer gallon. RINs are created by blending biofuel with petroleum fuel. The gasoline terminal in the figure creates 0.1 of a RIN by blending 0.1gal of ethanol into gasoline. So, the refiner can buy the required RINs from the gasoline terminal. This leaves the terminal with 0.017

Figure 1. The Making of a Typical Gallon of California Gasoline



Notes: Calculations are based on RIN price of 70¢/gal, LCFS credit price of $125/MT, and CAT credit prices of $14/MT. The corn-ethanol CI is 78.83g/MJ, the gasoline blendstock CI is 99.78, and the CI target is 96.5g/MJ. The energy density of gasolineblendstock is 119.53MJ/gal and the energy density of corn ethanol is 81.51 MJ/gal.

surplus RINs, which it could sell to another regulated party. For example, a refiner may want to purchase RINs to cover it for the diesel it produces.

The price of RINs is determined by the extra cost of using biofuel in place of petroleum. The terminal in Figure 1 will use the 7¢ earned from selling RINs to help pay for ethanol (if ethanol is priced higher than gasoline blendstock) or to pay distribution costs (if blended fuel is more costly to deliver to consumers than pure gasoline). Any remaining cost increases will be passed along to consumers, but this amount is likely to be small. The RFS essentially taxes the oil refinery to subsidize biofuel; it transfers money between fuel producers rather than only taxing petroleum. For this reason, the RFS has little effect on gasoline prices, even if RIN prices are high.

The LCFS requires the average gallon of fuel to hit a carbon-intensity (CI) target. It assigns a CI score to each potential fuel based on its estimated emissions. These scores can be used to compute the CI of each gallon of fuel. The CI is a measure of how dirty the fuel is.

The gasoline terminal is the regulated party in the LCFS. In 2016, it has to deliver gasoline with a CI of 96.5 grams of CO_2 per megajoule. The gasoline blendstock exceeds this target. The corn ethanol in this example is below the target, which helps bring down the CI of the blended fuel, but it still doesn't reach the target. There is a deficit of 1.2 in the CI, which translates into 0.00021 LCFS credits. The terminal must buy these credits from an entity that has excess credits, such as another terminal with a cleaner fuel mix or a biogas producer. The terminal would pass the cost of these credits on to consumers. Alternately, the terminal could purchase ethanol with a lower CI, such as corn ethanol from a cleaner plant or ethanol made in Brazil from sugar cane.

The existence of the CAT program potentially curtails the role of the LCFS in reducing carbon emissions from California. The idea behind the CAT program is to set total allowable emissions and let the market determine where those emissions occur. By enacting the LCFS, the state mandates how much of those emissions occur in transportation rather than other sectors such as electricity production, thereby undermining the flexibility of the CAT program. At present, however, there is a surplus of CAT allowances. This means that the CAT program is not actually constraining emissions, which leaves the possibility that the state has lower emissions with the LCFS than without.

Credit prices under the RFS and LCFS have both spiked to eye-popping levels in recent months. The high prices of RFS and LCFS credits arise because it is costly to meet the standard, either because of a lack of fueling infrastructure for renewable fuels or because of the high cost of raw materials. Because these policies effectively take money from petroleum producers and give it to renewable fuel producers, these credit price increases are mostly invisible to consumers. However, the high costs lead firms to mount political and legal challenges.

Technical, Political, and Legal Challenges to the RFS

Until recently, the fuel industry was able meet the RFS mandate without too much difficulty. However, the mandate now requires more biofuel than the fuel industry can easily absorb.

The RFS has hit two barriers. The first, known as the blend wall, is that regular gasoline can contain up to 10% ethanol without affecting engines or fueling infrastructure. The RFS now requires more biofuel than 10% of regular gasoline.

Breaching the blend wall will entail either expanded consumption of biodiesel, which does not face any relevant blend restrictions, or increasing sales of a high-ethanol blend of gasoline known as E85, which contains up to 85% ethanol and can be used in flex-fuel cars. Although about 6% of registered vehicles in the U.S. have flex-fuel capability, very few gas stations sell E85.

The second barrier is that production of second-generation cellulosic biofuel continues to be close to zero. Cellulosic biofuel is made from the non-food portion of plants and generates much lower greenhouse gas emissions than first-generation biofuels such as corn made from ethanol. The RFS requires large and increasing amounts of cellulosic biofuel to enter the fuel supply.

The EPA, which enforces the RFS, has the authority to set the required biofuel volumes below the mandate if there is insufficient supply. It has used this authority to deal with both barriers. This has been without controversy for the lack of cellulosic production, but has met with stiff opposition when used to deal with the blend wall.

In November 2013, the EPA announced that it intended to waive the above-blend-wall quantities of the ethanol mandate for 2014. This announcement caused a strong reaction from the biofuel industry, and the associated political opposition prevented the EPA from finalizing the required biofuel volumes in a timely fashion. This left the industry in limbo, not knowing how much biofuel it should be using.

In May 2015, the EPA finally proposed a new set of rules, this time for the amount of biofuel to be used in 2014, 2015, and 2016. Because 2014 was history by this time, it set 2014 volumes at actual 2014 production. The proposed volumes for 2015 and 2016 were lower than expected and so would be less costly for the industry to meet. Accordingly, the price of RINs dropped from $0.80 to $0.40. The EPA took feedback on the proposed rule and in November 2015 it announced the final rule. It increased volumes over the proposed rule, which caused an immediate jump in RIN prices to $0.70.

