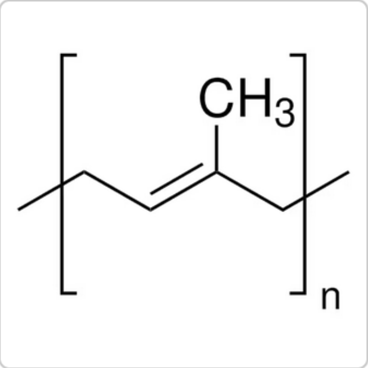
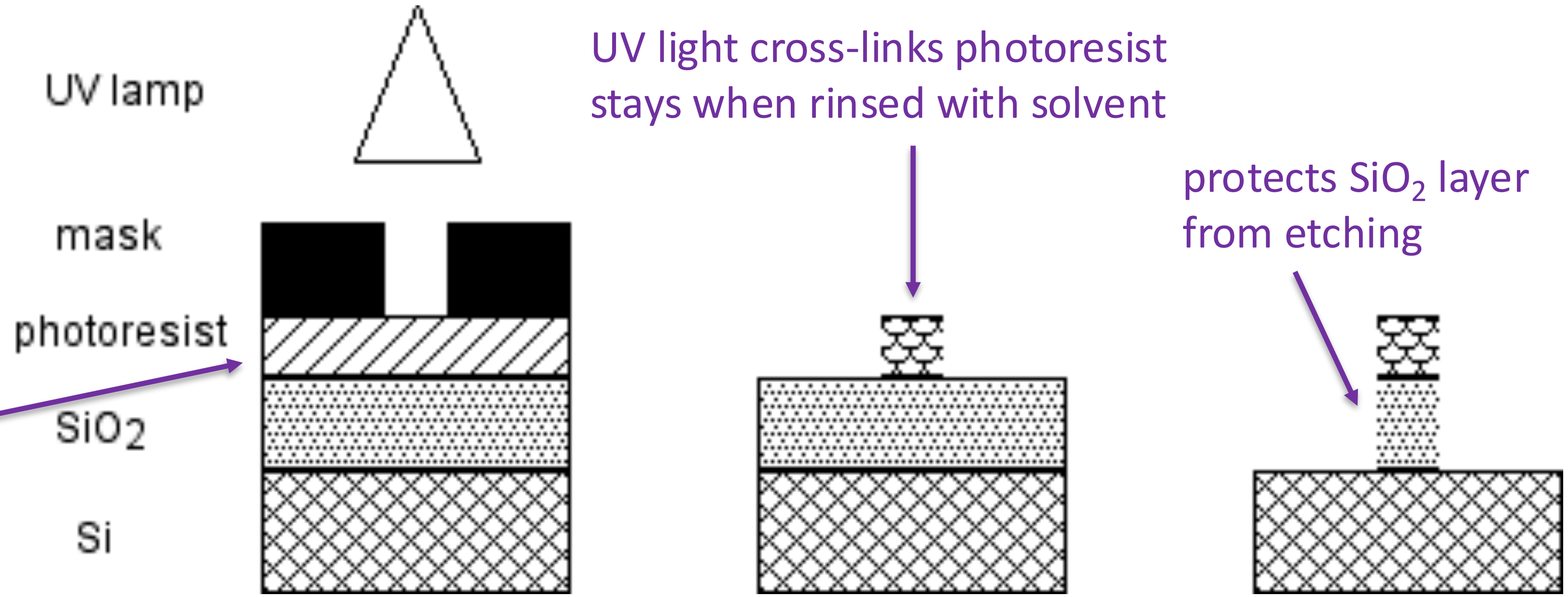
Fig. 12.8 Patterning with Photolithography

