I

GETTING STARTED IN MATERIALS

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MATERIALS BASICS

A house, office building, car, paved road, manufacturing plant, power plant, TV, and computer all have one thing in common: None would be possible without the use of basic materials. Unless you're living under a rock in the middle of the Amazon, you probably depend upon a variety of basic materials everyday. Modern society would not exist without them.

This book's goal is to help you gain a basic understanding of the Materials sector, its components, drivers, challenges, and history, as well as be a general guide to Materials investing success. Wherever possible, we'll also help you *think critically* about the sector to generate your own views, rather than just dictating a bunch of rules. Successfully investing in Materials companies does not require a PhD in chemistry or geology. What is important is a firm grasp of the laws of supply and demand, and understanding what drives the earnings and stock prices of Materials companies.

This chapter covers the basics of the Materials sector, including an overview of common traits across material producers, how materials are priced, and a primer on how basic materials are extracted and processed. At this point, we're just looking at the firms and their structures. In later chapters, we'll translate a firm's structure into performance (earnings, profitability, productivity, etc.) and detail how to use that to build an appropriate portfolio strategy.

MATERIALS 101

Let's start with the basics. What's the Materials sector made of? If you said "commodities," you'd have plenty of company, but you'd be wrong. Technically, a *commodity* is anything with no differentiation in quality (i.e., it's generally *fungible*—one unit of specified size and characteristics is perfectly interchangeable with any other unit). In other words, gold is gold.

But not all commodities fall in the Materials sector. Most notably oil, by far the largest commodity of all by value, falls in the Energy sector. Most agricultural products—also commodities—are found in the Consumer Staples sector.

The Materials sector is composed largely of metals, chemicals, paper, lumber, cement, crushed rock (called construction aggregate), and packaging. As Chapter 4 will cover, these products are not equally represented in the sector—some are more important than others (i.e., they drive more revenue). But before we get into the specific industries, let's cover some broad characteristics all Materials firms generally share.

Materials Are Extremely Capital Intensive

Perhaps the most common Materials trait is capital intensity. From multibillion dollar mines with construction lead times up to 10 years, to enormous chemical, steel, and paper plants where size and economies of scale can be vital, the sector features some of the most *capital intense* industries in the world.

It takes tremendous money to start a new business in these industries, often hundreds of millions or even billions of dollars. The nearby picture shows a large machine sometimes used in coal mining. Notice how small the white cars are in the bottom left. The Materials sector is characterized by *huge* machines, *huge* mines, and *huge* manufacturing plants—not many mom-and-pop shops in these industries. This creates a tremendous barrier to entry for new entrants and provides significant pricing power. As Chapter 4 covers in greater detail, it also creates concentrated industries dominated by a small number of large firms.

Capital investments in Materials firms are not made for next year, but for long time horizons. With the rapid pace of technological innovation and the inherent difficulty in long-term forecasting, today's business investments are often failures. This creates significant shifts in industry leadership over time with new companies with new technologies overtaking older and once-dominant firms.

Table 1.1 lists the 10 largest domestic Materials firms (including Canada) in 20-year intervals, starting in 1965. The order changes frequently with many once-dominant firms falling off the list or disappearing entirely. Three of the top six 1965 firms no longer exist today (Union Carbide, Bethlehem Steel, and Inco Ltd).

Not all firms that disappeared went bankrupt. Some were acquired by stronger competitors aiming to enhance the targets' values with updated technology or a new strategy.

Coal Excavator at Work

Source: Getty Images.

Table 1.1 Largest US and Canadian Materials Firms

Company	Market Cap (Million US$)
1965	
Du Pont (E I) De Nemours	$ 11,012
Union Carbide Corp.	$ 4,137
United States Steel Corp.	$ 2,829
Inco LTD	$ 2,675
Dow Chemical	$ 2,326
Bethlehem Steel Corp.	$ 1,856
Alcoa Inc.	$ 1,642
International Paper	$ 1,342
Weyerhaeuser Co.	$ 1,218
FMC Corp.	$ 1,198
1985	
Du Pont (E I) De Nemours	$ 16,333
Dow Chemical	$ 7,797
Union Carbide Corp.	$ 4,792
Weyerhaeuser Co.	$ 3,995
Allegheny Technologies Inc.	$ 3,868
Gulf Canada Corp.	$ 3,412
Fort Howard Corp.	$ 3,292
Alcoa Inc.	$ 3,133
PPG Industries Inc.	$ 3,023
Alcan Inc.	$ 2,894
2005	
Dow Chemical	$ 42,381
Du Pont (E I) De Nemours	$ 39,083
Alcoa Inc.	$ 25,734
Newmont Mining Corp.	$ 23,912
Monsanto Inc.	$ 17,121
Praxair Inc.	$ 17,071
International Paper	$ 16,482
Weyerhaeuser Co.	$ 16,266
Alcan Inc.	$ 15,230
Barrick Gold Corp.	$ 14,994

Source: Standard & Poor's Compustat® Database,[1] 12/31/2007.