The RFS statute specifies that 22.25bgal (billion gallons) of biofuel be used in 2016, of which no more than 15bgal can be corn ethanol. The blend wall was projected at 13.8bgal in 2016, but is likely to be slightly higher as low gas prices cause people to drive more.

The EPA set the final rule at 18.11bgal of biofuel, of which no more than 14.5bgal can be corn ethanol. The gap between the rule and the blend wall is most likely to be met by increased biodiesel use, but the gap is large enough that some increase in E85 sales may be required. Private market investment in E85 infrastructure has been slow, but in early 2016, the USDA spent $100m to fund the installation of E85 fuel dispensers, with the goal of doubling E85 retail capacity.

The current RIN price of $0.70 means that each gallon of ethanol receives a subsidy of 70 cents and each gallon of gasoline blendstock is taxed at a rate of 6.4 cents. (The 2016 rule specifies that regulated parties turn in 0.0919 RINs for each gallon of gasoline blendstock sold.)

In 2013 when the mandate first hit the blend wall, RIN prices reached $1.40, which at current mandate levels would imply a 12.8 cent tax on gasoline blendstock. The significant political impediments faced by the EPA in setting a rule suggest that the fuel industry views this as a substantial cost. Several ethanol industry groups have petitioned a federal appeals court to hear a challenge to the 2015 final rule. These groups want the EPA to enforce the full mandate. Put another way, they would like a larger subsidy than $0.70.

Technical, Political, and Legal Challenges to the LCFS

The LCFS has faced several lawsuits. It was challenged on the grounds that imposing regulatory costs on out-of-state producers violates the Commerce Clause. The courts rejected this challenge, but in July 2013, the California Court of Appeal held that the California Air Resources Board (CARB) had committed procedural violations when it enacted the LCFS. The court froze the LCFS at 2013 levels until CARB could correct its procedural errors and re-adopt the standard.

The LCFS is highly detailed. The CI for each fuel is estimated from a computer model that accounts for numerous factors that could affect emissions, including oil extraction, oil refining, method of ethanol production, land-use change, and transportation of the fuel, in addition to the final act of burning the fuel. The computer model is transparent (an Excel spreadsheet on the CARB website allows anyone to perform these computations), but the complexity means that small changes in the formula can have large effects on compliance costs.

One particularly contentious issue has been the additional emissions that occur when new agricultural land is brought into production to produce the corn that would be made into ethanol. CARB estimated that these so-called indirect land-use change effects were large, whereas industry groups argued that they were small.

CARB re-adopted the LCFS in September 2015. In addition to correcting its procedural violations, it came up with lower indirect land-use change estimates, tweaked the computer model, and determined a new set of CI targets. Since the re-adoption, LCFS credit prices have jumped from $20 to $125 per metric ton.

Table 1 on page 4 translates the price of LCFS credits into amounts per gallon of fuel for the most commonly used fuels. These amounts vary across fuels. Fuels with a high CI have a positive value because firms must pay for above-mandate emissions from that fuel. Fuels with low CI values are subsidized under the program because they generate LCFS credits. The amount of the tax or subsidy also changes by year because the CI target changes.

The table shows that, at the current price of $125 per ton, gasoline

Table 1: Fuel Taxes Implied by LCFS (Cents per Gallon)

	Final Fuel			Blendstock				
	E10 (Corn Ethanol)	E10 (Sugar Ethanol)	B5 (Soybean Biodiesel)	Gasoline	Corn Ethanol	Sugar Ethanol	Diesel	Soybean Biodiesel
LCFS Credit Price = $125/MT								
2016	2.6	-0.9	-0.1	4.9	-18.0	-52.7	3.4	-85.0
2017	4.8	1.3	0.3	7.1	-16.5	-51.2	6.0	-82.6
2018	6.9	3.4	0.7	9.3	-15.0	-49.7	8.6	-80.2
2019	10.5	7.0	1.4	13.0	-12.5	-47.2	12.9	-76.2
2020	14.0	10.5	2.1	16.7	-10.0	-44.7	17.1	-72.1
LCFS Credit Price = $200/MT								
2016	4.2	-1.4	-0.8	7.8	-28.8	-84.4	5.5	-136.0
2017	7.6	2.0	3.3	11.4	-26.4	-82.0	9.6	-132.1
2018	11.0	5.4	7.4	14.9	-24.0	-79.6	13.7	-128.3
2019	16.7	11.2	14.2	20.8	-20.0	-75.5	20.6	-121.8
2020	22.4	16.9	21.1	26.7	-16.0	-71.5	27.4	-115.4
Carbon Intensity of Each Fuel								
CI	97.69	94.28	99.21	99.78	78.83	44.75	102.01	46.06

Notes: CI standards for gasoline are 96.50, 95.02, 93.55, 91.08, and 88.62 for 2016–2020, respectively. CI standards for diesel are 99.97, 98.44, 96.91, 94.36, and 91.81 for 2016–2020, respectively. MT = metric ton E10 is gasoline that contains 10% ethanol and B5 is diesel that contains 5% biodiesel.

blendstock is taxed 4.9¢ and corn ethanol receives a subsidy of 18¢ per gallon. (The actual ethanol subsidy can vary depending on the ethanol production process and emissions from transporting the fuel to the gasoline terminal, among other things.) As the CI target changes over time, the tax increases 16.7¢ and the subsidy drops to 10¢. These amounts translate into a 2.6¢ tax on retail gasoline in 2016, increasing to 14¢ by 2020. The LCFS credit price cannot go above $200. If it reaches this cap, the magnitudes increase proportionately.

