Material World

By

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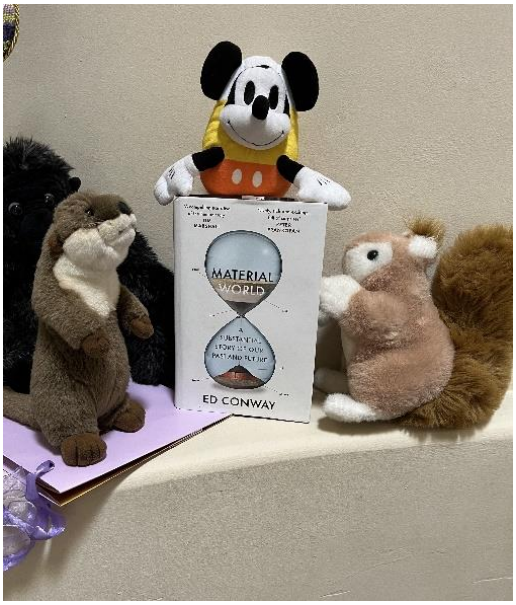
Discussion Questions for February 15, 2025, Meeting



Question 1

From the headlines:

US Chip Industry Aims to Cut China from Supply Chains

Technology Wars over Silicon

Sand (silicon) is the greatest enigma of the Material World. There is no shortage; it is the most common material mined in the world—over 50 billion tons each year. Yes, 50 billion! It is the silicon content of sand that matters because that ultimately determines what you can do with it. Some goes to making glass; lots goes into concrete; and high grade goes into silicon chips. Today, we will center the discussion on the process of turning sand into silicon chips, an amazing almost magical feat of engineering.

Nearly every economic activity, nearly every dollar of global GDP, relies in one way or another on the microscopic switches of semiconductors. Let us review the journey of the mined quartz to chips and boards.

From Quartz to Silicon to Chips to Boards

Location	Input	Output	Process	Purity
Spain	Mined quartz	Silicon	Smelting	98-99%
Germany	Silicon	Poly silicon	Siemens	99.999999-99.99999999
United States	Pure quartz	Boule	Czochralski	Pure crystal
Germany, Singapore, Korea	Poly Silicon	Wafer	Carbide saw	
Taiwan	Wafer	Transistor		
Taiwan	Transistors	Chips		
Malaysia	Chip	Assembly ready		
China	Chips	Boards		

The Chip Wars are being played out as China attempts to access leading edge technology. ASML (a Dutch) company is the only company to make the machines which can generate the extreme UV required to make chips. It is said that all the equipment in Taiwan is wired to blow up if the Chinese invade Taiwan. TSMC, the Tawain Semiconductor Manufacturing Company, is the only manufacturer which can make the advanced Nvidia chips which are required for AI (artificial intelligence). There are multiple reports of efforts by the Chinese to gain access to this technology. As the world is no longer a peaceful place and since all the advanced chips are made by TSMC, the geopolitical situation in Tawain is of increasing concern to the US.

Without the super-pure quartz for the boules (crucibles), it would be impossible to produce most semiconductors. Today there is only one place, Spruce Pine, North Carolina, where the quartz is suitable for this. What happens when hurricane Helene drops more than two feet of rain on the town? The mines close. What we know is that they have now reopened. However, the global silicon chip industry is totally dependent upon these mines.

When politicians talk lazily about reshoring chip manufacturing, it betrays a deep ignorance of what is happening out there in the Material World.

So, what do you think about this situation?

Question 2

From the headlines:

Nippon Offer for Takeover of US Steel

Cleveland-Cliffs and Nucor Mill Make Fresh Bid for US Steel

What gives a substance unmatched usefulness? Conway suggests there are three things:

- Superb physical properties
- Availability--Ability to procure the material relatively easily
- Low cost

Iron and the steel which is made from the iron are unmatched.

- Physical properties—highest strength-to-weight ratio, long lifetime when protected from oxygen and water
- Availability-5% of the earth's crust
- Low cost-technology development and cheap energy allow steel to be low cost

Steel matters—it is a foundational material and has evolved to be drastically more valuable than iron. Steel lasts longer than iron; steel tools are stronger than iron tools; and steel can span wider gaps.