Materials Are Hypersensitive to Economic Growth

Besides capital intensity, it's crucial to remember *economic growth is vital to Materials performance*. The reason can be directly related to supply and demand. In the short term, supply of any material is relatively fixed because bringing a new mine online takes a lot of time and effort. Outside of unexpected supply disruptions (natural disasters, strikes, etc.), strong or weak demand is the biggest determinant in basic material prices (and therefore firm profitability) over short periods.

Most products coming from the Materials sector have extremely long useful lives. Once installed, it takes years for steel to corrode, cement to break down, or plastic to wear out. When archeologists discovered a copper plumbing system in the Egyptian pyramid of the Pharaoh Khufu, it was still in serviceable condition 5,000 years after construction![2] Absent economic growth, particularly in the construction and manufacturing industries, demand can drop considerably and be easily outstripped by existing supply.

Pretend you're a factory owner. To increase production, you must build a new factory or expand your existing one. The construction takes metal, concrete, and so on. But if you're content to maintain production, other than occasional maintenance and steady use of any basic material in your product, you require no additional basic materials to maintain your existing production capacity. With no growth, demand for Materials doesn't just decline, it often falls precipitously. The combination of economic sensitivity and extremely high fixed-costs makes Materials firms very cyclical with large historic booms and busts. The high fixed cost structure creates significant operating leverage, which fuels tremendous profits during boom times and tremendous losses during busts, since raising or lowering production volumes only modestly changes total costs.

Though economic growth is a vital component of *demand*, you should be concerned about both supply and demand in your Materials analysis.

Will We Ever Run Out of Metal?

No! First, most metals can be recycled without any loss in performance or quality. It's estimated around 80 percent of all copper ever produced is still in use today. More importantly, as a metal (or any good) becomes increasingly scarce relative to demand, its price will rise, providing incentive for innovation and substitution. Free markets are incredibly adaptive and innovative.

An example of substitution can be found in the copper market. As the price of copper increased over 300 percent from 2003 to 2008, copper wiring became increasingly expensive. Consumers looked for alternatives and by 2008, cheaper copper-clad aluminum wire made inroads as a substitute.

On the other hand, an example of innovation can be found in the nickel market. When nickel prices rose over 400 percent from 2003 to May of 2007, a dramatic incentive arose for stainless steel producers (who consume two-thirds of the world's nickel production) to find cheaper production methods. This led to the re-introduction and improvement of an alternative processing method deemed inefficient at lower nickel prices. The new process allowed huge deposits of low-grade nickel to be used in production. The sudden increase in supply helped nickel prices fall 50 percent from the middle of May through the end of 2007.

Reported known metal reserves also don't represent all the known metal in the world. Metal reserves simply represent the estimated amount of known metal that can be mined for a profit at a given price. The price used for calculating reserves is often well below the current price. A margin of error is prudently built in to ensure long-term profitability should prices fall. As prices rise, the level of reserves also increases as less economical mines become profitable.

Between higher prices, increased exploration, and improved extraction techniques, metal reserves are likely to grow for a long time. For example, global copper reserves increased from 90 million tons in 1950, to 280 million tons in 1970, to 480 million tons in 2006.

Source: European Copper Institute; Bloomberg Finance L.P.; International Copper Study Group.

What's So Important About Supply and Demand?

The concept of supply and demand will come up a lot in this book, so let's tackle the topic head-on.

In a free market, prices are ultimately set by the interaction of supply and demand. A price is simply the representation of how scarce a good is and how much it's desired or valued.

Put another way, the global economy works on the same principle as a third-grader trading his potato chips for his friend's brownie. The value of that brownie depends on how much the third-grader wants it, how many other brownies or close substitutes are readily available, and how many competitors (schoolmates) have similar potato chips on the market. The brownie's worth or price is dependent on the interaction of the demand and available supply.

Although simple, never underestimate the power of this concept! Supply and demand determine prices for stocks, bonds, commodities, real estate, and virtually any other free market good.

COMMODITY PRICING BASICS

With globalization and trade rapidly growing, most basic materials are priced globally. This is possible because they're non-perishable (i.e., iron ore, cement, and steel deteriorate very slowly) and fungible.

Depending on availability, regional pricing differences may exist due to shipping costs and import or export taxes (tariffs). If regional pricing differs by more than the cost of shipping and taxes, a producer has an incentive to ship goods to the higher-priced region and sell them there. This incentive typically keeps regional prices relatively in line with each other.

The lower the value-to-weight ratio and the smaller the end market, the more likely regional differences exist since shipping costs become a larger percentage of total costs. Table 1.2 outlines the various costs of some common basic materials. It's very cost effective to ship gold, which was over $800 an *ounce* at the end of 2007, but often uneconomical to ship construction aggregate, which cost less than $10 a *ton*. And if only a few tons are needed, economies of scale are lost and the shipping becomes even more uneconomical. Therefore, gold prices have less regional disparity than construction aggregate.

Table 1.2 Basic Material Price Comparison

Material	Price (US$)
Platinum	$1,530/Ounce
Gold	$833/Ounce
Copper	$6,762/Metric Ton
Aluminum	$2,519/Metric Ton
Steel*	$661/Metric Ton
Coal*	$94/Metric Ton
Iron Ore*	$85/Metric Ton
Stone*	$8/Metric Ton
Sand & Gravel*	$6/Metric Ton

*Steel is US HRC Import Price (FOB), Iron Ore is fines 67.5% iron content (FOB), Coal, Stone, and Sand & Gravel are US and Canadian regional prices.

