

ASU

ARIZONA STATE UNIVERSITY
VOLUME 24 NUMBER 4

Thrive[®]

PLUS
CAREER HACKS
FOR YOUR 20s
3 key principles to
guide your ongoing
success

DOCTOR, DOCTOR
Meet two ASU Online
grads who earned
spots in medical
school

ECONOMIC GROWTH

Silicon IN THE Valley

**ASU is fueling
a semiconductor
revolution that
benefits Arizonans**

ASU
Arizona State
University

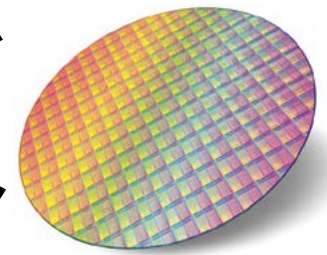
Scan with your
smartphone
camera to
view the
digital edition.





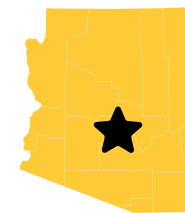
Semiconductor companies must squeeze more performance out of chips — and constantly optimize production processes. Through early stage research that translates into real-world applications, ASU researchers like Wahab Alasfour help the industry do both.

Silicon



IN THE

Valley



ASU is fueling a semiconductor revolution that benefits Arizonans

Story by DANIEL OBERHAUS, '15
BA ENGLISH, BA PHILOSOPHY
Photos by JAROD OPPERMAN



(Yes, even in traffic lights!)

Semiconductors power modern devices.

You rely on them every single day. We all do. They're in



phones, computers, smart appliances,



cars, solar panels and



more. These electronics depend on circuits etched on razor-thin

wafers of silicon.



Silicon is an example of a semiconductor, materials that have the characteristics of both a conductor, such as copper, and an insulator, like glass, allowing engineers to precisely dial in exact electricity flow under specific conditions. This makes semiconductors well-suited for building the microscopic circuits at the heart of the computers in our devices.

Every year, more than a trillion semiconductors roll off assembly lines to meet an insatiable appetite for microelectronics that are faster, smarter, cheaper; demand is growing.

The U.S., birthplace of semiconductors, was once the global manufacturing leader. But over the past few decades, competition drove many manufacturers abroad. According to the Semiconductor Industry Association, today, the U.S. manufactures about 12% of the world's semiconductors.

The coronavirus pandemic exposed the risks of relying on an international supply chain for a critical product. As the virus circled the globe, worldwide semiconductor manufacturing facilities — called fabs — came to a standstill. Suddenly, no one could get their hands on the chips that power the modern world. The shortage has held up production for cars, televisions, washing machines and even smart toasters.