The LCFS tax on diesel is similar to gasoline, but biodiesel receives a much larger subsidy than ethanol. It is 70–85¢, which is a similar magnitude to the subsidy implied by RIN prices in the RFS. This large subsidy means that the net effect on the price of retail diesel containing 5% biodiesel (a common blend) is small. This large subsidy also suggests that, like in the RFS, biodiesel is likely to be an important means of compliance. In fact, re-adoption of the LCFS has caused a massive increase in biodiesel use in California. The latest CARB reporting summary shows that biodiesel reached 9.2% of total diesel in the third quarter of 2015, after being around 5% for the prior two years.

Conclusion

The transportation sector burns too much fossil fuel because motorists do not pay for their effects on the environment. In particular, fossil fuels generate carbon dioxide emissions that contribute to global climate change. There are two levers policymakers can use to mitigate climate change: (i) reduce energy use, and (ii) replace fossil fuel with cleaner fuels.

The most cost effective policies use both levers. The best such policy is to tax each gallon of motor fuel in an amount equal to the marginal emissions damages from using it. This tax raises the cost to consumers, causing them to use less and it makes alternative fuels more competitive in the marketplace. Instead of a tax, policymakers could achieve the same objective through a cap and trade system.

California has a cap-and-trade system that adds a modest 10¢ per gallon to the price of gasoline. In addition, the state LCFS adds another couple of cents and the federal RFS adds a negligible amount. Thus, these policies do not have large effects on consumers at present, which means that the first policy lever is not really being used. The effects on gasoline consumers may increase somewhat in the next few years as the LCFS and RFS become more stringent.

The RFS and LCFS provide significant subsidies to renewable fuel producers paid for by taxes on petroleum. This setup pits the two industries against each other and causes the affected firms to lobby hard to increase their subsidy or reduce their tax.

The structure of the two programs allows such lobbying to occur. Every year, the EPA has to determine the amount of renewable fuel that will be required under the RFS. A move to a longer planning horizon would help reduce the lobbying pressure. Setting a price cap on RINs may also help as it would remove the possibility that the EPA may instead mitigate high RIN prices by reducing the required biofuel volumes. The LCFS is hurt by the complexity of its CI calculations, which opens the door for numerous challenges to the standard. The re-adopted standard is simpler, but still too complicated.

Smith, Aaron. 2016. “Biofuel Policies: Robbing Peter to Pay Paul.” *ARE Update* 19(3):1-4. University of California Giannini Foundation of Agricultural Economics. http://giannini.ucop.edu/media/are-update/files/articles/V19N3_1.pdf

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Which California Foods You Consume Makes Little Impact on Drought-Relevant Water Usage

Nina M. Anderson and Daniel A. Sumner

To be relevant to California's drought, discussions of water used to produce food items should focus on the irrigation water relevant to production in California. By that measure, drought-relevant water used to produce livestock products such as beef and milk is moderate compared to crop products such as wine and broccoli.

California's long drought drove mandatory water delivery cuts, mandates for changes in water practices, and recommendations for farmers and others to reduce water usage more than ever before. Much of the media surrounding the California drought contains information on farmer techniques used to save water and lessen economic losses. It also provides expert advice for households on how to reduce their water footprint. The mandates and recommendations were based on more and better information on how water is distributed across uses.

Because farming is a heavy user of irrigation water, most observers highlighted how efficient water use within agriculture is important. Experts point out that calculating water used by crops, for example, must account for water applied to fields but that is drained off for use again on another field or water that percolates into the groundwater table to be used in subsequent irrigation seasons.

Central to household use is water used indirectly through consumption of food products that consume water in their production, processing, and distribution. Because food products from California farms and ranches are consumed all over the United States and globally, food consumption by households outside California uses California water.

Newspapers such as *The New York Times* and the *Los Angeles Times* calculated and publicized quantities of water embedded in California food products, and therefore how much water households consume indirectly. They review the water embedded in long lists of food items produced in California.

Topping the lists—by a huge margin—in terms of water per ounce or per serving are livestock products such as meat and milk, because of the vast quantities of water used to grow the hay, corn, soybeans, and grass that make up a bovine diet. That is, just as most of the water used by humans is embedded in our diets, the same is true of livestock.

Governor Jerry Brown spoke to this issue in the "Water in the West" event at the University of Southern California. Governor Brown wondered aloud whether it was better or worse to export alfalfa rather than use it to feed cattle in California. He answered his own question by stating, "I don't know, I mean if you ask me I think you should be eating veggie burgers, but that's not the predominant sentiment," (*LA Times*, 2015).

Why is Water Use a Government Issue at All?

Of course, California, the U.S. Federal government, and many local jurisdictions are heavily engaged in the collection, storage and conveyance of irrigation water, as well as local purification and distribution for urban use. With governments at all levels dominating the supply side of the water balance, users could be charged the cost of water, and uses might reflect the social value of that water on the margin.

But, the general consensus is that neither of these conditions hold, and there are many situations in which water is supplied at prices well below its cost and well below its value for alternative uses. Government ownership and elaborate government regulations fail to generate optimal allocation of water across locations, time or use, and water prices are poor indications of the marginal social value of water. Thus, controversies continue and accusations abound of water being used for "low-valued" purposes.

The analysis below cannot answer those controversial issues, but we can contribute to clarifying some facts and their relevance.