Between 1958 and 1962, China consumed whole forest of wood to feed Mao's boasting of steel production via backyard furnaces. The extent of ecological and human disaster was unfathomable—floods, erosion, and starvation. Today, after importing steel production technology from Europe and the US, China accounts for about 54% of global steel production using primarily coal. Global steel production accounts for about 8% of global emissions.

China has become the dominant global steel producer—1 billion tons/year. About 90% of this is produced in blast furnaces using coal. China is the primary destination for about 80% of the Australian iron ore from the Pilbara mine. This trade relationship is crucial to both economies.

US steel production is declining while consumption of steel (construction is the largest component) has not declined. Today the US is the #1 importer of foreign steel from Canada, Brazil, Korea, Germany. Imported Chinese steel is 1-2 % of the US imports.

Using steel became common place when fossil fuels were substituted for wood in the steel production process. Turning iron ore into steel requires ENERGY.

Steel, the bones of our society, is used to reinforce concrete, to fashion tools/equipment, to make machines, and to build everything from buildings, bridges, and data centers.

The world's twin goals of decarbonization and development are heading for a collision. Today the disparity in steel infrastructure across the globe is startling. There is no substitute for steel; yet steel production generates 8% of global green house emissions.

Global Steel Infrastructure

Country	Steel Infrastructure
US, Europe	15 tons/ person
China	7 tons/person
Sub-Sahara Africa	<1 ton/person

In addition, no one likes the idea of having to make weapons out of another countries steel. Make no mistake, twenty-first-century wars are still fought with steel : steel guns, steel bombs, and steel armor.

What do you think about this?

Question 3

From the headlines:

Biden signs executive order imposing restrictions on oil and gas exploration.

Trump signs executive order reversing restrictions on oil and gas exploration

For me, this topic turned out to be the most difficult to construct for healthy discussion. What we have is an ethical dilemma.

Dilemma: a situation in which choice has to be made between two or more alternatives, especially equally undesirable ones. A dilemma is more dire than a difficulty, a problem, or a predicament. This is an existential dilemma.

The world runs on energy. Indeed, human history is fueled by harnessing the ever increasing density of fuels: wood to coal to oil to natural gas to nuclear.

Energy Density Ladder

Fuel	Energy density	Emissions
Nuclear	Extremely high	Small uranium pellet=1ton of coal
Hydrogen	120	0
Natural Gas	54	60
Gasoline	46	
Ethanol	30	
Coal	27	
Wood	16	110
Renewables	Lowest	0

Oil, along with its sister natural gas, are the greatest energy force of the last century. Besides energy density, liquid fuels can be pumped and thus are efficiently extracted from the earth, transported, and stored. Consequently, they are low cost and compared to coal they have fewer emissions. In addition, about 10% of the fossil fuel plays a disproportionate role in our lives—fertilizer, packaging, pharmaceutical, paints, adhesives, dyes flavoring, resins, preservatives, building materials, etc.

Just as the world was learning to harness the higher density fuels, the global population was exploding. So even though each unit of fuel was able to generate more energy with fewer emissions, the global population was increasing faster than the density of the fuel. Thus, the demands for 8 billion people have driven the use of fossil fuels.

The next energy transition: Eliminate carbon emissions. Even though there is progress in producing renewable electricity, there is no way today to mass produce the solar panels and wind turbines without the use of fossil fuels to manufacture the solar panels and wind turbines.

The world runs on energy and energy runs the world. What do you think about this?

Question 4

Device extracts lithium from the Dead Sea brine

Lithium producers zero in on technology for direct extraction

Rio Tinto to buy Arcadium Lithium for $6.7 billion

No other metal is quite the same combination of lightness, conductivity, and electrochemical power. This is why lithium is at the heart of the most powerful batteries and therefore the heart of the twenty-first century. Unless we have a way to store energy, there is little hope of reducing, let alone eliminating carbon emissions. There is no shortage of lithium. The real question is not so much whether enough exists but what will it take both in terms of money and environmental impact to remove it.

The nut to be cracked, if there is any hope of arresting climate change, is to turn the best lithium chemistry into affordable reality. However, lithium ion batteries are significantly less energy-dense than oil, gas or even coal. This is a move down the energy ladder.

China may be struggling to produce silicon chips equivalent to their Taiwanese counterpart, but there is no doubt who is winning the battery race. Chinese companies control 80% of battery production as well as 80% of the manufacture of the materials that go into these batteries.