Source: Global Financial Data; Thomson Datastream; Bloomberg Finance L.P.; International Monetary Fund; Government of British Columbia.

Note: Data as of 12/31/07.

Bulk materials with low value-to-weight ratios like coal, iron ore, lumber, and construction aggregate have the greatest regional disparities. Steel and specialty chemicals, with hundreds if not thousands of product variations and niche markets, can also have significant regional pricing disparity. Most precious and industrial metals, along with commodity chemicals, have relatively small disparities.

Basic materials with relatively small regional pricing differences are typically priced globally on commodity exchanges. Prices for products with greater regional differences are typically priced regionally upon sale by producers.

Iron ore is a notable exception. The majority of its prices are negotiated annually in year-long contracts between steel makers and miners. This helps provide stability for both highly capital intensive and cyclical industries. A spot market with prices set by regional producers does exist, but it's relatively small. Under the annual pricing system, the largest producers negotiate annual prices and smaller producers have little choice but to follow. In economic terms, this makes the large producers "price setters" and the small producers "price takers."

My Year's Different Than Your Year

Annual iron ore contracts do not begin in January. Instead they begin at the start of Japan's fiscal year—April 1. Japan was historically the world's largest iron ore importer (China surpassed it in 2003), representing the steel industry in negotiations with iron ore producers.

In 2008, BHP Billiton (the world's third-largest iron producer) called for the elimination of annual price contracts, believing they didn't properly reflect supply and demand. While the firm eventually agreed to annual contracts, it's possible someday annual contracts will give way to a larger spot market or even pricing on an exchange.

Source: John D. Jorgenson and William S. Kirk, "Iron Ore," U.S. Geological Survey Minerals Yearbook (2003).

Futures Exchanges

A commodity exchange provides a market for buyers and sellers to trade contracts of a physical commodity with a specified future delivery date. Because the delivery date is in the future, these exchanges are also commonly called *futures exchanges*. For example, on an exchange you could buy 100 tons of copper for delivery in three months, six months, two years, and so forth.

While contracts typically originate at set intervals starting at three months and going out as far as five to ten years, once the contract is created it trades on a daily basis until maturity. Figure 1.1 shows a graph of futures prices for copper at various maturities. In this case, investors expect the price to fall over time. They'll ultimately be proved right or wrong and the price of their contract will equal the going spot price upon maturity.

When the *futures curve* (also known as a forward curve for non-exchange traded commodities) is inverted and the future price is below the current price, the commodity is in *backwardation*, reflecting current scarcity relative to future expectations. When the futures curve is positively sloped and the future price is above the current price, prices are in *contango*, reflecting a surplus relative to future expectations. Because of storage, insurance, and financing costs, it's normal for non-perishable commodities to be in contango.

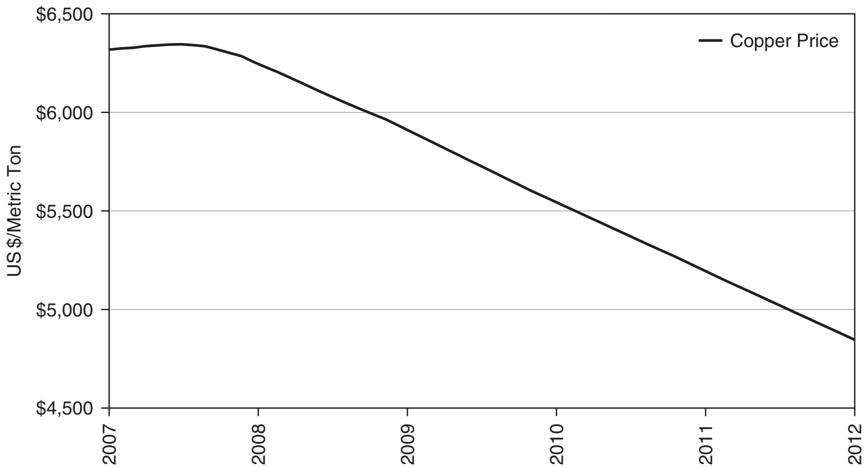

Figure 1.1 Copper Futures Curve
Source: Bloomberg Finance L.P. as of 12/31/07.

Modern futures exchanges originated with the Chicago Board of Trade in 1848. It was created to provide stability to Midwestern farmers' incomes. Without futures or forward contracts, a farmer's business is quite risky. A farmer invests substantial money in seeds, fertilizer, weed killers, machinery, and labor to grow and harvest crops, but doesn't know what the crop will sell for, even months after it's planted. By pre-selling the crop, the farmer knows exactly what can be spent along the way while still ensuring a profit. The futures market takes the price risk out of the equation. Taking risk out of the equation proved to be very popular and the Chicago Board of Trade quickly grew.

Traditions at Work

Futures contracts for metals are sold in three-month intervals because in the late 1800s, it took about three months for Chilean copper to reach English ports. The three-month forward contract allowed merchants to hedge or protect themselves from the possibility of a fall in copper prices while merchandise was in transit.