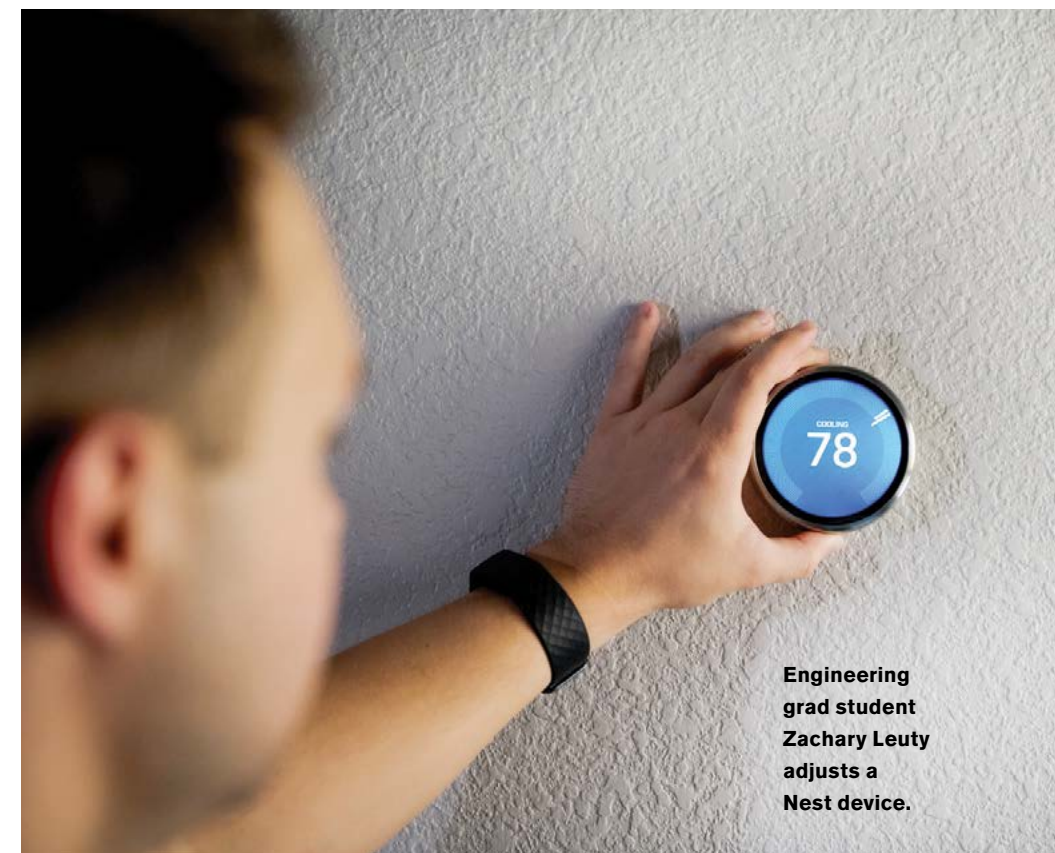
Politicians in Washington, D.C., realized that semiconductor manufacturing in the U.S. is a matter of national security.

“Building up the semiconductor ecosystem in this state will bring industry and jobs. This is an economic opportunity that improves our well-being.”