What do you think about this situation?

ENERGY STORAGE

Tesla fires up US lithium chemical plant

China will control lithium refining in the near term

The electric car company Tesla has fired up a large lithium chemical plant in Texas. But despite efforts by Tesla and other firms to establish lithium facilities in the US, China will remain the world's main source of lithium chemicals in the near term.

Tesla says the $1 billion plant near Corpus Christi, Texas, will eventually refine enough lithium for 50 GW h of batteries per year, likely enough for at least half a million cars. The company is feeding raw materials into the factory and hopes to start producing lithium hydroxide later this year. The facility will convert lithium-containing ore into chemicals using an acid-free process that avoids environmentally problematic waste products.

More than 60% of lithium chemicals are produced in China, according to data from S&P Global Market Intelligence and World Economic Forum. The US only has a few lithium chemical plants, operated by Albemarle and Arcadium Lithium. Tesla claims its facility will be the largest in North America.

Tesla's project is part of a wider effort to increase lithium production in the US. Lithium Americas plans to start mining and refining lithium in Nevada by 2027. Stardust Power hopes to soon begin building a lithium carbonate plant in Oklahoma.

But the crash in lithium prices over the past year has stalled other US projects. Albemarle has delayed plans for a large lithium facility in the southeastern US. Similarly, Piedmont Lithium was going to build lithium refineries in Tennessee and North Carolina but is now focusing just on North Carolina.

Tesla has agreed to buy lithium ore from mines operated by Sayona Mining in Quebec and Liontown Resources in Australia. Chris Berry, president of the battery industry consultancy House Mountain Partners, anticipates that Tesla will convert lithium hydroxide from the new plant into battery cathodes at a facility it's constructing in Texas.

But Berry says warns that the first year of production almost inevitably reveals unforeseen issues. "After the ribbon cutting is when the fun begins," he says.—MATT BLOIS

Tesla has started feeding raw materials into its $1 billion lithium chemical plant near Corpus Christi, Texas.

CREDIT: REC SILICON (PLANT); TESLA (GROUP)

Question 5

Repeatedly, in multiple ways, Conway reminds us of the criteria for unmatched usefulness.

- Superb physical attributes, properties
- Availability and relatively easy to procure
- Low cost

He presents the case that all 6 of these materials (sand, salt, steel, copper, oil, and lithium) meet these criteria. In addition, he traces for us the interconnectedness of this material world. My favorite example is the neon from the steel mill in Ukraine that is used to create the atmosphere in the Taiwan chip manufacturing facilities.

Were there any examples that stuck with you?

Question 6

The epitome of both the modern world and the material world—The Smart Phone. In 2025 the number of mobile devices is expected to reach 18 billion globally; 40% of these are smartphones. The are more smart phones than people. Let us think about some words that define these instruments—complicated, elaborate, sophisticated, advanced, intricate, revolutionary.

The complex requirements of strength, thermal conductivity, corrosion resistance, electrical storage capacity, electrical conductivity—have driven the development of sophisticated, revolutionary products.

Let us look at the components of the smart phone:

- Copper (35%), probably mined in Chile, electrical conductivity, connectors, and wires
- Silica (20%), mined many places, semiconductor chips and microprocessors AND Gorilla glass the screen
- Lithium (5%) probably extracted from Atacama Salt Flat Chile, rechargeable lithium ion battery
- Oil (40%) made into polycarbonate the plastic that provides durability and strength to the phone casing and can be molded into multiple shapes
- Micronutrients—stainless steel screws; cobalt, nickel, and zinc in the batteries; aluminum (the most expensive raw material) provides the shielding material

So, on the one hand, these 6 materials are foundational for building massive things (roads, bridges, buildings, power plants, etc.); and on the other hand, these same materials are foundational for building little wee things Do you find this amazing?

One more thing about the cell phone:
China's role in the global smart phone supply chain remains resilient in the strategic semiconductor industry by maintaining its dominance in higher value core manufacturing. In 2022, 70-80% of the global smart phones were produced in China. What do we think about this?

Question 7

In conclusion, Conway suggests that if there is one lesson you should take from our trip through the Material World, it is that with enough time, effort, and collaboration we get better at solving impossible obstacles.
What is the lesson you take from this trip through the Material World?