All Water Versus Drought-relevant Water

California agriculture produces food products using water from several sources. First are those sources and uses that are directly relevant to competition for water during a drought. Crop irrigation usually competes for water that may also provide environmental and ecological benefits and services, such as water that flows through streams and is stored in lakes and reservoirs. Water used in urban water systems has value to industrial and commercial (including food processing) users and households, and these uses often compete with irrigation and environmental and ecological uses. Farms also pump groundwater from underground aquifers that could be available for later use or used for other purposes. These sources, both surface water and ground water used for irrigation, are California drought-relevant water (drought water) for which agriculture must compete with other uses.

The second large category of agricultural water is water imported from outside of California in the form of commodities used to produce livestock products here in California. The largest

Table 1. Water Use of Wine Produced from California Winegrapes

Evapo-transpiration (ET) Acre-Ft./Acre	Grape Yield (Tons/Acre)	Gallons Wine/Ton	Gallons ET Water/ Gallon Wine	Gallons Winery Process Water/ Gallon Wine	Total Gallons Water/ 5 oz. Wine Serving
1.84	8.75	170	403	4.15	15.9

Note: There are about 25.6 5-oz. servings in one gallon of wine.
Source: Authors' calculations using Jim Lapsley and Dan Sumner's draft of "Water into Wine." See additional information for detailed methodology, calculations, and a full list of sources.

part of such water is that embedded in feed grains, oilseed meals, hay, and other animal feeds shipped into California to feed the cattle and poultry that are raised in intensive feeding operations.

The water embedded in feed shipped into California may be relevant to a drought in Nebraska, Idaho, Alberta, or some other state or province from which the feed is shipped, but it is not part of the drought-relevant water allocated in California. Therefore, when accounting for California drought-relevant supplies, such imported water must be carefully netted out.

A third source of water is that embedded in livestock shipped into the state after spending part of their life consuming water in other places. So, for example, steers shipped into California from Oregon for intensive feeding here or dairy heifers shipped to milk herds in California bring with them water that the animal has consumed earlier in its lifecycle. This imported water is also not California drought water.

The fourth major source of water for California agriculture is the precipitation that falls directly on hills and mountains in California. Some of this water, that which is not absorbed where it falls, enters streams and becomes the drought-relevant water used for environmental, urban, or irrigation purposes.

Some of the precipitation is absorbed and used to grow forage in pastures located in the hills and mountains that cover about 15 to 20 million acres of agricultural land in California. This water, which nourishes pasture forage used primarily by cattle in California, does not flow into streams and would not be used for any other purpose if not grazed by livestock. Indeed, the grazing of such pastures likely allows more water to flow into streams and enter the natural river and storage systems. In this way, grazing likely has a small positive impact on the amount of drought water.

The main point, however, is that the water that nourishes the non-irrigated pastures used largely by the cow-calf and feed cattle industry in California has a direct impact on food produced in the state, but is not available for competing uses and is therefore not drought water.

In sum then, we define agricultural drought water that enters the food supply from California to include all irrigation water from whatever source, but to exclude water embedded in livestock feeds shipped into the state and water that falls onto non-irrigated pastures that are used by grazing livestock in California.

Drought water used for food production is available for competing uses in California. Water embedded in livestock feed shipped into California and livestock forage produced on non-irrigated pastures play no role in relieving the California drought, even when such water is located in California.

The next sections present calculations that illustrate the role of drought water in the production of food and how food consumers use water that is relevant to California drought. We begin with two cases of California crops, almonds and lettuce, grown entirely with drought water. We then highlight drought water used for the production of wine. Finally, we consider the more complex cases of livestock products that have been deemed the most water-intensive foods by Governor Brown and many others. Below, we only provide summaries of the detailed calculations; the complete sources of information are available on our website at http://aic.ucdavis.edu.

Irrigation Water Used to Grow California Crops

In this section we consider all irrigation water consumed in production and processing of crops as drought water consumed. We use estimates of the amount of water actually used up by the plants or evaporated into the atmosphere (evapotranspiration) and not simply irrigation water applied to the fields. In that way, for example, water that percolates down to the underground aquifer is not counted as "used" by the consumption of the crop.

With more acres than any crop in California, and with rapid acreage increases in recent years, almonds have received a great deal of attention during this drought. California almonds are grown in the Central Valley under irrigation and about two-thirds of California almonds are exported. Almonds, and other Central Valley orchard crops, use substantial amounts of water per acre and generate high revenue per acre ($6,772/acre for almonds in 2014). Evapotranspiration of almond trees is estimated at 3.1 acre-feet per acre and yield averages about 1 ton per acre in the northern San Joaquin Valley. At about 326,000 gallons per acre-foot, it takes approximately 1 million gallons of drought water to produce one 2,000-pound ton of almonds. A 1-ounce serving therefore requires about 31.8 gallons of irrigation water.

Lettuce is another high-revenue per acre California crop ($10,343/acre in 2014), but uses substantially less irrigation water than almonds for several reasons. First, lettuce plants are smaller; second, much of the lettuce is grown in cooler regions along the coast or during the cooler times of the year; and third, lettuce matures in a matter of a few weeks, not over a six-month irrigation season. Evapotranspiration of lettuce is approximately 1.4 acre-feet per acre and yield averages about 20 tons per acre for iceberg lettuce grown in the Central Coast. This equals 23,000 gallons of drought water per ton, or 1.8 gallons for a 1-cup serving that weighs about 2.5 ounces.