Products Applications

Back Products Electronic



solution of photoresist spread on surface



UV light cross-links photoresist stays when rinsed with solvent

protects SiO_2 layer from etching

1954 first Silicon transistor

Welcome | Timeline | People | Companies | Resources | Glossary

THE SILICON ENGINE

A TIMELINE OF SEMICONDUCTORS IN COMPUTERS

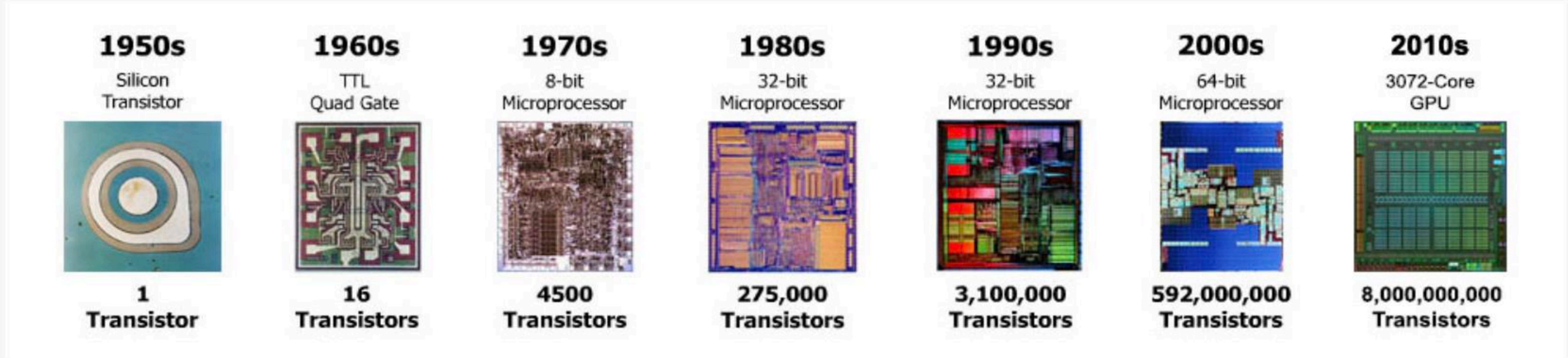


Photo credits: Fairchild Camera and Instrument Corporation, Intel Corporation (Note that images are not to scale), Nvidia Corporation

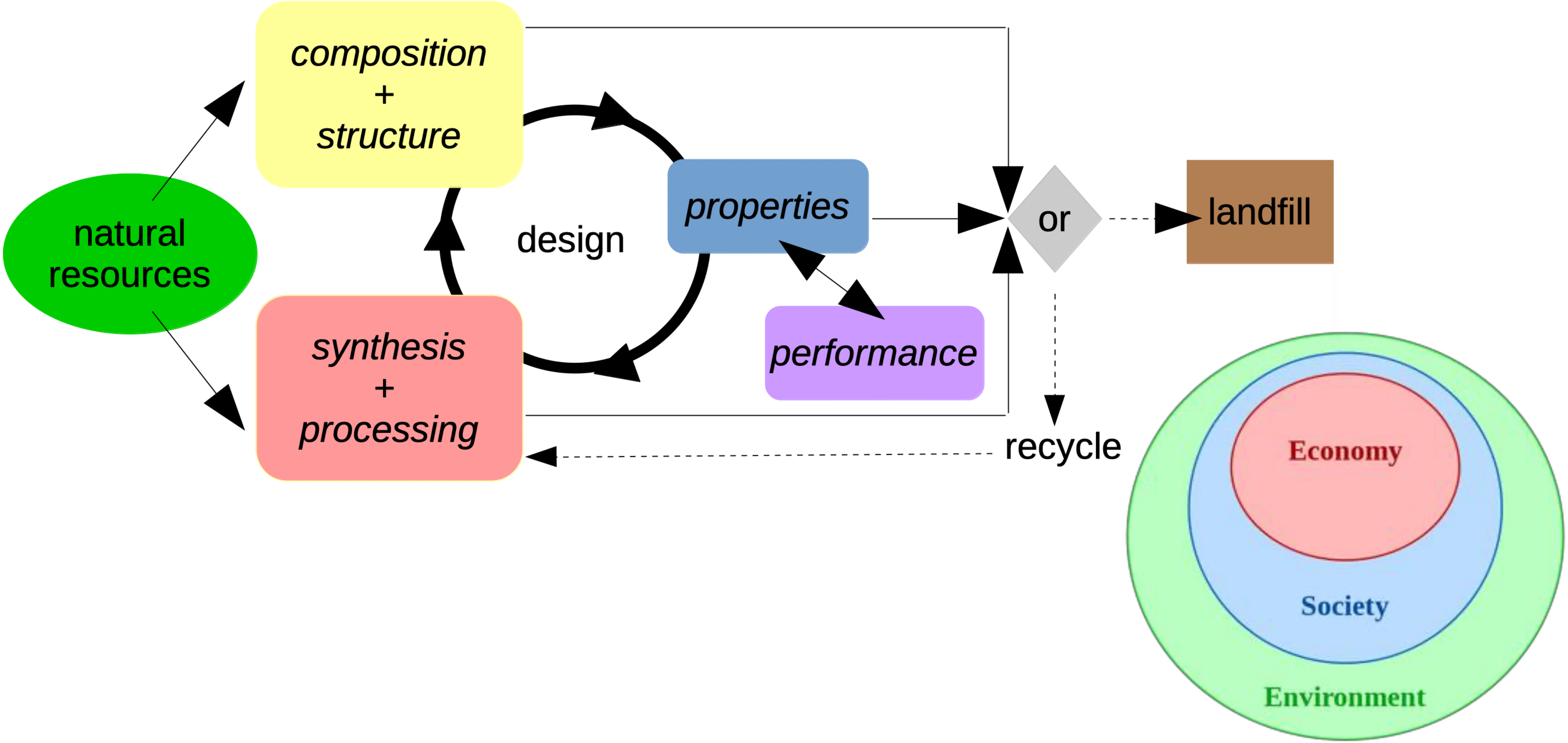
> *Moore's Law "Transistor density on integrated circuits doubles about every two years."*
>
> *— Source: "Moore's Law: Raising the Bar" (Intel Corporation 2005)*