Source: London Metal Exchange.

Speculators also engage in futures trading, although they rarely hold a contract to maturity and therefore don't take physical delivery of the good. Future exchanges like the London Metal Exchange (LME), the Chicago Board of Trade (CBOT), the Chicago Mercantile Exchange (CME), the New York Mercantile Exchange (NYMEX), and the New York Commodities Exchange (COMEX) all provide pricing information and venues for Materials trading.

Different commodity exchanges often specialize in different products. Chicago's commodity exchanges oversee greater volumes of agricultural-based commodities (tied to their history as an exchange for Midwestern farmers). The London Metal Exchange is historically the global leader in metals because England was first to experience an industrial revolution.

THE PRODUCTION PROCESS

A good understanding of how basic materials are produced provides a foundation for further analysis and insights into costs, potential production bottlenecks, and other risks faced by producers. So let's look at the following basic life cycles:

- Metals
- Chemicals
- Concrete
- Paper

But first, some definitions.

Upstream Versus Downstream

An operation is considered *upstream* if it is closer to the starting point of the production process—usually involving pulling actual raw material out of the ground. *Downstream* operations are closer to the finished product purchased by end consumers.

The terms stem from the metaphor of a stream or river. A river's flow starts upstream at its source and ends downstream. The closer the source, the farther upstream you are. In steel making, an iron ore mining operation is about as far upstream as you can go. By comparison, a steel producer is downstream and a steel distributor is even farther downstream. Upstream and downstream operations usually have very different margins, business models, and benefit from different economic environments. Vertically integrated producers have both upstream and downstream operations complementing each other.

The Life Cycle of Metals

Unless you believe in medieval alchemy, you probably know metals come out of the ground. Finding them in commercially viable quantities and mining them with the proper approvals, however, is no easy trick.

Finding Metal and Securing Permits. The search for minerals begins far above the ground. Satellite imagery allows geologists to scan for appropriate topography and view regions under different wavelengths of light to find resource-rich sites—allowing for geological analysis otherwise invisible to the naked eye. Geologists then create detailed maps of the earth's mineral content based on the reflection and absorption properties of the clay, rock, soil, or vegetation of the terrain.[3]

Once a promising search area is discovered, the interested firm meets with the land owner (usually governments) to negotiate broad exploration or mineral rights covering wide territories, often tens of thousands of acres.[4] Governments typically negotiate contracts as leases with specific exploration and development time frames to ensure firms are actively investing in their country rather than speculatively purchasing rights to sell at a higher price in the future.

Geologists then survey and take samples to assess likely ore veins and identify spots for drilling exploratory holes. They often explore sparsely inhabited areas with no more than their packs, a donkey, and a few local guides. Based on the geologists' findings, firms drill exploratory holes. And with costs often over $300,000 to drill a 3,000 foot deep hole, the decision isn't made lightly.[5]

The Long Arm of the Law Reaches Underground

In the legal world, "mineral rights" can be separated from "surface rights"—the right to anything, literally, on the land's surface. Owners wanting to retain use of their land and the buildings on it maintain surface rights and grant mineral rights to miners who want access, but don't want to pay for the buildings and any surface use.

All contracts vary, but they typically detail how the underground minerals can be extracted, the extent of the miner's right to surface use, and any reclamation by the miner to return damaged portions of the surface to their previous state. Most landowners sell their rights in some form rather than develop the resources themselves because mining is so highly capital intensive.

If a viable quantity of ore is discovered, the firm applies for government and environmental permits to construct a mine. Approval usually involves fees, royalty agreements based on a percent of revenue or mine production, taxes, and even mandated social programs for the community. (And sometimes a bit of backroom dealing with government officials.)

Such agreements are permanently binding only in theory. Governments have a funny habit of coming back for more and re-negotiating terms when it suits them. Additional fees and other alterations years later are not uncommon. A recent example is the dramatic changes to South African mining laws in 2004. Called the Black Economic Empowerment program (BEE), it addresses previous racial inequality under apartheid, but also represents a dramatic shift in ownership requirements. Existing mining companies must transfer 15 percent of ownership to individuals designated as historically disadvantaged South Africans by April 2009 and 26 percent of ownership by April 2014. South Africa also reviewed mining royalties and proposed significant changes on each type of metal.[6]

Building a Mine. Once a viable metal deposit is identified and necessary permits obtained, a firm begins development. This is often a multi-billion dollar process depending on the size of the mine, necessary roads, rail lines, access to power and water, and the nearest shipping ports. (Because ore is heavy and mined in huge quantities—over 2 billion tons mined globally each year[7]—it's typically transported by rail and sea.) The largest mines can reach over two miles wide and a mile deep.

Powering Mines Takes Serious Power

Mining is extremely power intensive. BHP Billiton forecasts its Australian Olympic Dam mining complex will require about 690 megawatts of power when development is completed around 2018. That's equivalent to over 40 percent of South Australia's electricity in 2007.

Source: Rebecca Keenan, "BHP Says Labor, Tool Shortages Strain Olympic Dam Update 2," Bloomberg (May 29, 2008).