— SALLY C. MORTON,
EXECUTIVE VICE
PRESIDENT, ASU
KNOWLEDGE
ENTERPRISE

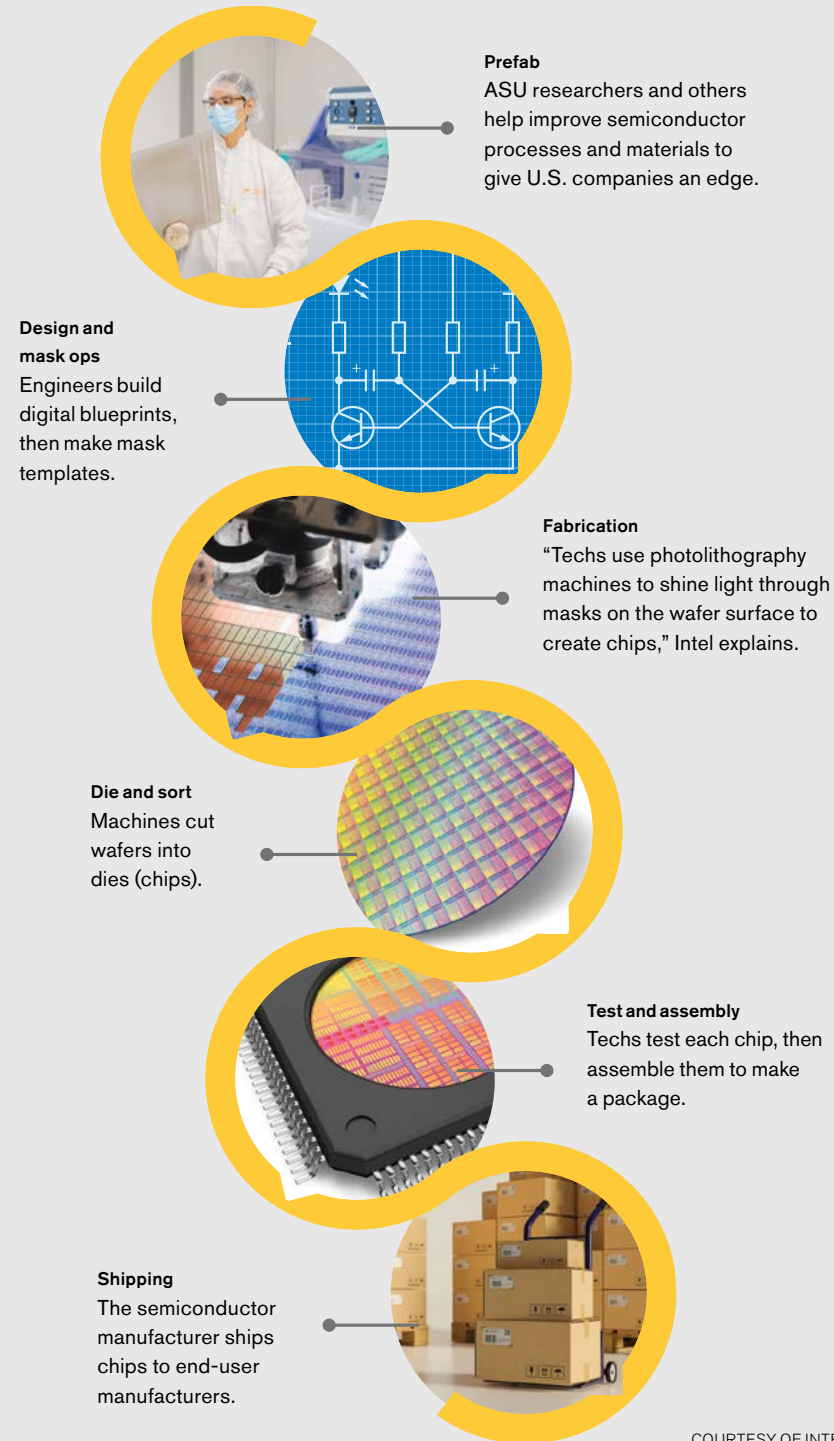
When President Joe Biden announced his administration's \$2 trillion infrastructure bill, he held a semiconductor chip aloft to underscore the industry's prominent place in the bill. “This is infrastructure,” Biden said. “We've been falling behind on research and development and manufacturing, and, to put it bluntly, we have to step up our game.”

Sally C. Morton, executive vice president of ASU's Knowledge Enterprise, agrees. She highlights the fundamental importance of semiconductor chips in our daily lives and in national security.



Engineering grad student Zachary Leuty adjusts a Nest device.

A computer chip's journey



“Everyone is impacted by semiconductors, but we don’t always see all the ways that microchips support the lives we lead,” Morton says. “We need to have autonomy in this space for both production and distribution.”

Arizona’s chip investment

Because of strong historical roots and rapid expansion, Arizona is poised to be at the epicenter of the American semiconductor revolution, with ASU playing a starring role. Last spring, two of the world’s largest chipmakers, Intel and Taiwan Semiconductor Manufacturing Company, announced plans to spend a combined \$32 billion building three semiconductor fabs in the Phoenix region, with TSMC purchasing enough land to possibly build five more fabs, which would invest billions of dollars more. Around the same time, Samsung shortlisted Phoenix as a possible factory site.

The interest in Phoenix makes sense. For decades, city officials, business leaders and ASU cultivated the infrastructure, regulatory environment and human talent the industry needs. And their timing couldn’t have been better. Worldwide semiconductor industry sales hit \$439 billion in 2020, according to the SIA, with the industry projected to reach \$803.15 billion by 2028.

“Building up the semiconductor ecosystem in this state will bring industry and jobs,” Morton says. “This is an economic opportunity that improves our well-being.”

Local partnerships, global impact

When Michael Kozicki, a professor of electrical engineering and director of the Center for Applied Nanoionics, first arrived at ASU in 1985, semiconductor manufacturing had already established a foothold in the area. Intel and Motorola anchored it, building a foundation that includes NXP, ON Semiconductor, Microchip Technology, Medtronic and others.