March 24, 2023, *The New York Times*

Gordon E. Moore, Intel Co-Founder Behind Moore's Law, Dies at 94

His prediction in the 1960s about rapid advances in computer chip technology charted a course for the age of high tech.

life cycle for electronic devices



PACE
PLATFORM FOR ACCELERATING THE CIRCULAR ECONOMY

WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

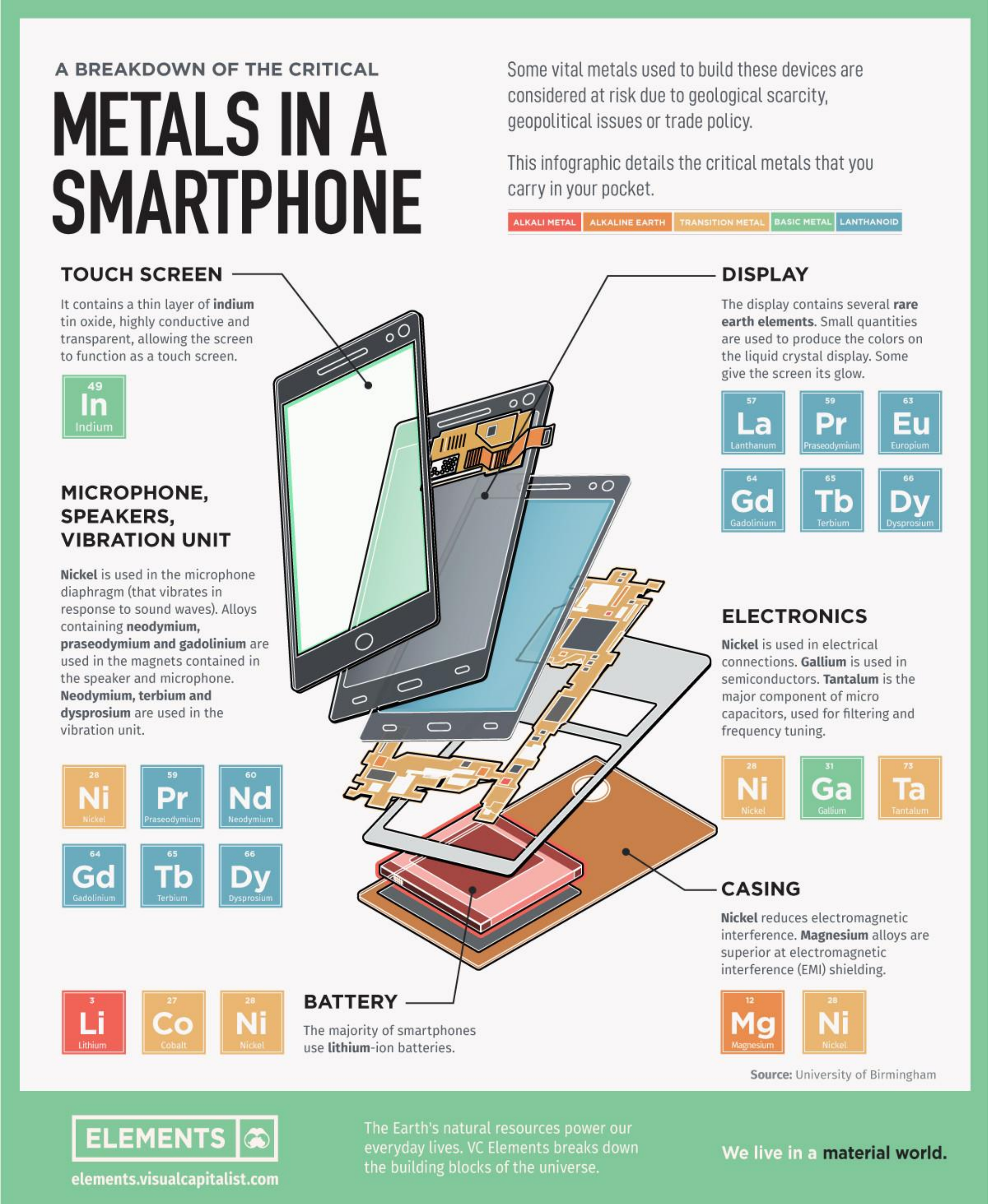
A New Circular Vision for Electronics

Time for a Global Reboot

In support of the United Nations E-waste Coalition

January 2019

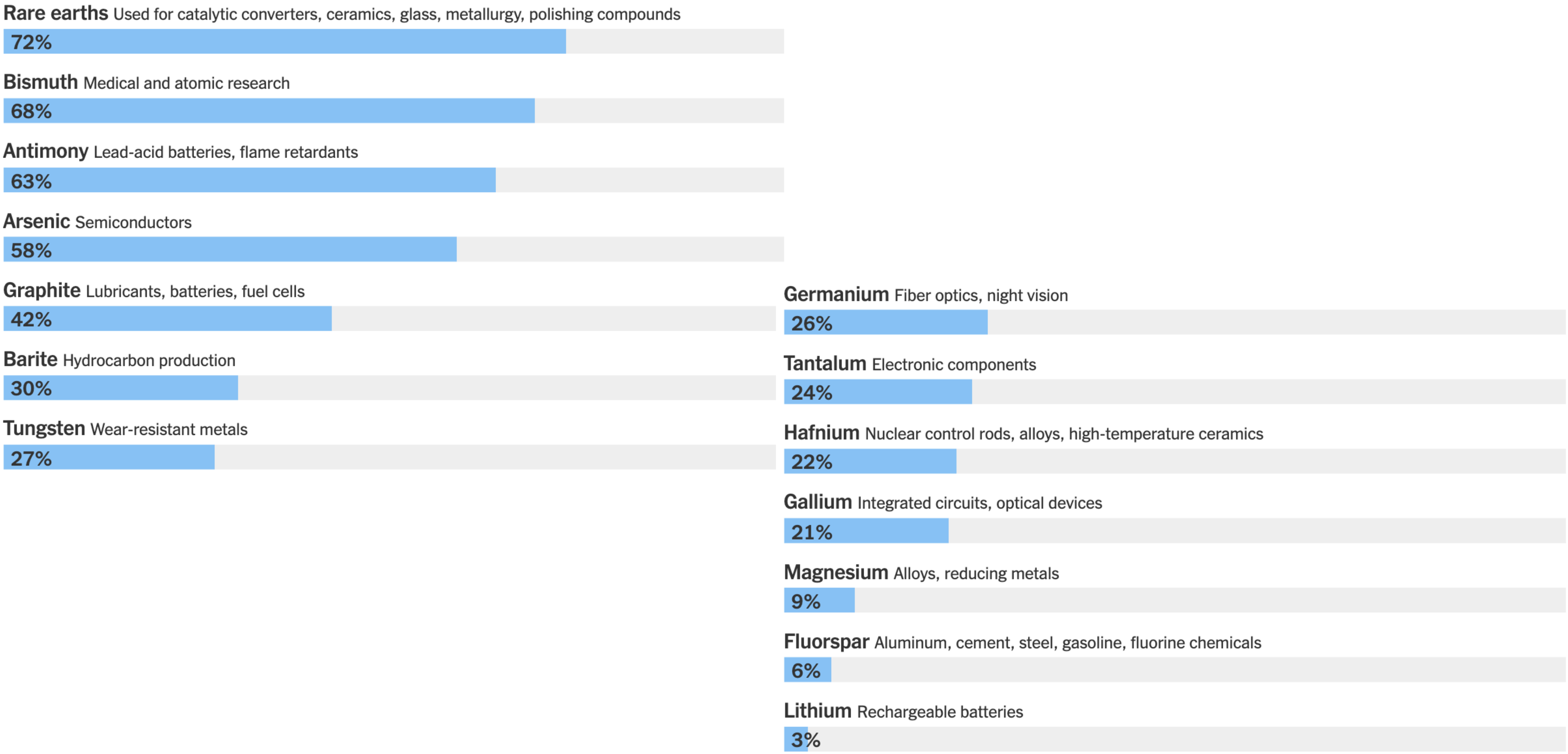
defining the problem



What other materials are in a smart phone?

