

‘A thirsty operation’: TSMC plant arrives amid water doubts, but Phoenix isn’t worried

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Greg Jackson doesn’t have a window in his office, but he says he doesn’t need one.

As the facilities manager for the Taiwan Semiconductor Manufacturing Company’s massive new factories in north Phoenix, Jackson spends a lot of time away from his desk, on his feet.

Jackson’s responsibilities cover the mundane and the complex. One moment, he is overseeing the janitorial staff that keeps the office windows clean, and another he is managing the delicate etiquette of shipping and receiving sensitive chemicals.

And he will continue to oversee the construction of the most advanced semiconductor manufacturing facilities in the U.S. on a plot of desert near Interstate 17, a vast project that, over the next six years, will rise literally from the dust.

As with all new growth in the desert, the facility requires water, and semiconductor manufacturing is a particularly water-consumptive industry. That, too, falls under Jackson's purview, everything from the fountain outside the office entrance to the facility's massive internal water treatment facility, which will handle the equivalent of a 90,000-person town's wastewater.

The Arizona facility is being built to mimic its "mother fab" in Taiwan, where TSMC has already invested heavily in water reuse at its existing fabs. Company officials say the new facility in Arizona aims to be as efficient as possible. With blueprints in hand, Jackson's job is to make that statement a physical reality.

"I live here. I've got a family here," said Jackson, who's lived in Arizona for 28 years. "The last thing I want to do is use all the water. We want to be good stewards of water and be good community citizens."

TSMC says its reuse and recycling efforts will make its water use manageable and even small compared with other Arizona water uses. Phoenix doesn't expect it to strain city resources. At the same time, other growth stemming from TSMC's arrival, uncertainty around the region's Colorado River supplies, and additional environmental concerns related to semiconductor manufacturing generally could create more troubling questions for the Phoenix community.

Phoenix already had a nearly 80-year relationship with the chipmaking industry before TSMC came to the city. Seven semiconductor fabs operate in metro Phoenix, not counting TSMC and 20 associated manufacturers. With them, dozens of tool and chemical companies are setting up shop or working to scale up. The growth of the competitive industry is palpable nationwide, across communities that still bear historic scars inflicted in part by that same industry.

In Phoenix, the industry's early history was toxic, contributing to groundwater pollution that government agencies are still addressing. Today, there are higher standards in place, and the industry says it will be a good neighbor. But environmental critics don't want to take their word for it.

Judith Barish, coalition director for CHIPS Communities United — a national alliance organizing to ensure the CHIPS Act also benefits workers and protects the environment — said her biggest concerns are regulation and oversight.

“We think that if (the semiconductor industry) it’s going to be supported by massive infusions of taxpayer dollars, billions of dollars, that we should get it right this time,” Barish said.

Bringing a ‘thirsty operation’ to the desert

TSMC, the world’s second-most valuable semiconductor company and the largest company in Taiwan, announced its intention to build a “fab,” or semiconductor factory, in north Phoenix in 2020.

By April of this year, the company had expanded that vision to three fabs, announcing the third after it received a \$6.6 billion federal award through the CHIPS and Science Act. The company has space for a total of six fabs at its north Phoenix location.

TSMC says its first fab has begun limited operations, while it plans to bring the second and third fabs online in 2028 and 2030, respectively. Already, Phoenix city water is coursing through the futuristic facility’s pipes.

Arizona’s desert may seem like an unwise location for a water-intensive industry. Semiconductor fabs have high water requirements because they must rinse the individual tiers that make up each semiconductor to keep their electrical pathways clear of dust. Fabs also use water to run cooling towers and scrubbers — systems that remove gas pollutants from the plants’ exhaust.

“You can’t hide that it is a thirsty operation,” Jackson said.

TSMC has now brought that operation to its most arid location yet. Phoenix’s average annual precipitation is around 7 inches, while Hsinchu City, Taiwan, where most of TSMC’s fabs are located, receives an annual average of 64 inches. Camas, Washington, the site of TSMC’s only other existing U.S. fab, also receives about 64 inches annually.

What’s more, the Phoenix area is navigating an uncertain moment in its water history. Arizona’s yearly deliveries from the Colorado River, which makes up roughly 40% of Phoenix’s water supply, are becoming harder to predict as states figure out how to manage lower flows and overuse. That water is growing more important as the city moves away from local groundwater supplies, which are dropping at an unsustainable rate.

A TSMC public information officer said she has received one question consistently in roughly 20 years of working for semiconductor companies in Arizona: “Why build a semiconductor fab in the desert?”