Kozicki’s ability to straddle the divide between industry and academia has proved invaluable for preparing generations of Sun Devils for careers at the world’s largest chipmakers. Today, he leads courses covering everything from working in the planet’s cleanest laboratories to designing next-gen chips, a heady mixture of practical and experimental knowledge that students need to drive nonstop innovation in microelectronic engineering.

“There are not many universities that do courses in semiconductor fabrication where you get a hands-on, industry-relevant education,” Kozicki says. “It’s all part of getting people ready to be productive professionals within the semiconductor industry. We’re a major supplier of talent.”

ASU’s emphasis on industry-relevant research has forged mutually beneficial partnerships with local semiconductor firms. In 2017, for example, the university partnered with ON Semiconductor, a Phoenix-based supplier to the global industry, to establish a \$2 million, five-year

“There are not many universities that do courses in semiconductor fabrication where you get a hands-on, industry-relevant education. We’re a major supplier of talent.”

— MICHAEL KOZICKI,
PROFESSOR OF
ELECTRICAL
ENGINEERING
AND DIRECTOR OF
THE CENTER FOR
APPLIED NANOIONICS

award to support two ASU professors working on the leading engineering and supply chain issues faced by manufacturers.

One of the award recipients is Bertan Bakkaloglu, a professor of electrical engineering. His research focuses on analog circuit design. It’s foundational for the emerging Internet of Things, connecting machines to the web to monitor and control them remotely. To turn off lightbulbs while away, a conventional copper switch isn’t going to cut it.

Bakkaloglu says the ON Semiconductor professorship critically supports his students’ research efforts. Manufacturing small batches of experimental semiconductor chips can cost tens of thousands of dollars. Still, the process of taking a chip from concept to fabrication is a critical experience that prepares students for the industry’s challenges.

Fabricating a chip

Worldwide semiconductor manufacturing facilities — called fabs — came to a standstill during the coronavirus pandemic, creating ripple effects now being felt throughout the economy. The shortage has held up production for devices across commercial and residential uses from industrial machinery to cars to home appliances. Each delay in the steps in the process makes delivery of final goods more difficult to predict. Adding capacity with new fabrication lines in Arizona is expected to impact the availability of goods in the years to come.

Semiconductor fab production time scales required to increase fab utilization



COURTESY OF SEMICONDUCTOR INDUSTRY ASSOCIATION



Through a partnership, Zachary Holman and his research group help semiconductor giant Applied Materials improve processes and materials.

“Our students gain experience in areas that almost every semiconductor company in town requires,” Bakkaloglu says. “My PhDs don’t go to the Bay Area or Texas. They stay in Arizona. So it’s a fundamental win-win because there’s a shortage of qualified semiconductor designers, and these companies get graduates who hit the ground running.”

“The more of those kinds of interactions with prominent industry people in the semiconductor space, the better ideas faculty develop.”

— KYLE SQUIRES,
DEAN OF ASU’S IRA
A. FULTON SCHOOLS
OF ENGINEERING

Last year, the university struck an agreement with Applied Materials, a California-based company that builds the precision machinery used in most of the world’s chip fabs. As part of the partnership, Applied Materials funds at least five years of research with selected faculty members, including Kozicki, and their students, and leases lab space at ASU’s MacroTechnology Works in Tempe.

MTW, formerly a fabrication facility, came equipped with specialized infrastructure

to handle semiconductor research. It already housed two semiconductor research powerhouses — ASU’s Flexible Electronics and Display Center and the Solar Power Laboratory.

“Faculty connecting with industry leaders not only speeds the process of translating university research discoveries and innovations to practice but can also provide a critical pathway for industry to de-risk some of their early ideas,” says Kyle Squires, dean of ASU’s Ira A. Fulton Schools of Engineering. “Promoting interactions with industry leaders matters. It helps our faculty sharpen their research ideas, substantially benefits our students, and leads to genuine impact. Unique infrastructure in locations such as MTW has given Arizona a competitive advantage.”