U.S. relies on China for many critical minerals

Share of U.S. imports sourced from China



Percentages refer to minerals in their raw and refined forms, not finished goods. Uses are listed for illustrative purposes. • U.S. Geological Survey, TD Bank • By The New York Times

April 16, 2025

How China Took Over the World's Rare Earths Industry

By Keith Bradsher, *The New York Times,* April 16, 2025

China shook the world in 2010 when it imposed an embargo on exports of crucial rare earth metals to Japan. Panicked Japanese executives appeared on television to warn that they were running out of the critical raw materials.

The embargo, prompted by a territorial dispute, lasted only seven weeks. But it changed the global supply chain for these metals. When the embargo was over, China took forceful control of its mineral bounty. Top officials in Beijing rooted out corruption, crushed smugglers and consolidated the industry under state control.

The world was put on notice, especially Japan and the United States, two of China's biggest customers for rare earth metals used in everything from cars to smartphones to missiles. Governments from both countries drafted detailed plans for how to mitigate their dependence on China. Japan has largely followed through on its plans and today can source the minerals from Australia.

Not the United States. Even after 15 years, the country is still almost entirely reliant on China for the processing of rare earth metals. As a result, American automakers, aerospace companies and defense contractors have been left vulnerable.

Angry about President Trump's tariffs, China has suspended all exports of certain rare earths, as well as the even more valuable magnets made from them.

Sc Y Sm Gd Tb Dy Lu

BBC 2 April 2015

The dystopian lake filled by the world's tech lust

Bautou, Inner Mongolia, China

http://www.bbc.com/future/story/20150402-the-worst-place-on-earth

Nd is no rarer than **Cu** or **Ni**, and evenly distributed throughout the world's crust. While China produces 90% of the global market's **Nd**, only 30% of the world's deposits are located there. Arguably, what makes it, and **Ce**, scarce enough to be profitable are the hugely hazardous and toxic processes needed to extract them from ore and to refine them into usable products. **Ce** is extracted by crushing mineral mixtures and dissolving them in sulphuric and nitric acid, on a huge industrial scale, resulting in a vast amount of poisonous waste.

Where are electronic devices manufactured?

New York Times, March 10, 2025 The United States pioneered the semiconductor industry, designing the first microchips and the processes for making them, allowing it to become an early tech leader. But in the 1980s, companies began outsourcing most production to Asia.

U.S. lawmakers began pushing to rebuild domestic chip production after the pandemic created a global chip shortage that forced some U.S. auto factories to shutter, resulting in the CHIPS Act. Lawmakers on both sides of the aisle worked with private companies to draft a bill that would funnel $50 billion to rebuild the U.S. semiconductor industry, which makes the foundational technology used to power cars, computers and coffee makers. After President Joseph R. Biden, Jr. signed it into law in 2022, companies found sites in Arizona, New York and Ohio to construct new factories. The Commerce Department vetted those plans and began to dole out billions of dollars in grants.

So far, the Commerce Department has signed contracts to grant more than $36 billion in federal subsidies under the CHIPS Act. Samsung, **Intel**, Micron, Taiwan Semiconductor Manufacturing Company, known as TSMC, and others in response have pledged to invest hundreds of billions of dollars in U.S. chip-making facilities.

Disentangling the Worldwide Web of E-Waste and Climate Change

Academic Minute 03/20/2023 Oladele Ogunseitan
Distinguished Professor of Population Health & Disease Prevention, U California - Irvine

My team and I set out to quantify the carbon footprint of electronic waste. To do this, we analyzed 1,003 life cycle reports from different manufacturers to determine the amount of carbon dioxide emissions created during the lifespan of the electronic devices.