Though its climate is hot and dry, the area is the meeting point for some of Arizona’s largest rivers. The same waterways that fed Hohokam cornfields in the sixth century and settlers’ orange groves in the 1880s will now feed the cooling towers and ultrapure systems of the Taiwanese plant, with the colossal added benefit of Colorado River water transported from 190 miles away through the Central Arizona Project Canal.

TSMC will follow at least seven other semiconductor companies that have opened fabs in central Arizona. Phoenix, Tempe, Mesa and Chandler all provide water to existing semiconductor fabs in their areas. TSMC seems to have chosen Arizona largely because Phoenix and state officials made repeated efforts to draw them here. TSMC likely also appreciated Phoenix’s history of semiconductor manufacturing, lack of seismic activity and professional programs at Arizona State University.

City officials approved a development agreement in 2020 promising up to \$205 million for road and water infrastructure to serve the facility. Even before TSMC purchased its property, the city set to work constructing water and sewer infrastructure.

How much water will it use?

Ultimately, TSMC’s fabs are unlikely to make a serious dent in Phoenix’s water budget. When completed, TSMC projects the three Phoenix fabs will require a combined 16.4 million gallons per day to operate, according to a company spokesperson. The fabs will lose 2.9 million gallons of that amount to evaporation and send 1.3 million back to the sewer.

According to Jackson, the company will treat and reuse the remainder. As a result, Phoenix only will need to deliver 4.2 million gallons to the facilities each day, roughly one-quarter of the fabs’ daily usage.

Those deliveries equate to the yearly demands of three typical golf courses or roughly 14,000 single-family households.

TSMC has stated a goal of reusing 90% of its water at its Arizona fabs, but the company clarified in an email that this goal applies to water left over after evaporation from manufacturing processes. With evaporative losses factored in, the fabs' total water reuse goal is 74%.

Those evaporative losses should effectively represent the fabs' only depletion of the city's water supply as the city could potentially reuse the wastewater that goes to the treatment plants. The company says it has already reached similar rates at other fabs outside the United States, though Arizona's facility is planned to be the company's most water-efficient in the world.

Cynthia Campbell, Phoenix's water resources management adviser, said the city has been working to add a new wastewater treatment facility in north Phoenix to manage existing growth in that area, meaning the city has not had to make any special system improvements to accommodate TSMC specifically, other than pipe infrastructure at the actual fab site.

The fabs will draw from almost all of Phoenix's water sources, according to Campbell. She confirmed that water supplies going to TSMC are currently unused, meaning no one will have to cut back their use to accommodate the fabs.

From the Salt and Verde basins, TSMC will draw on two pools of water: so-called "new conservation" water stored in Roosevelt Lake on the Salt River and "gate water" stored in Horseshoe Reservoir on the Verde. Campbell said some of those supplies currently evaporate while sitting idle.

TSMC will also use some Colorado River water and some groundwater. The city can mix and interchange these resources depending on momentary needs, Campbell said.

In total, the three fabs planned will increase the city of Phoenix's current average daily water production by 1.6%.

Some city elected officials say they want to better understand the long-term impact of that growth. Phoenix City Councilmember Laura Pastor asked city staff during a February meeting to provide her and the public with long-term estimates for the city's water supplies.

“I think it’s important for the public to know that,” Pastor said. “And we, as council people, have to understand that because we’re out recruiting companies to come to our state.”

Uncertainty on the Colorado River has made those numbers difficult to nail down, Campbell said. Traditionally, the city has mapped out projections of its water demand and water supply, allowing it to plan for future needs. With negotiations over Colorado River management now stalled, Campbell said this simple formula is harder to create.

Campbell said if it weren’t for the ongoing tensions on the Colorado River, TSMC would not have generated difficult discussions around water use in Phoenix.

“The irony is that if we were not facing the Colorado River shortage ... there really wouldn’t be a conversation at all about whether there was any concern about having enough water for TSMC or anybody else,” Campbell said.

Campbell said the city is nowhere near exceeding its available water supplies, even with uncertainty on the Colorado.

“In our last water resource plan, you can look at the craziest demand hypothesis they came up with, and even then, we didn’t jump the shark,” Campbell said. “If you look now, would it be closer? It would be. It would be closer. There’s no way to deny that. But do we see a point yet where we are going to jump the shark? No.”

Is the project worth the water?

The simultaneous arrival of TSMC and ongoing cuts on the Colorado River have pushed the city to regulate its large water users. The City Council passed a “Large Water User Ordinance” in March, which requires some users to submit water conservation plans and adhere to reuse requirements. Mesa already has a similar ordinance.