We also calculate that one cup of broccoli uses about 7.6 gallons of irrigation water and one cup of processed tomatoes uses about 8.3 gallons. All water used to produce these vegetables in California is drought water.

Winegrapes are grown throughout California with major centers of production in the hot and dry San Joaquin Valley and along the much cooler North and Central Coast regions. Water use per acre of winegrapes differs widely by region, as does tons of grapes per acre and the price of grapes per ton. Using statewide averages, evapotranspiration of California winegrapes is estimated to be about 1.8 acre-feet per acre and yield averages about 8.75 tons per acre. Winery production also uses water at a statewide average rate of about 4 gallons of winery water per gallon of wine. Putting this all together, we get about 16 gallons of total water use for a 5 oz. serving of wine (Table 1).

All Water and Drought Water Used to Produce California Beef

This article takes the case of a beef animal that is born, raised, and slaughtered in California, even though most of the beef consumed here is actually fed and processed out of state. The water used to produce a California beef animal can be separated into the following seven categories: (1) rainfall onto pasture that cows and calves use as forage, (2) irrigation to grow roughage in the intensive feeding phase, (3) water used to grow protein-rich feed ingredients, (4) water to grow grain feed ingredients, (5) water used in the production of mineral supplement feed, (6) drinking water, and (7) water used for processing the carcass.

Figure 1 summarizes water used to grow the pasture consumed during the first phase of the beef animal's life, corn, soybeans, and alfalfa consumed during the feedlot phase, and relatively small amounts for feed supplements, drinking water consumed throughout the animal's life, and processing the carcass.

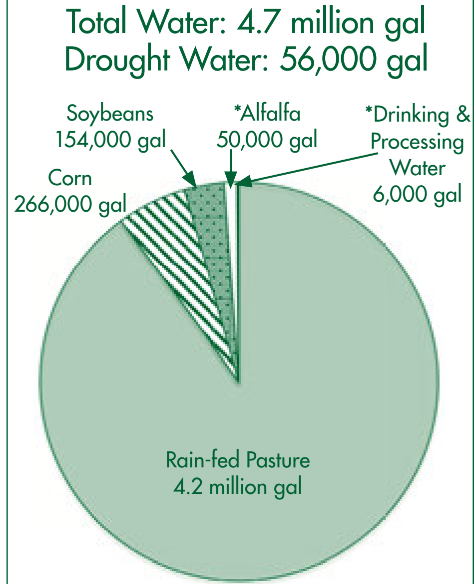
By far the largest water use is for the one-year pasture phase, where we assume about 13 acres of California pasture with about one acre-foot of rainfall per acre are attributed to each cow-calf pair. This equates to about 13 acre-feet or 4.2 million gallons of non-drought water for each calf that moves into the feeding process. As noted above, the feed during this phase of the animal's life does not use drought-relevant water.

Using the typical daily ration of a steer finishing in a 6-month feedlot phase, we find average amounts of feed consumed per day, accounting for weight gain. In total, one California steer eats about 3,200 lbs. of corn, 800 lbs. of soybeans, and 600 lbs. of alfalfa during its lifetime.

Corn and soybeans are typically imported from the Midwest, and are therefore not drought water. We estimate about 266,000 gallons of water for corn and 154,000 gallons for soybeans are consumed during the feeding of a beef steer or heifer.

Alfalfa differs from corn and soybeans in that it is produced in California and uses drought water. The evapotranspiration and typical yield of alfalfa were used to find total acre-feet and gallons consumed over the steer's life. A total of 50,000 gallons of drought water are used to grow the 600 lbs. of alfalfa consumed in the steer's life. Additionally, less than 10,000 gallons of drought water are consumed for feed supplements, direct animal consumption, and through the processing of the carcass.

Figure 1. Water Used for a Steer Born and Raised in California



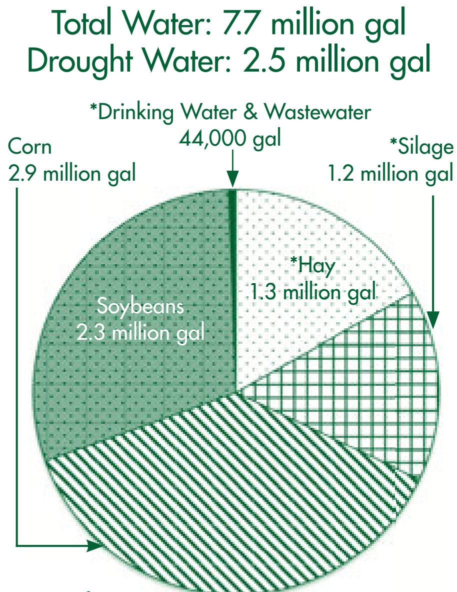
**Drought water*
Note: Most of the rain-fed pasture water use is attributed to the mother cow.
Source: Authors' calculations. See additional information for detailed methodology, calculations, and a full list of sources.

Putting these pieces together, we find that a total of 4.7 million gallons of water are used to produce a 1,400-lb. live steer with a 1,000-lb. carcass. For a steer with a 1,000-lb. carcass, approximately 4,700 gallons of total water are used to produce one pound of meat, or about 884 gallons for a 3-oz. steak. But out of these 884 gallons per serving, only 10.5 gallons are California drought water—water to grow alfalfa, drinking water, and water for processing—that could be potentially shifted to other uses during a California drought.