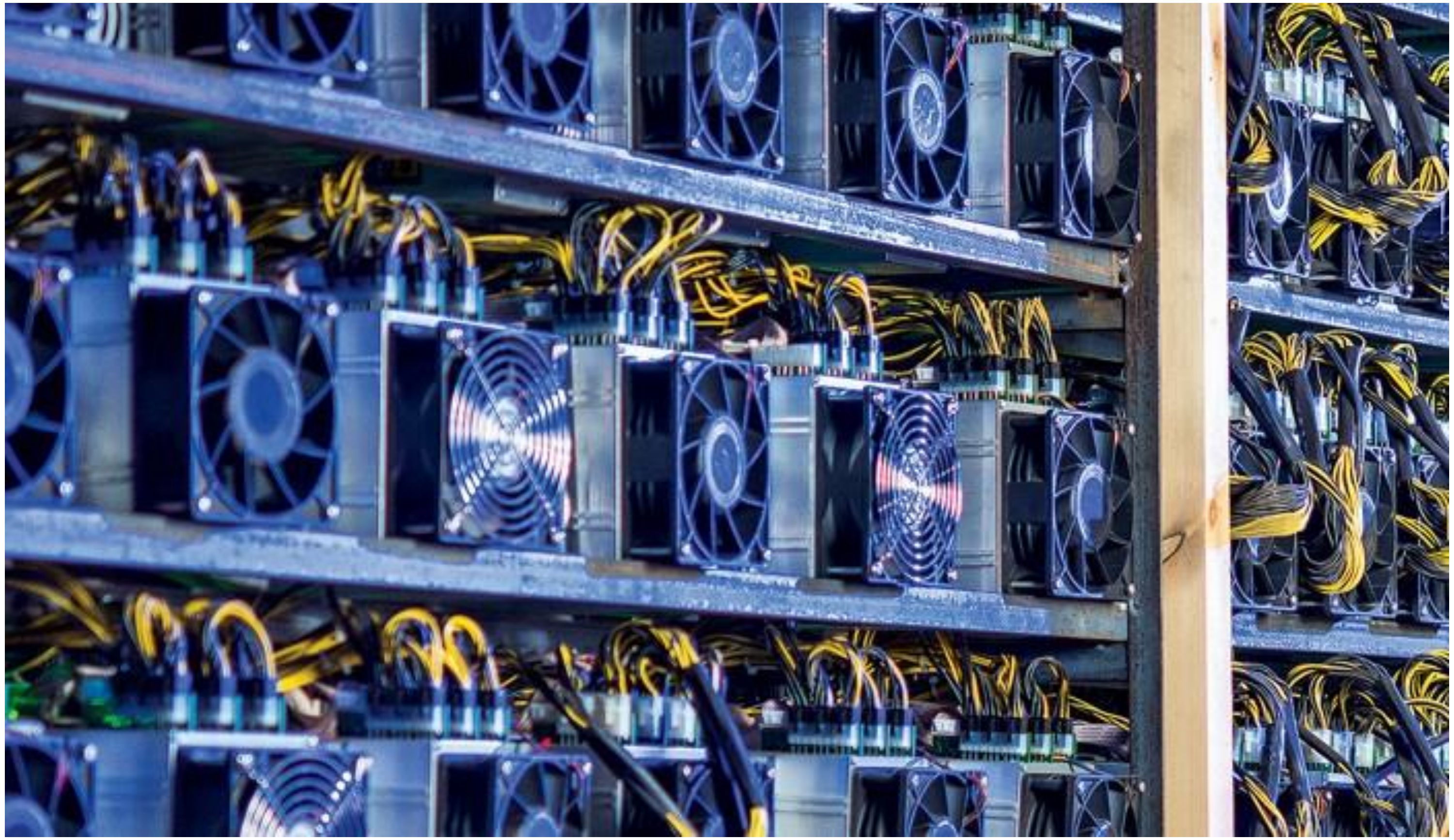
The results of this analysis show that **flat-screen TVs** were associated with the highest emissions when compared to other electronics such as **computers** or **phones**.

We saw that in one scenario, an estimated 19 - 28 million metric tons of e-waste could have been prevented through a 50% -100% increase in the lifetime of these devices if they were to be **repaired, reused, and recycled**.