Although TSMC’s arrival partly inspired the ordinance, the new fabs may not fall under its restrictions because the company could be grandfathered in, according to Campbell. And even if the ordinance does apply to TSMC, city officials can loosen certain regulations if a large water user brings particularly high economic benefit to the city.

Sarah Porter, the director of Arizona State University's Kyl Center for Water Policy, believes the fabs probably provide excellent economic benefits for each drop of water they use.

"My bet is that semiconductor plants would come out looking really good in terms of the benefit to the city compared with some other high-volume water users," Porter said. "I'm not saying that we shouldn't have these things, but bottling plants and craft beer use a lot of water, and probably don't provide the same dollar return that semiconductor plants do."

Those economic benefits, and the water use associated with the fabs, will grow as new development continues at sites near the fabs. TSMC's fabs typically rely on nearby residential development and "science parks" to provide support services for their employees and the facilities themselves.

Within 10 miles of the plant, about 2,500 apartment units are under construction, according to CoStar data, with 3,500 new units opened since TSMC bought the land. A New York-based real estate company bought 2,340 acres of land immediately surrounding the TSMC site in May, which it intends to develop (<https://www.azcentral.com/story/news/local/phoenix/2024/10/28/halo-vista-development-around-taiwan-semi-conductor-arizona/75815092007/>) into a "city within a city." The planned development, currently known as Halo Vista, could hold nearly 30 million square feet of buildings, including hotels, industrial buildings, offices, apartments, retail and public uses like education facilities.

That is precisely what worries Scott Meyer, president of Don't Waste Arizona. It's a positive that the TSMC site is far away from existing residential neighborhoods, he said.

"They need to maintain that buffer, especially if there is going to be a chemical plant there too, which is much more concerning," Meyer said.

The organization consolidated three decades ago to actively advise the cleanup process of the Motorola Superfund site.

"Most of our battles are because of some industries slammed in the middle of a neighborhood and its causing impacts," he said. "You want to do monitoring to make sure you don't have any hidden trouble spots that you find about decades later."

Are fabs, and cities, learning from the past?

Like any growing industry, challenges to protect people and the environment are scaling up in semiconductor manufacturing. Even as the industry has modernized, advocates worry that local and federal authorities won't do their due diligence in regulating these companies.

Just as Phoenix worked for years to draw and accommodate TSMC in the 2020s, it lured the arrival of Motorola in the mid-20th century.

Motorola opened the first of two flagship plants in 1956, becoming at one point the state's largest employer. Some of the most important environmental regulations in this country weren't in place yet, and the manufacturing boom of those years created lasting pollution.

By the 1980s Scottsdale and Tempe found TCE, an industrial solvent and carcinogenic chemical, in municipal water wells. The Environmental Protection Agency declared the neighborhoods around the Motorola plants, at 52nd Street and McDowell Road in Phoenix, and at Scottsdale's Indian Bend Wash, Superfund sites. A third site, next to the 52nd Street plant, has still not been added to the EPA's Superfund list or cleanup programs.

To this day, volatile chemicals dumped by the industry decades ago cause indoor air contamination in some downtown Scottsdale buildings. Groundwater cleanup is ongoing.

Motorola stopped using TCE in the 1970s and no longer has plants in Phoenix. Manufacturers are starting to phase out use of gasses like NF₃, SF₆, and CF₄, which damage the ozone layer, and finding cleaner ways to produce needed chemicals. But dozens of hazardous substances are still in use.

Environmental groups want foundries to use alternatives to per- and poly-fluoroalkyl substances — “forever chemicals” or PFAS — in chipmaking, for example, and require them to disclose how they treat and dispose of these dangerous substances. PFAS are unregulated and still essential in the manufacturing process, although the industry has begun phasing out two kinds, PFOS and PFOA.

In other states, PFAS chemicals have been found in fabs' wastewater discharges. ADEQ has no data on the discharge made by Arizona chip manufacturers but acknowledged that nationally it is known the industry is a potential source for PFAS contamination.

Reducing the industry's carbon footprint is what is taking more of the companies' headspace.

Chipmaking takes enormous amounts of energy. In Kaohsiung, Taiwan, TSMC's three factories account for 18% of the city's total electricity consumption, said Cheng Tai-Chun from Citizen of the Earth, Taiwan.

"Since Taiwan inherited a highly polluting, high-carbon-emitting petrochemical industry, it may be said that the semiconductor industry in Taiwan has become relatively 'less polluted' and more welcomed," he wrote in a statement to The Republic.