All Water and Drought Water Used to Produce Dairy Products

On the next page, Figure 2 summarizes the water use by a dairy cow in California. A total of about 23.7 acre-feet or about 7.7 million gallons of water are used by a dairy cow over her lifecycle. For simplicity, we assume the cow spends her whole life in California and all the water use is attributed to milk production—not

Figure 2. Water Used During a Dairy Cow's Life Cycle



**Drought water*
Source: Authors' calculations.
See additional information for detailed methodology, calculations, and sources.

to the value of her male calves that may be raised for beef or to the meat contributed by her carcass when she is culled from the dairy herd.

The distribution in Figure 2 assumes each cow spends one year as a calf and one year as a heifer before entering the milking herd. The following three years are spent as a milking cow, with two months of each of those years spent as a dry milking cow. Multiplying typical rations in each stage of a dairy cow's life over the respective time periods, we find that over her life, a dairy cow consumes about 8 tons of alfalfa and other hay, 29 tons of corn and other silage, 17.5 tons of corn (or the equivalent in grain), and 6 tons of soybeans (or the equivalent).

The calculations are similar for the feeding of a beef steer for corn, soybeans, and other items. About 2.9 million gallons are used for corn and 2.3 million gallons for soybeans, none of which is drought water. About 1.3 million gallons of drought water are used to grow hay, about 1.2 million gallons are for silage, and 44,000 gallons of drought water are used for drinking and other uses.

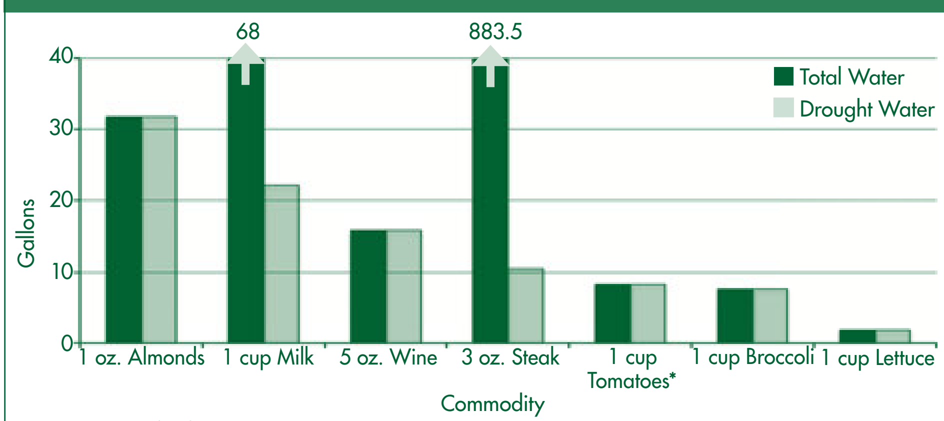
A California dairy cow produces about 7,000 gallons of milk during her life. Therefore, it takes almost 1,100 gallons of water to produce one gallon of milk—354 gallons of which are drought water. Each 8-ounce serving of milk requires about 68 gallons of total water and 22 gallons of drought water.

Summary and Conclusion

Figure 3 summarizes the total water and drought water used to produce a variety of foods in California per typical serving. By these measures, the livestock products top the chart in total water use but are moderate in terms of drought water implied per serving.

Remarkably, a serving of steak uses much less water than a serving of almonds, or a glass of milk or wine, and about the same as a serving of broccoli or stewed tomatoes.

Figure 3. Total Water and Drought Water per Serving for Select Commodities



** Crushed Tomatoes*
Source: Authors' calculations. See additional information for detailed methodology, calculations, and a full list of sources.

The drought relevance of water consumption depends on where that water falls and how it is used.

This article has clarified that discussion of water use in the California drought should at least focus on water use relevant to that topic. But more fundamentally, a measure of water per unit of output might be better measured per unit of value generated or by the enjoyment of consumers buying the product. Different products are intensive in the use of farm or land area or water. None of these simple ratios of inputs to outputs in themselves tell us much about efficient allocation of resources.

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For full documentation of methods and sources and details of our calculations, see http://aic.ucdavis.edu/water-in-food_background.

Europe's Migration Crisis

Philip L. Martin

The European Union's 28 member nations received 1.2 million applications from asylum seekers in 2015. One reason for the upsurge in asylum applicants is that German Chancellor Angela Merkel in August 2015 announced that Syrians could apply for asylum in Germany even if they passed through safe countries en route. The challenges of integrating asylum seekers are becoming clearer, prompting talk of reducing the influx, reforming EU institutions, and integrating migrants.

Europe is *the* continent of international migration, with a third of the world's international migrants. The UN reported that 244 million people left their country of birth and moved to another country for a year or more in 2015, making 3.3% of the world's 7.3 billion people international migrants. Some 76 million were in Europe, including a third in the second and third largest hosts of migrants, Germany and Russia, which each had 12 million.

Many European countries have shrinking populations and labor forces, making more tax-paying workers that could stabilize economies and fund comprehensive social welfare programs seem welcome. EU leaders want to attract skilled foreigners with college degrees, but programs to attract skilled migrants have not attracted large numbers—fewer than 25,000 a year.

Most of the migrants who arrived in Europe before 2015 were joining family members already there. Many settled migrants have relatively little education, as do their family members, which can complicate their integration into work and society. Migrants and those with migrant backgrounds generally have low labor force participation rates and, among those in the labor force, high unemployment rates—raising fears that more low-skilled migrants could add to unemployment and welfare dependence rather than employment and taxes.