Bitcoin poses major electronic-waste problem

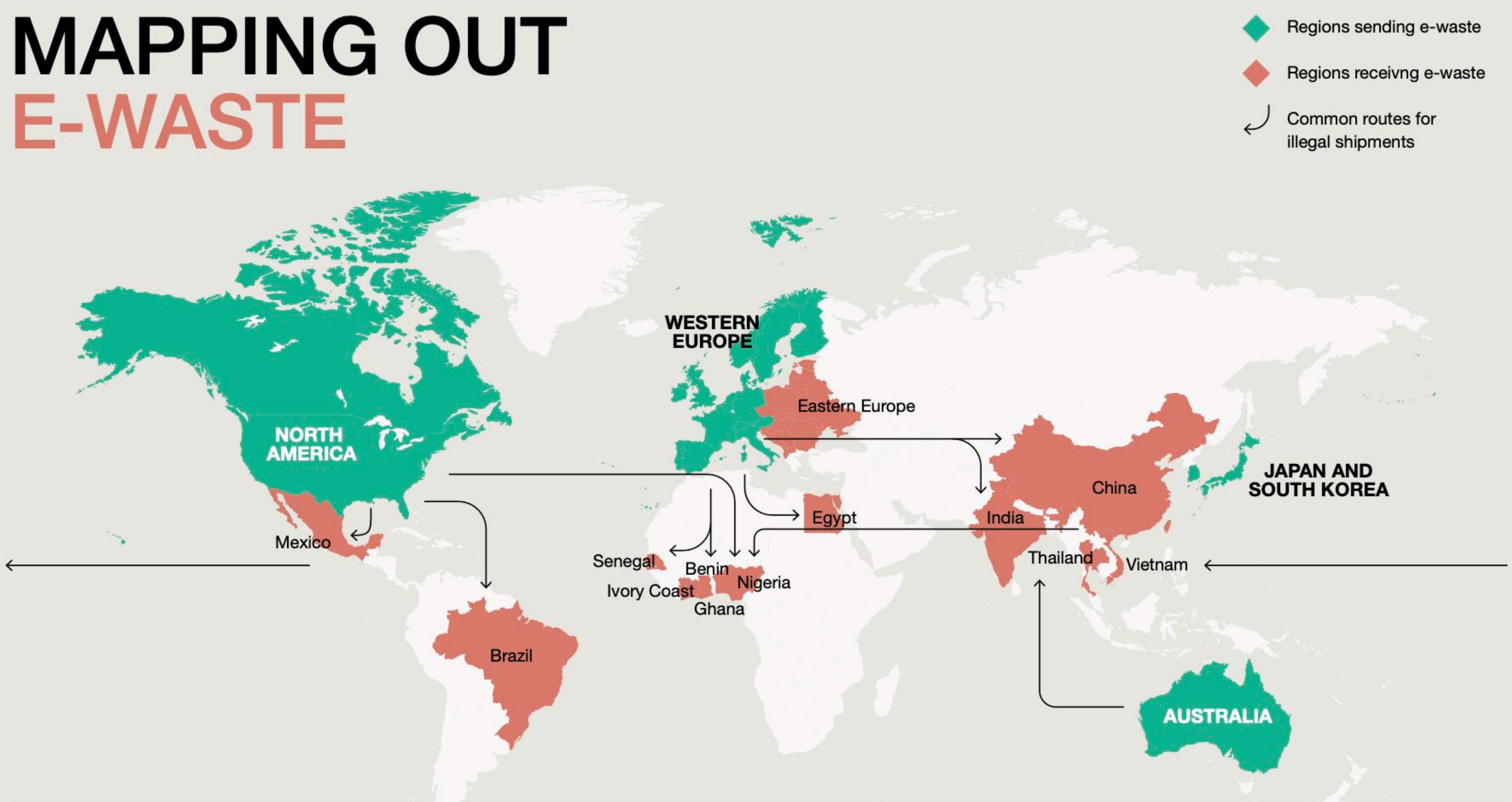
A global race for the cryptocurrency is consuming vast amounts of energy and materials

by *Mark Peplow special to C&EN* March 14, 2019 | APPEARED IN VOLUME 97, ISSUE 11



Mining Bitcoins uses enormous amounts of electricity, and creates thousands of metric tons of electronic waste when specialized equipment like that shown here is trashed. Credit: Shutterstock

MAPPING OUT E-WASTE



Some of the highest and lowest e-waste generating nations E-Waste generated (kg per capita), 2016

28.5	24.9	24.8	23.9	23.6	0.4	0.5	0.6	0.6	0.8
Norway	United Kingdom	Denmark	Netherlands	Australia	Niger	Ethiopia	Afganistan	Uganda	Nepal

See one of the world's dirtiest jobs: e-waste disposal
New Scientist 11 February 2015

collecting **Cu**, **Au**, **Ag**, **Pb** from circuit boards
in one of about 3000 workshops in Guiyu, China
Image: Kai Loeffelbein/Laif/Camera Press