New mining projects are known as "greenfield" projects because the project was started in an unspoiled "green field." Expansions to an existing mine or drilling at a nearby site is known as a "brownfield" project—a project commenced in a well-traveled area with established roads and infrastructure.

Brownfields typically represent less risk. Mineral rights are generally already established and the terrain is well understood. However, most brownfield regions with potential for significant ore deposits have already been explored, and current brownfield projects are typically smaller expansions. So although greenfield projects are much riskier, they often have the potential for much larger discoveries.

Mines can either be built underground or as open pits, depending on the depth and concentration of ore veins. Collapsing tunnels, toxic fumes, and operating heavy machinery in close quarters make underground mines significantly more dangerous. They typically have a conveyor belt system to transfer out rock and ore. Open pit mines involve blasting rock, loading it into large dump trucks, and hauling it out.

The Benefits of Working in Open Pit Mines

South Africa has many of the world's deepest mines, reaching depths of over two miles. A study by the Leon Commission found an estimated 69,000 workers lost their lives in South Africa's mines from 1900 to 1994. Unfortunately, such incidents persist. In 2006 alone, South Africa's underground mines claimed 199 lives.

Not only are open pit mines much safer, but the dump trucks used are some of the most impressive vehicles in the world. The largest sport tires over 12 feet high, payload capacities of up to 380 tons, and a 24-cylinder, 3,500 horsepower engine under the hood. The nearby picture shows how massive these dump trucks and their tires are. These trucks often run continuous shifts, 24 hours a day, 7 days a week, trucking mined material to processing centers. Tires for these trucks can cost up to $40,000 each and burst with the force of up to 16 sticks of dynamite!

Source: Jeremy Roberts, "BHP's Olympic Dam Mine will Need Half of SA's Electricity," The Australian (March 27, 2008); Ndaba, "Can South Africa Stop Mine Deaths?" Mining Weekly (February 1, 2008); Caterpillar Inc. Press Release, "Power Train Simulators Put New Large Mining Trucks to the Test—Long Before They Hit the Haul Road," (September 2007).

Liebherr T 282B Mining Truck

Courtesy of www.openstockphotography.org.

Separating Metal from Rock. Mined rock is crushed smaller than the size of a dime and sent through a grinder, turning it into a fine powder. Then metal is separated from rock and minerals to create "concentrate."

Chemical flotation or leaching is typically used to create concentrate. The process involves a bath of water and a chemical reagent. When air is pumped into the solution, chemicals cause the ore to attach to rising air bubbles forming a surface froth that is skimmed off. This easily allows sorting multiple types of ore from the same batch of rock. Simply by changing the chemical composition of the bath, another ore type rises to the surface. Once skimmed, the material is filtered and dried to remove excess water and reduce shipping weight.

Why Miners and Environmentalists Don't Always Get Along

Leaching poses some hefty environmental drawbacks. Per ton of rock, often less than a quarter ounce of precious metals and only 10 to 20 pounds of industrial metals are recovered. This means large water supplies are needed to process millions of pounds of metal each year.

In 2000, the US Geological Survey (USGS) estimated the US mining industry used approximately 3.5 billion gallons of water a day, or about 1 percent of the country's total water consumption. In addition to draining local water resources, mines must dispose of water along with leftover rock, called *tailings*. Since chemicals (such as cyanide and sulfuric acid) used to leach out the metals are often toxic, the tailings are often contaminated and can damage the surrounding environment if not properly disposed.

Because of this risk, mining firms are subject to strict environmental regulations and liable for clean-up costs and punitive penalties if they fail to comply. The permit requirements and potential costs of deviating from them increase the cost of doing business and serve as additional barriers to entry.

Concentrate is still not pure metal and requires additional refining or *smelting*. The metal percentage in concentrate (called *concentrate grade*) depends on the metal type, processing efficiency, and presence of other impurities. Copper concentrate for example typically only holds between 15 and 35 percent actual metal depending on the quality of the ore and efficiency of the leaching process.[8]

Metal Smelting. Concentrate is typically created on site or in close proximity to a mine to reduce transportation costs. Once the metal has been processed into a concentrate, it's shipped to a smelter for further refining. Metal smelters are to the metal industry what oil refineries are to oil. Many firms specialize in either smelting or mining. For example, most Chinese copper firms mine very little of the metal and focus on smelting since copper is scarce in China but demand is high. Therefore, China imports vast amounts of copper concentrate, making it one of the world's largest copper smelters.

Smelters melt concentrate down and mix it with materials like limestone, which absorb impurities and leave a material with a 40 to 60 percent metal ratio called *matte*. Hot, oxygen-enriched air is blown through the molten matte to purify it over 95 percent and create *blister* (named for the air bubbles that form on the surface). The blister is then heated in an anode furnace to burn off excess oxygen and form *anodes*, which are 99 percent pure metal.[9]

While this quality level is usable for many purposes, some uses require 100 percent purity. Copper used in electrical wiring is further refined to maximize its electrical conductivity. To further refine it, the anodes are put through electrolysis. The metal is dissolved in a water and chemical bath and attracted to an electrically charged pole. As it dissolves and attaches to the pole, impurities left behind fall to the bottom of the tank, and the result is metal with 99.99 percent purity, called a *cathode*. The various stages of the smelting process are summarized in Table 1.3.