The 2015 Migrant Influx

The number of asylum applications in EU member states began rising after the Arab Spring of 2011, when protestors beginning in Tunisia overthrew entrenched leaders. The disruptions of the Arab Spring turned into a civil war and competing governments in Libya, allowing North African and other migrants to leave in small boats for Lampedusa, an Italian island less than 200 miles from the Libyan coast.

A boat of migrants sank near Lampedusa in October 2013, resulting in 360 deaths and prompting the Italian government to rescue migrants traveling from Libya to Lampedusa in boats. Some smugglers used the prospect of a quick rescue to put migrants on less-viable boats with satellite phones, instructing them to call for help as soon as they left Libyan waters, an example of a moral hazard when providing help encourages more people to pay smugglers and undertake risky journeys.

Dangers from the Libyan civil war and the destruction of boats used to smuggle migrants shifted the major migrant-smuggling route to the Turkish-Greek coast. There were four million Syrians outside Syria in 2015, including half in Turkey, and they began to use small boats to travel the 10 to 15 miles from the Turkish coast to Greek islands such as Kos and Lesbos. Once in Greece, migrants traveled by ferry to Athens and made their way north through the Balkans to Hungary and Austria and on to Germany and Sweden. Although Syrians were the single largest nationality arriving in Europe in 2015, most asylum seekers were not from Syria, Afghanistan, and Iraq.

After Hungary blocked some asylum seekers from going on to Austria and Germany, Merkel in August 2015 announced that Syrians could apply for asylum in Germany even if they passed through Hungary and safe countries en route; thus, disregarding the Dublin Regulation that requires asylum seekers to apply for refuge in the first safe country they reach. Syrians and others responded to Germany's welcome, and over 12,000 arrived in Munich on September 12, 2015.

German states and cities scrambled to register, house and feed, and integrate the arriving migrants. Sport clubs, schools, and other public facilities were converted to migrant shelters, and many Germans volunteered to help the new arrivals. Others protested the arrival of especially Muslim migrants, arguing that they would be difficult to integrate and could adversely affect Germans. Some housing that was meant for migrants was burned.

As numbers rose, Germany, Sweden, and other governments tried to slow the influx by checking the foreigners arriving at their borders to find and return those unlikely to receive asylum, such as citizens of Kosovo and Serbia. Germany and other EU governments announced that foreigners who were granted asylum would receive only temporary protected status and many would not be able to bring family members to join them for several years.

Two events changed attitudes and policies toward migrants. First, eight Muslim terrorists killed 130 people in Paris on November 13, 2015, including two who entered the EU using the Turkey-Greece route. EU leaders urged citizens not to confuse refugees with terrorists, most of whom were EU citizens, but the Paris attacks highlighted the threat that terrorists could lurk among migrants. Second,

Table 1. Native-and Foreign-born Employment Rates, 2014 (Percent)

	Natives	Foreign-born	Difference
Austria	72.6	64.9	7.7
Belgium	63.8	52.8	11
Denmark	74.2	63.9	10.3
EU 28	65.2	62.1	3.1
France	65.3	56.7	8.6
Germany	74.9	68.3	6.6
Greece	49.3	50.3	-1
Italy	55.3	58.4	-3.1
Spain	56.6	52.3	4.3
Sweden	77.7	63.5	14.2
UK	72.4	69.4	3
U.S.	66.5	69.1	-2.6

Source: OECD. Share of 15-64 year-old persons employed. https://data.oecd.org/migration/foreign-born-unemployment.htm.
Difference: A positive sign indicates a higher native than foreign employment rate.

on New Year's Eve, migrants attacked hundreds of German women near the Cologne train station, prompting an outcry that emphasized the need for newcomers to respect German cultural norms.

Three things are clear. First, migrants continue to arrive from Turkey at the rate of 2,000 a day, as Syrians and others worry that the doors to Europe are closing. Second, Germany, Sweden, and other EU countries that accepted large numbers of asylum seekers are taking steps to reduce the influx. Third, half of all asylum seekers are being recognized as in need of protection, making the next challenge to integrate Syrians and other migrants.

Migrant Integration

Most of the migrants who arrived in Europe in 2015 are there to stay: EU member states deport relatively few migrants. Deportation is difficult because many migrants destroy their passports, knowing that their countries of origin will not accept the return of persons without proof that they are citizens. Others are from countries to which European countries do not return migrants because they are at war, such as Syria.

The first EU priority is to reduce the influx. Many German leaders advocate quotas on the number of asylum seekers. Merkel and others counter that the German constitution guarantees foreigners facing persecution the right to asylum, so what will Germany do with asylum seekers who arrive after the quota is filled?

The major policy instrument to reduce numbers is to provide aid to Turkey in exchange for their help to improve conditions for refugees and to impede smuggling. The Office of the United Nations High Commissioner for Refugees (UNHCR) spent about $7 billion to care for 14 million refugees around the world in 2015, while Germany's federal government spent $7 billion to care for one million asylum seekers in Germany. The EU committed €3 billion ($3.3 billion) to Turkey, which promised to allow the two million Syrians in the country to work and to enlarge schools for refugee children. Many Syrians are unsure if they want to learn Turkish and remain in Syria; most prefer to return to a peaceful Syria or to move on to Germany.

The second challenge is to reform EU institutions. The Dublin Regulation of 1990 requires foreigners seeking asylum to apply in the first safe country they reach, which fingerprints them and makes a decision on whether they need protection that is binding on other EU member states. The major country of arrival is Greece, whose government has been unable to register and process asylum applications or accept the return of foreigners who transited Greece en route to other EU countries to apply for asylum.