If TSMC expands to five plants in the city, as it has announced, energy use would require 30% of Kaohsiung City's energy supply, which is still largely generated by fossil fuels, they added.

Advocates also worry about basic protections that are still missing in the U.S.

Worker protections are grossly outdated, said Barish, from the Chips Communities United Coalition. Chemical management standards from the Occupational Safety and Health Administration are "worthless" since they date from the 1970s.

Regulations need to catch up, she said. And modern environmental protections only work if industry standards and requirements exist.

Citing the enormous economic benefits these companies will bring, agencies in Taiwan conducted "perfunctory" environmental impact assessments, Tai-Chun said.

The U.S. government also has stripped down environmental review processes for chipmakers. Sen. Mark Kelly, D-Ariz., successfully passed a bill in 2023 exempting many CHIPS Act projects from a full environmental review under the National Environmental Policy Act.

A spokesperson for Kelly said the senator wanted to avoid unnecessary layers of review, pointing out that many of the exempted projects are connected with facilities that already have received other local and federal environmental permits. Activists,

however, worry that the projects will now go ahead without the reporting requirements and public information that come with formal NEPA reviews.

Chips Communities United wants the Commerce Department to require public reporting from the chipmakers and establish mechanisms to ensure they are protecting workers, nearby communities and the environment.

“My assumption is that there will not be any more environmental review for TSMC or Intel,” Barish said.

The coalition successfully worked with the Commerce Department to introduce modernized Clean Electronics Production Network standards for smaller semiconductor facilities, such as Tempe-based Amkor Technology.

Transparent contracts with clear requirements and protocols to protect workers and the environment could make up for an incomplete NEPA review, Barish said.

Competition is also driving sustainability

Some of the industry’s environmental risks could shrink dramatically in a couple of years with the right partnerships.

Massive federal investment and the extremely competitive environment of microelectronics are intensifying research and development efforts. In September, the National Science Foundation announced \$42.4 million in research grants to fund semiconductor research and boost the industry. In October, the Department of Commerce announced \$100 million for collaborations relevant to sustainable manufacturing. Industry goals are aggressive.

“They’re world leaders in chips, and they want to be world leaders in all these other things,” said Paul Westerhoff, an ASU professor and Fulton Chair of Environmental Engineering who has worked for more than a decade with the semiconductor industry. He leads a dozen scientists in research for semiconductor water treatment.

“What we’re trying to do is to figure out how they can take that wastewater, clean it up and make new chips again with it.”

Many of the chemicals they are trying to remove don’t present any health concerns, but they have properties that could affect chip manufacturing.

He expects that in two years, Phoenix fabs will be able to reuse 90% of all wastewater on-site and have the technology to treat it to ultra-pure standards necessary to make the chips. TSMC said it already has the know-how and technology to treat wastewater and reuse it in other parts of the manufacturing process.

“We want to push them, scientifically and technology,” Westerhoff said. “There’s no real barrier to doing this.”

Existing semiconductor fabs such as Intel’s already claim a near-zero liquid discharge. Of the water they use, most is evaporated to reduce, crystallize and dispose of chemicals, or treated to a standard where it can be reused in a different industry instead of discharged into the sewer.

Offsets — reducing the water consumption of others — reduce the fab’s overall water footprint, the same way other companies offset emissions by joining the carbon market.

Growth in the industry also will increase the use and disposal of hazardous chemicals. Heavy metals, solvents, nanomaterials and other substances will be needed in greater quantities. Companies will need to ramp up proper management.

Daniel Alvarez is in the business of finding solutions to reduce their waste steam and lower costs.

“The chip market worldwide is extremely competitive. It’s difficult for them to be the best in the world at the core competency and sustainability at the same time,” said Alvarez, founder and CEO of Purity ReSource. His philosophy is that to remain competitive, foundries can focus on what they do best and outsource sustainability challenges to companies like his.

Purity ReSource is working on technology that will recover, process and reuse seven to eight times the solvents used in chipmaking.

Other competitors recover and process the chemicals to use in other industries, but so far there aren’t tools on the market to reuse them at the fabs, where the waste is generated, Alvarez said.

The three-year-old company moved to Tempe about a year ago and hopes to go into business with semiconductor manufacturers like TSMC in two or three years. It's already working on test and trial, and small-scale recovery, with leading tool and components manufacturers in the industry.

Chipmaking uses anywhere from 200 to 500 steps, depending on the chip complexity, Alvarez said. All those steps require manufacturing tools, water and chemicals. The company focuses on solvents because most of those are now incinerated.

"There are many other chemicals that right now we don't address," Alvarez said. "But eventually down the road, when we have more resources, we will. "

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