Refining differs slightly for each metal. Some metals like gold require little to no refining. Others like copper must undergo the full

Table 1.3 Stages in Copper Smelting

Stage in the Smelting Process	Metal Percentage
Concentrate	15% to 35%
Matte	40% to 60%
Blister	95% to 98%
Anode	99%
Cathode	99.99%

Source: US Environmental Protection Agency.

smelting process. Iron ore doesn't even use the basic leaching process in its transformation into refined iron (called pig iron) and then steel. There's also usually more than one way to refine a metal, but this is among the most common processes.

Smelting typically yields lower profit margins than mining. Smelters generally sign annual contracts to provide a stable flow of input materials. When global smelter capacity exceeds the supply of concentrate produced by the miners, negotiating power falls into the hands of miners and smelting fees decline. When the reverse occurs, smelting fees rise.

Smelters buy ore from miners at the daily London Metal Exchange (LME) benchmark rate, minus the amount of the annual pre-negotiated fee. Since annual contracts are long term, smelters typically negotiate what's known as *price participation*, allowing smelters to increase fees by a pre-determined level if prices exceed a certain threshold. For example, a smelter may charge $0.25 per pound to refine copper, with the agreement that for any period in which copper exceeds $4 per pound, the charge increases to $0.35 per pound.

In 2008, smelting capacity outpaced copper production from mines by such a large margin that miners eliminated the price participation clause and smelting fees dropped by 25 percent. That year, it cost $0.20 per pound to form anodes, and roughly another $0.05 per pound to further refine it into cathodes. These charges are called treatment (TC) and refining charges (RC), respectively, and often are denominated as TC/RC in shorthand for the total smelting fee.[10]

Metal Recycling. Metal can be recycled once its useful life has passed. Today, recycling is a $70 billion industry in the US alone. Two-thirds of the steel and a third of the aluminum produced in the US now comes from recycled scrap.[11] And recycling can mean significant energy savings, as seen in Table 1.4.

The US isn't the only energy-conserving country. In 2007 the US exported over 19 million metric tons of scrap metal to foreign countries. Emerging markets rank among the largest scrap importers, with China leading the way. Since most construction is brand-new in

Table 1.4 Energy Savings From Recycling vs. Using New Ore

Metal	Energy Saved
Aluminum	95%
Copper	85%
Steel	74%

Source: Institute of Scrap Recycling Industries.

developing regions, they are forced to import large quantities to realize the savings.[12]

The Life Cycle of Chemicals

Chemicals and their products are pervasive—paints, glues, plastics, fabrics, lubricants, cleaners, and many others. Even the binding of this book is held together by a chemical adhesive! So how are they made?

First, a disclaimer: Detailing how thousands of different chemicals are made would require many encyclopedias, so the following description is simply a guide to typical chemical synthesis. But keep in mind the process won't apply to all chemicals.

A few products in the chemicals industry are mined, like potash and phosphate for fertilizer. But the majority of chemicals start with oil or natural gas. Once petroleum is out of the ground, its next step to becoming a finished chemical is through commodity chemical plants.

Commodity Chemicals. Commodity chemicals are typically intermediate steps on the way to becoming final products. They are mass-produced in plants attempting to manufacture material of acceptable quality at the lowest possible cost.

End markets are huge, which makes competition fierce. A producer who can gain an edge and undercut its competitors stands to benefit tremendously. As competitors battle to gain efficiencies and drive down marginal costs, the size of the operation typically grows to exploit economies of scale. The commodity chemical industry is characterized by large manufacturing plants producing large volumes of chemicals at a steady rate. In fact, these plants often run 24 hours a day.

The most commonly used feedstock for commodity chemicals are naptha, a by-product of oil refining, and ethane, the second largest component of natural gas behind methane. Once isolated, these products go through a process called "cracking" to break down large hydrocarbons into smaller ones like ethylene and propylene.

Steam cracking is the most common process. Naptha or ethane is heated to over 750 degrees Celsius until a reaction occurs. Depending on the specifics of the input, scientists know the exact temperature the reaction will take place and stop it milliseconds after it starts. That short time, however, is enough to break down hydrocarbons, which are then filtered into ethylene, propylene, and other basic substances.

Ethylene and propylene are two of the most commonly used commodity chemicals because they are among the simplest forms of hydrocarbons in existence, making them extremely versatile for use as building blocks in specialty chemicals.

The Secret Behind Fresh Produce

While ethylene is primarily used to create other chemicals, one of its few retail uses is as a ripening agent for fruits and vegetables.

Specialty Chemicals. There are thousands of specialty chemicals filling countless niches for various products and purposes. Often, new chemicals are even developed by working directly with a specific customer to improve a single product, enter a new market, or increase efficiency. On a higher level, one of the biggest end markets is the industrial manufacturing sector.