The Schengen agreement abolished border checks between most EU member states, making travel and trucking much more efficient. Schengen member states may reinstate border controls if there is a serious threat to security, as France did after the November 2015 terrorist attacks in Paris. If EU countries reintroduce border controls, is the single market at the core of the EU at risk?

The third challenge is to integrate the new arrivals. The U.S. has an integration-via-work policy based on a flexible labor market and a relatively thin social safety net that is normally off limits to unauthorized foreigners, asylum seekers, and even legal immigrants until they have worked in the U.S. at least 10 years. Most European governments provide asylum seekers with housing, food, and other benefits, but make it more difficult for them to get the work permits to work lawfully in Europe's more regulated labor markets.

Table 1 shows native- and foreign-born employment rates for persons 15–64 in 2014. In the EU-28 countries, native-born employment rates of 65% are three percentage points higher than for the foreign-born, compared with 66–69% in the U.S., where foreigners are more likely to have jobs than Americans. In EU countries that have higher-than-EU-average native employment rates, such as Austria, Germany and Sweden, the gap between native- and foreign-born employment rates is much larger, from 6–14%. In southern European countries with low employment rates for natives such as Greece and Italy and more informal labor markets, foreign-born residents have higher employment rates than natives.

Getting newly arrived migrants into language classes, developing networks to link them with jobs, and encouraging them to accept jobs on the bottom rungs of the job ladder could prove difficult. Migrants from Syria, Afghanistan, and Iraq have significantly less education than natives and settled immigrants, prompting talk of sub-minimum wages and wage subsidies to encourage employers to hire migrants. However, some migrants may have little incentive to shift from tax-free welfare benefits to taxed low-wage work.

Global Challenges

One-sixth of the world's people live in what the World Bank defines as industrial or high-income countries with a per capita income of $12,736 or more. The incentive to migrate reflects from the demographic inequality that all population growth is in developing countries and the economic inequality that almost 70% of the world's national income accrues to high-income countries. The average resident of high-income countries had a per capita income of $40,000 in 2013, almost ten times the $4,200 of lower-income countries, providing a powerful incentive for young people to migrate.

Demographic and economic inequalities are like positive and negative battery poles: nothing happens without a connection. Three revolutions over the past half-century have increased cross-border connections and facilitated migration. The first is the communications revolution, which makes it easier than ever before to learn about opportunities abroad. With most high-income countries including diasporas from countries around the world, cell phones and the internet quickly inform friends and relatives in developing countries about opportunities abroad, finance their travel, and help them after arrival.

The second revolution involves transportation. Many Europeans migrating to North American colonies in the 18th century could not pay one-way transportation, so they indentured themselves for four to six years to whomever met the ship and paid the captain. Transportation today is much more accessible and cheaper, usually less than $2,500. Even migrants who pay smuggling fees of $20,000 to $30,000 typically repay them from higher earnings within two years.

The third revolution involves the rights of individuals vis-à-vis governments. Dictatorships and wars early in the 20th century led to the creation of the UN and an elaboration of human rights. Many human rights protect all persons, including foreigners, making it difficult for governments to remove those who want to stay.

Policymakers faced with an influx of asylum seekers are unable to do much in the short term about the demographic and economic inequalities that motivate migration, and do not want to roll back the communications and transportation revolutions that do far more than facilitate migration. Their default option becomes adjusting the rights of migrants, making it more difficult to enter countries with liberal asylum policies and restricting the access of newcomers to social welfare systems. For example, the U.S. in 1996 enacted welfare reforms that reduced benefits for all poor people, but especially immigrants. At a time when the foreign-born were 11% of U.S. residents, restricting their access to welfare accounted for 44% of expected federal savings from welfare reform.

Merkel and some other EU leaders have stressed the importance of tackling the root causes of migration, suggesting that peace and speeding up economic and job growth in lower-income countries are alternatives to restricting the rights of migrants. Promoting peace is a laudable but difficult challenge, as is fostering stay-at-home development. The UN emphasizes that three-fourths of international migrants are from middle-income developing countries such as Mexico and Turkey, where faster economic growth can increase international migration, as aspirations and the ability to migrate rise faster than economies can generate decent jobs, an example of the migration hump.

The EU Challenge

The EU generally and Germany in particular face a daunting challenge to deal with migrants, to reform institutions and coordinate migration policies, and to integrate the million-plus foreigners who arrived in 2015. Achieving peace in Syria would help, but the experience of Afghanistan and Iraq demonstrate that fighting is likely to continue even after peace agreements are signed. The migration networks forged during fighting may support continued out-migration.

The EU also faces institutional challenges. Agreements such as Dublin and Schengen were tested in 2015 and found wanting. The so-called front-line states of Greece and Italy were unable to control their external borders, so that foreigners entered and traveled to richer EU countries. Efforts to develop a quota system to redistribute asylum seekers from front-line states among EU member states floundered.

The integration challenge is most important. Almost all of the several million foreigners who have or are expected to arrive in 2015–16 are likely to remain in Europe. The question is whether social welfare states developed and expanded after World War II should be expanded further to deal with largely non-European newcomers, or whether the better integration strategy is to focus on a work-first integration strategy. It is often said that governments can accept more low-skilled migrants, or have better support policies for them, but they find it hard to pursue both work and welfare strategies simultaneously. Developing the optimal trade-off between work and welfare could prove particularly challenging in Europe.

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