The Fulton Schools will further boost Phoenix’s reputation as semiconductor central with the recent launch of the School of Manufacturing Systems and Networks, which focuses on the research and education needed to drive the ideas critical to technology development for the Fourth Industrial Revolution. ASU’s newest engineering school will prepare students to meet the challenges of industry 4.0, with semiconductor-related engineering and research a core component.

“Without a doubt, the school will play a role in helping industry leaders think about what the fab facility of the future looks like,” Squires says. “How can you neglect that, given what’s

Semiconductors: By the numbers

#1

**contributor to labor
productivity growth**

The U.S. semiconductor industry has made virtually all sectors of the U.S. economy, from farming to manufacturing, more efficient.

277,000

**Number of people
employed in the U.S.**
by the semiconductor industry

1.6 million

Additional U.S. jobs
the semiconductor industry supports

~1 trillion

**Number of semiconductors
sold in 2020**

\$440 billion

**Worldwide semiconductor
industry sales in 2020**

Source: Semiconductor Industry Association

happening in the Valley with semiconductor manufacturing?”

ASU science and engineering driving innovation

Advanced research and development is the name of the game in the semiconductor industry, and those who can't innovate don't last long. Throughout Kozicki's time at ASU, he's seen the industry undergo massive changes. When he first started, "We thought we were cool for making chips on the micron-scale," he says. These days, semiconductor companies manufacture chips hundreds of times smaller. The complex process involves stacking layers of silicon and other materials that are just a few atoms thick and etching microscopic circuit patterns into them by exposing them to chemicals and intense UV light. While these processes have

“Every electronics manufacturing job accounts for another five or so jobs in vendors and suppliers. It's a valuable asset for the state's economy.”

— DENNIS HOFFMAN,
PROFESSOR OF
ECONOMICS AND
DIRECTOR OF THE
L. WILLIAM SEIDMAN
RESEARCH INSTITUTE
AT THE W. P. CAREY
SCHOOL OF
BUSINESS

enabled chips with circuits just a dozen atoms wide, manufacturers constantly look for ways to achieve more performance.

Cun-Zheng Ning is a professor of electrical engineering whose research shows just how far semiconductor fabrication techniques have come. Ning joined ASU in 2006 from NASA's Center for Nanotechnology, and his work focuses on using semiconductors to create optical devices such as nanolasers. These tiny lasers are made by growing semiconductor wires only a few nanometers in diameter — thousands of times smaller than a human hair — but their exact mechanisms aren't fully understood. The goal of Ning's research group is to probe the limits of nanolaser size and performance. He hopes to lay the foundation for a "supercomputer on a chip" that would allow small electronic devices to crunch data at speeds that today would require a room-sized computer.

Historically, the primary driver of performance increases in semiconductor devices has been size. For decades, the industry has been locked in a race to make ever smaller circuits. But as semiconductor companies approach the physical limits of circuit miniaturization, to improve chips, they're looking to advanced manufacturing processes that use tools such as 3D printing or artificial intelligence.

Bruno Azeredo, an assistant professor of manufacturing engineering, recently won a \$500,000 award from the

National Science Foundation to continue his work on Mac-Imprint, a new way of mass manufacturing 3D chips. Today, most chips are made by stacking films, but this creates performance issues. Building circuits in three dimensions can solve this problem and open new applications. But existing 3D nanoscale fabrication processes are ill-suited for mass manufacturing. Azeredo's technique uses electrochemistry carving to make 3D structures in silicon at unfathomably small scales.

These days, he's working with Honeywell to develop optical interconnects that allow data to flow from a chip into an optical fiber without losing information. The semiconductor lenses can focus the light pulses from the chip and cross the barrier into the optical fiber so it can be routed to another location.

"The companies that are coming here are doing more advanced work," says Azeredo. "The semiconductor industry wants to have an edge, they want to know what's coming next, and I can get the technology from readiness level 0 to readiness level 1."