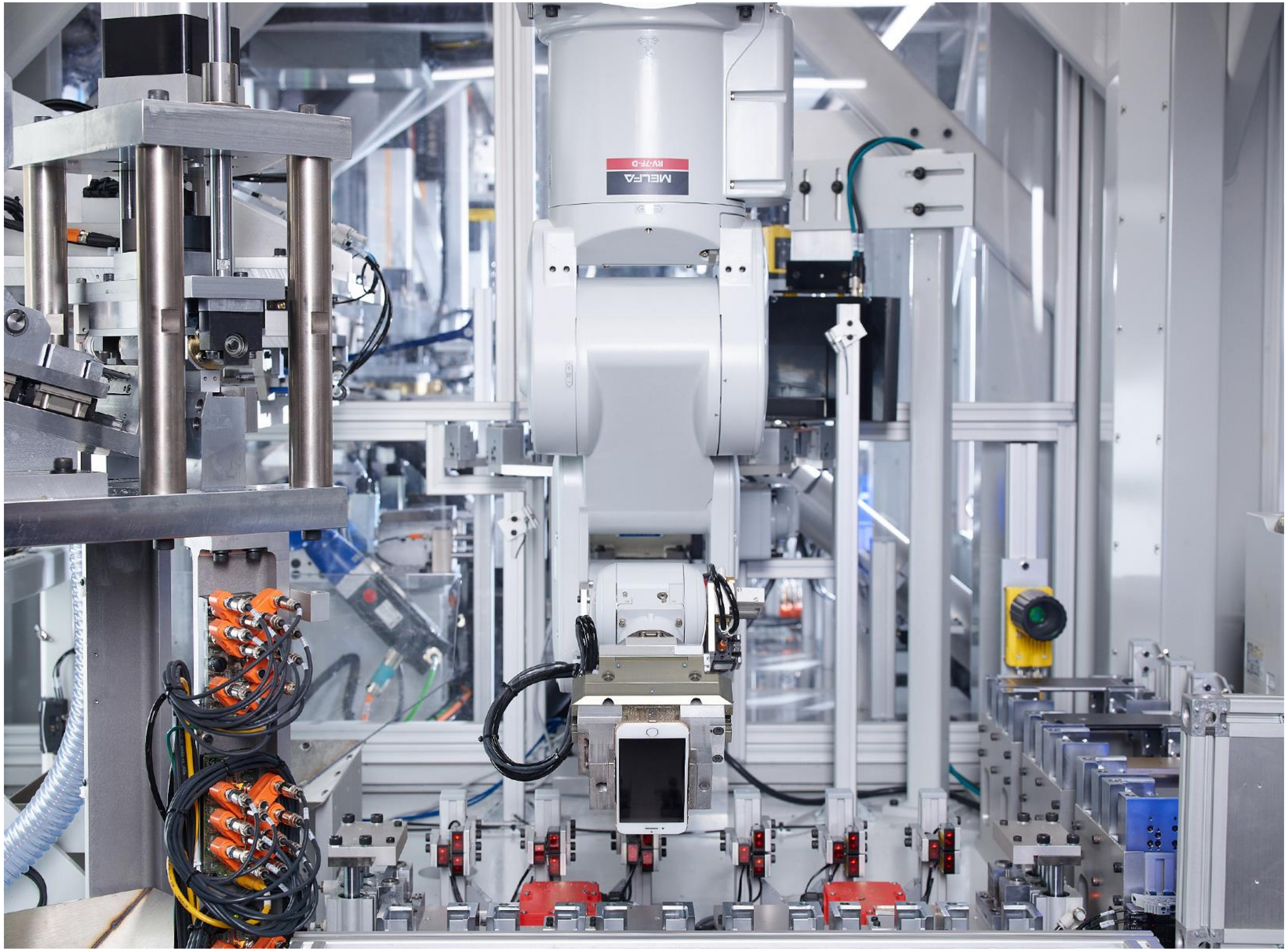
Much of the e-waste is the product of China's domestic electronics boom, with over 7 million tonnes created in 2012. But shipments from the US, Australia and Europe regularly circumvent an import ban instituted in 2000.

The cost to the environment and human health is high: run-off from **acid baths** used to strip out metals has entered watercourses, while **burning off plastics** has fouled the air. **Neurotoxic PCBs** have been found in fish, and children in the area have unusually high levels of **lead** in their blood.

What are some ethical responses to the problem of e-Waste?

1. from electronic device manufacturers
2. from consumers
3. from governments

Apple iPhone recycling with robots



[Daisy]

Recycling Robotics - Electronic Waste Recycling

We live in a world where most sensitive information is stored on our devices. Eventually, like many things, those devices are thrown away. Existing waste management has more than half a century of experience in handling materials the right way, but dealing with electronics items poses a new challenge and if not done properly can be hazardous to the environment. The main idea is to identify parts that can be remarketed or recycled. In this work we are trying to classify electronics, develop semantic understanding of their components using X-ray images, manipulate them to respective stations and then autonomously disassemble them to smaller components. The key idea in classification is to train a visual classifier using simulated images and then test it on real world images using domain randomization. We are using an attention based classification approach and trying to combine RGB+ X-ray domain for classification. For developing semantic understanding of the internal components, we are using a state of the art registration approach to match the given electronics with their ground truth label. We are also looking into ways of auto-labelling electronics components for this task. For the manipulation task we have developed a high speed direct drive parallel link manipulator as well as direct drive grippers. Using this we are looking to generalize pick-and-place motion using reinforcement learning and dynamics randomization.