While commodity chemical plants typically run continuously, specialty chemical plants produce ad hoc batches of chemicals with volume dependent on current customer needs. Since markets for specialty chemicals are smaller, competition is not as fierce. The gains from improving efficiencies and undercutting a competitor on a single chemical are relatively small and not worth large investments of time or capital. Pricing power is therefore strong, and the specialty chemical industry is much less cyclical than the commodity chemical industry.

Overview of Chemical Production. In broad terms, the chemical-making process can be thought of as a tree. Oil or natural gas forms the trunk, commodity chemicals are the relatively few large branches that split off from the trunk, and specialty chemicals are the thousands of twigs that split from the main branches. As covered in greater detail in Chapter 4, the only force generally large enough to move all of them at the same time is economic growth.

Chemical Recycling. Many chemicals cannot be recycled (such as household cleaning products), but plastics can be. In fact, recycling plastic is 80 percent more energy efficient than producing new plastic. In 2007, the US is estimated to have recycled 576,000 metric tons of used plastic bottles.[13] But that doesn't mean there isn't room for improvement. The Container Recycling Institute estimates only one-third of all plastic beverage containers in the US are recycled.

The Life Cycle of Concrete

Whether used to lay a home's foundation, hold up walls, build a skyscraper, or pave a sidewalk, concrete is a vital component of the construction industry. In fact, concrete is the second most consumed substance on earth after water.[14]

Concrete is a mix of 80 percent construction aggregate (crushed rock) and 20 percent cement. Once water is added, cement remains malleable for a period before hardening into its final rock-like form.[15]

I Speak Roman. Do You?

The Romans are considered to be the greatest users of concrete among ancient civilizations (though the Greeks and other societies also used it). Not only did they use it prolifically, but their use of fine volcanic sand made their concrete harder than previous versions—much of it still stands today. We owe the name *concrete* to the Roman term "concretus," meaning grown together or compounded.

Making Construction Aggregate. Construction aggregate has many grades or sizes, but can generally be separated into *fine* and *coarse*. Fine aggregate, like sand, is often dredged from lakes, rivers, or sea beds; while coarse aggregate, like gravel or crushed rock, is typically mined from quarries with explosives and broken down into various sizes by machines called crushers. Aggregate is quarried near its end market because its low value-to-weight ratio makes it too expensive to ship long distances. Gaining permits for quarries near large population centers can be difficult, since most communities don't want to be near a business that regularly sets off loud explosions. The aggregate used in concrete is typically about 60 percent gravel and 40 percent sand.[16]

Making Cement. The most commonly used cement is *Portland* cement, primarily a mix of limestone, clay, and sand, with about 85 percent of its final mass made up of lime and silica (the limestone mixture used to remove impurities in metals, called "slag," is often recycled in this mix as well).[17] The ingredients are ground to a fine powder, mixed in exact ratios, and placed in a furnace. While there are wet and dry methods of creating cement, most new furnaces are dry furnaces because they use less energy.

Dry cement furnaces are typically long rotating tubes, up to 12 feet in diameter (wide enough to drive a car through) and 400 feet long, set at a slight incline. The mixture is placed in the top of the furnace and slowly travels down the inclined and rotating tube while being heated to over 2,700 degrees Fahrenheit. Chemical reactions take place along the way and the result is marble-sized pieces of new material called clinker.

Clinker is ground into a fine powder and mixed with various additives, depending on the characteristics of the cement desired. Cement powder is ground so fine it can pass through a sieve capable of holding water.

Cement is primarily manufactured regionally due to its low value-to-weight ratio, but unlike construction aggregate, some global trade does exist. In 2005, the US imported approximately 28 percent of its cement, with most going to coastal regions like California.[18] However, the US is expected to expand its cement production capacity by 27 percent between 2007 and 2012 to replace the higher cost imports.[19]

Alternative Uses for Your Kitchen Stove

The discovery of Portland cement is generally credited to a British stone mason named Joseph Aspdin in 1824. He invented the substance by baking a mixture of limestone and clay in his kitchen stove before grinding it into a fine powder. He is said to have called it Portland cement because it looked like a stone quarried on the Isle of Portland off the British coast.

Source: Portland Cement Association.

Heating the large cement furnaces to high temperatures is very energy intensive. It takes about a half pound of coal to produce one pound of cement. Over 1.6 billion tons of cement is produced globally each year—that's a lot of coal.[20]

Concrete Recycling. Over 140 million tons of concrete are recycled each year—the most recycled material in the US by weight. Once cement bonds with water, its chemical properties change and can't easily be returned to its old use. Recycled concrete is often used as filler in place of crushed rock. Its most common end market is providing a foundation for roads.[21]

The Life Cycle of Paper

Paper, of course, starts with trees. For our purposes, trees can be segmented into two categories: *hardwoods* and *softwoods*.

The World Runs on Paper

On average, over 120 pounds of paper per year are consumed for every person on earth! In the developed world, the annual consumption rate is even higher at an average of 661 pounds per person.* While it depends on the type and size of the tree along with the type of paper being made, it's estimated one ton of paper takes between 12 and 24 trees to produce.

*"Wood for Paper: Fiber Sourcing in the Global Pulp and Paper Industry," Seneca Creek Associates, LLC and Wood Resources International, LLC, (December 2007).
Source: Conservatree (www.conservatree.com).