These represent some of ASU's many faculty members engaging in semiconductor research. A few others include additional Applied Materials funding awardees Sefaattin Tongay, associate professor of materials science, for new semiconductor base material for advanced transistors; Heather Emady, assistant professor

of chemical engineering, for material flow and heat transfer in semiconductor materials and processes; and Zachary Holman, associate professor of electrical engineering, for new materials and device designs for high-efficiency silicon.

Benefiting Arizonans

Dennis Hoffman, a professor of economics and director of the L. William Seidman Research Institute at the W. P. Carey School of Business, says semiconductor manufacturers making a home in the Grand Canyon State support Arizonans.

"Every electronics manufacturing job accounts for another five or so jobs in vendors and suppliers," Hoffman says. "It's a valuable asset for the state's economy."

Earlier this year, the Senate passed the United States Innovation and Competition Act, which includes \$52 billion to boost semiconductor manufacturing in the U.S. Hoffman sees this, and other national and state funding, as prudent investments that will deliver benefits to Arizonans.

For Morton, the growth of the semiconductor industry in Phoenix underscores the importance of collaboration between the university and industry driven by organizations such as ASU's Knowledge Enterprise. It's critical that the R&D Sun Devils do in the lab makes its way into the real world so that new technologies don't get trapped in the so-called "valley of death," the gap between academic innovation and



Supplying the supply chain

Global supply chains matter. Disruptions lead to decreased output — and product shortages. Each year, the W. P. Carey School of Business graduates talent to keep supply chains functioning better.

3,431

Number of ASU supply chain management grads from 2011–21

Source: W. P. Carey School of Business

commercial application.

"We don't want to just do research, we want to disseminate research and implement it to have an impact on the world," Morton says. "This is at the heart of the mission of ASU: research of public value and service to our communities. This is what we do. This is primary." ■

Entrepreneurship at ASU

#4 in startups launched

#4 in patents

Source: Skysong Innovations



#1 in U.S.

for innovation for six straight years

140 patents issued in 2020: ASU ahead of MIT and Stanford

Magnetic centers

Industry highlights

Greater Phoenix is one of America's longest standing semiconductor hubs. Motorola kicked off the region's microelectronics boom when it opened a research and development facility in Phoenix in 1949. Now we have a thriving and diverse ecosystem that is home to research and development, manufacturing and headquarters facilities.

1 Intel established a presence in Arizona in 1979 that has grown into the company's second largest site in the U.S. Each year, Intel spends more than \$500 million to support areas such as packaging and autonomous vehicles.
Total employment: 11,405

2 Taiwan Semiconductor Manufacturing Company is building a fabrication plant, with the first phase expected to produce computer chips by 2024.
Estimated first wave employment: 2,000

3 NXP entered Greater Phoenix when it merged with a Motorola spinoff in 2015. Its facility in Chandler is a wafer fab, one of three operated by the company in the U.S.
Total employment: 1,696

4 Microchip Technology is a spinoff of General

Instrument that became fully independent in 1989 and is headquartered in Chandler.
Total employment: 1,953

5 ON Semiconductor headquartered in Phoenix, was spun out of Motorola in 1999. It has been at its Phoenix campus since 1952, both as a part of Motorola and as its own company.
Total employment: 1,038

6 Benchmark Electronics relocated its headquarters and opened an Internet of Things Design Center for sensor design and wireless infrastructure. It also does manufacturing for circuit design and precision machining.
Total employment: 670

7 Amkor Technology moved its headquarters to the Valley in 2005 and leads in packaging and testing.
Total employment: 332

ASU West campus
High-potential development opportunities tapping into research and technology on the campus.

Deer Valley Municipal Airport

Health Futures Center
Biomedical discovery hub offering opportunities for premier academic and clinical collaborations, including at the new Health Futures Center adjacent to Mayo Clinic Hospital in Phoenix.

ASU Downtown Phoenix campus
In the heart of the state's capital, provides connections for students across the health care spectrum; in law, government and public service; with nonprofit and public social service providers; and in arts and sciences, journalism, media and the corporate sector.