Cutting Lumber. Hardwoods are primarily used as veneer, furniture, cabinets, flooring, doors, and other specialized interior applications. Examples of hardwoods are walnut, maple, oak, cherry, elm, and beech. These woods are typically too valuable to be used for paper and are sent to sawmills to be turned into lumber, but the leftover scrap is often used in the paper industry. About 40 percent of US timberland is composed of hardwood timber, which has given rise to the largest hardwood sawmilling and processing industry in the world.[22]

Softwoods are primarily used as lumber for construction and to make paper. The largest end market for softwood lumber is the residential housing market. Examples of softwood are pine, Douglas fir, and redwood. Wood used for paper production is called pulpwood and results from diseased or heavily branched softwood trees unusable for making lumber, the scraps from sawmills, and a few trees such as eucalyptus, which are widely grown specifically for pulpwood.

Urban Sprawl Meets Its Match

About a third of the US is covered in forest land, and there are an estimated 20 percent more trees in the US today than 25 years ago.

Source: American Forest & Paper Association.

Forest land owners have a variety of harvesting methods, including clear-cutting (where every tree is cut down), diameter limit cuts (where any tree over a specified diameter is cut), and selective harvests (where only designated trees are cut). One of the most commonly used methods is a variation of the selective cut called a "group selection" harvest.

In a group selection harvest, small patches of forest, up to about an acre in size, are cut in scattered fashion throughout the forest. Most forests in highly regulated areas are cut using the selective or group selective method because they are considered the most sustainable practices. To help sustainability, new young trees are planted in place of the removed mature trees to help the forest re-grow.

Most trees planted specifically for lumber or paper are given an 8- to 15-year life cycle prior to harvest, but it varies depending on the tree and climate. Trees can be felled by hand with chainsaws or much more efficiently and safely with tree harvesters. Tree harvesters are somewhat like large tractor capable of grabbing a mature tree, felling it, shearing its limbs, cutting it to the desired length, and stacking it for transport at a rate of about 45 trees per hour.[23]

Processing Paper. Once lumber is cut and delivered to a paper factory, the paper-making process has only just begun. Wood is first put through rollers to remove any bark and then ground down into small chips. The chips are placed in large tanks and boiled at high temperatures with sodium hydroxide and sodium sulfide. This breaks the wood down into pulp and dissolves the lignin (the natural glue holding the wood together), leaving behind cellulose fibers.

In most cases, the pulp is bleached white and put through a process called "beating," which mashes the pulp. At this point, fillers like chalk and starch are added, affecting the final opaqueness and paper quality. Then pulp is laid on a fine mesh screen and subjected to rollers, pressing water out through the screen, leaving behind compressed pulp. Despite attempts to recycle its water when possible, the pulp and paper industry is the single largest industrial water consumer in the developed world.[24]

The pulp sheet is pressed into form and sent over a number of hollow, heated rollers to dry the paper. At this point, pigments or latex finishes may be added for color patterns or a glossy coat depending on its intended use. The final result is a sheet of intertwined cellulose fibers we call paper. No glue is used in the process. Because of all those steps, the paper industry is one of the most capital intensive industries in the world.

The Origins of Paper

The invention of paper is typically credited to a Chinese court official around 100 AD. He is thought to have mixed mulberry bark, hemp, and rags into a pulp before pressing out the liquid and hanging it to dry. However, paper makers didn't successfully begin using wood fiber for mass production until the 1800s.

Source: American Forest & Paper Association.

Paper Recycling. Used paper can be recycled very affordably. In fact, the most expensive part of recycling paper is gathering it. Recycled paper is dissolved in a chemical bath to turn it back into pulp, filtered to remove the additives, and then re-processed just like normal paper.

Besides reducing landfill size, recycling paper also has the advantage of taking 64 percent less energy to produce than making it from scratch.[25] The amount of paper recycled in the US has increased an impressive 87 percent from 1990 to 2007, with 56 percent of the paper consumed in the US in 2007 being recycled. This equates to nearly 360 pounds of paper recycled for every man, woman, and child in the US!

There is a limit, however, to our ability to recycle paper. Paper can only be recycled five to eight times before the fibers become too short and weak to be reused.[26] Nonetheless, approximately 36 percent of US paper production (including exports) is now made from recycled paper.[27]

Chapter Recap

Now you have the foundation and basic tools to begin greater analysis of the Materials sector. You'll continue to see the processes in this chapter pop up throughout this book and a solid understanding of them is critical to analyzing the sector in greater depth.

- The Materials sector is made up of metals, chemicals, paper, lumber, cement, construction aggregate, and packaging.
- The sector is extremely capital intensive, often requiring tremendous initial investments of hundreds of millions or billions of dollars to start a business.
- The sector's capital intensity creates large barriers to entry, provides pricing power, and encourages consolidation into large dominant firms that maximize economies of scale.
- The sector is extremely economically sensitive.
- Pricing of its products (and any free market good) is always determined by supply and demand.
- Basic materials are priced either globally or regionally depending on how economical it is to ship them. This is typically determined by their value-to-weight ratio.