Phoenix Biomedical campus
Vibrant community built on a foundation of research, discovery, innovation and entrepreneurial activity.

SkySong
High-growth community for technology-based companies.

Novus Innovation Corridor
New development opportunity includes prime locations for large-scale regional offices or headquarters.

ASU at Mesa City Center
Studios and programs for entrepreneurship, media arts, gaming and film production.

Key

- ASU Innovation Zones
- High-tech manufacturing and development
Size of circle indicates number of employees.
- Airport
- Light rail
- Interstate
- Federal highway
- State highway

Mapping is approximate, not to scale.

See more companies in the ecosystem at gpec.org/ecosystem-semiconductor.

ASU Tempe campus
Historic campus offers hundreds of majors that engage undergraduates and graduates in multidisciplinary research and exploration in first-rate facilities.

ASU Research Park
Home to ASU's MacroTechnology Works, a state-of-the-art research center with office space, labs and equipment to support collaboration with commercial partners such as Applied Materials, which leads in materials engineering for almost every new chip in the world.

ASU Polytechnic campus and ASU Polytechnic Innovation Zone
Lab and major specialties include engineering and other technical expertise, this campus is ideal for advanced manufacturing, aviation and alternative energy.

Research and business alignments lure (and spur) jobs creators

Generating high-paying clusters of jobs in the Greater Phoenix region takes planning — sometimes over decades. ASU; the Greater Phoenix Economic Council; city councils, chambers of commerce and mayors; the legislature; homegrown industries and local startups all make it happen.

More than 2,800 Arizona-based advanced manufacturers directly create more than 138,000 high-paying jobs, according to GPEC, with many more businesses and jobs generated in downstream industries. Bringing together vibrant economic ecosystems requires prime conditions purposefully designed. Big multinational companies and research universities like ASU act as magnetic centers, producing and attracting skilled workers that create conditions for companies — big and small — to thrive.

Learn more at innovationzones.asu.edu.

Map Sources: Maricopa Association of Governments, GPEC, ASU
MAP BY ASU KNOWLEDGE ENTERPRISE AND ASU THRIVE

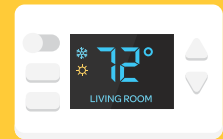
Smart appliances

Home appliances have leveled up. They are saving energy and offering new functionality, just for you. TV apps recommend shows you might like and new washer and dryer sets share your settings between them via Bluetooth.



Power, power, power

What's at the root of all technological devices? Energy. Because solar cells are made of semiconductors, they play a pivotal role in the global shift to a more energy-efficient future.



Comfort and safety

Thanks to devices like smart thermostats and wireless security systems, managing your home has never been easier, more sustainable or more cost-conscious.



In the kitchen

High-tech appliances can schedule your next pot of coffee or order your groceries when they are low. Scheduling and maintenance reminders use semiconductors to make life a little easier.



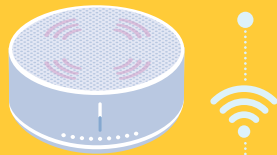
The ultimate remote control

Making devices "smart" is one thing, but controlling them is another. Smartphones, made of billions of microscopic transistors composing each tiny semiconductor, use apps to pair with and control your smart devices remotely.



Synchronizing and sustaining the modern home

Semiconductors are tiny but mighty. From a technological standpoint, this small microchip packs quite the punch and helps put the "smart" in our smart devices. From TVs to refrigerators and almost everything in between, semiconductors fuel the Internet of Things by connecting devices that aren't computers to the internet. **Learn more about Internet of Things research and innovation at iot.engineering.asu.edu.**



ASU Charter

ASU is a comprehensive **public research university**, measured not by whom it excludes, but by **whom it includes** and how they **succeed**; advancing **research and discovery** of public value; and assuming **fundamental responsibility** for the economic, social, cultural and overall health of the **communities** it serves.



**Arizona State
University**