Name: **ESS 315**

Lab # 7 Earth Resources

Introduction

Earth resources have played an integral part in shaping civilization. Until the Industrial Revolution, consumption of Earth resources was negligible. In today's resource-based society every U.S. citizen accounts for the consumption of 1300 lbs. of steel, 65 lbs. of aluminum, 25 lbs. of copper, 15 lbs. of manganese, 15 lbs. of lead, 15 lbs. of zinc, and 35 lbs. of other metals. Energy consumption by each U.S. citizen equates to 8000 lbs. of oil, 4700 lbs. of natural gas, 5150 lbs. of coal, and 1/10 of a lb of uranium (Taken from Youngquist, 1990. *Mineral Resources and the Destinies of Nations*).

In the table below list seven raw earth resources that you use in everyday life. What is the principal use of this resource and where is its source?

Table 7-1 Earth Resources

Earth Resource	Use	Source
1.		
2.		
3.		
4.		
5.		
6.		
7.		

As the world population has grown over time earth resource use has increased. What other factors control rates of resource use?

How are predictions about resource depletion made?

What are the major sources of uncertainty in these predictions?

Metal Resources

When humans use mineral resources, matter is neither created nor destroyed, although energy is consumed in changing the raw materials to useable forms. Mineral resources are not uniformly distributed on or within the Earth. Nations may be rich in some resources (e.g., the U.S. holds 58% of the world reserves of molybdenum), but lack adequate supplies of others (e.g., Japan and France must import almost all of their petroleum). The non-uniform spatial distribution of Earth resources leads to trade in good times and war in bad times. Mineral resources, like all commodities, are valued according to their availability.

Aluminum Case Study

Before 1885, no simple chemical process existed for refining aluminum. Pure aluminum metal was extremely rare and valuable, and worldwide consumption was negligible. For example, in 1852, aluminum cost $545 (1852 dollars) per pound!

In 1885, Charles Hall, an undergraduate chemistry major at Oberlin College (OH), developed an inexpensive method for extracting aluminum from ore. He established the Aluminum Company of America (Alcoa) and became a wealthy man. His single technological breakthrough made a once scarce resource widely available.

In today's laboratory you will explore the redistribution of aluminum by tracking its history in soda cans.

Aluminum in Earth's Crust

Aluminum (Al) is the third most abundant element in the Earth's crust (Table 9-2) and is present in many common silicate minerals (i.e., feldspars, micas, and garnet). The bonds between the Al atoms and O atoms are very strong in these minerals; thus, a tremendous amount of energy is required to separate them.

Table 7-2
Weight % of Element in the Earth's Continental Crust

ELEMENT	WT.%	ELEMENT	WT.%
Oxygen (O)	46.60	Carbon (C)	0.020
Silicon (Si)	27.72	Manganese (Mn)	0.095
Aluminum (Al)	**8.13**	Sulfur (S)	0.026
Iron (Fe)	5.00	Barium (Ba)	0.043
Calcium (Ca)	3.63	Chlorine (Cl)	0.013
Sodium (Na)	2.83	Chromium (Cr)	0.010
Potassium (K)	2.59	Fluorine (F)	0.063
Magnesium (Mg)	2.09	Zirconium (Zr)	0.016
Titanium (Ti)	0.44	Nickel (Ni)	0.008
Hydrogen (H)	0.14	**Lead (Pb)**	**0.0013**
Phosphorous (P)	0.11	Others	0.011

Aluminum Ores

Although aluminum is very abundant on Earth, extracting it from silicate minerals requires too much energy to be practical. Instead, aluminum is extracted from ore minerals in which the element is bound less tightly. The distribution of these ore minerals is controlled by climatic factors; the vast majority of the world's aluminum supply comes from tropical regions or areas that once had tropical climates in the geologic past.

Why do you think that aluminum-bearing ores are more common in tropical locations than temperate?

Soil and rock made up of aluminum oxides and hydroxides, such as gibbsite [$Al(OH)_3$], are called laterite and bauxite. Note that the U.S. lacks major aluminum deposits and currently imports 97% of its aluminum ore. **Examine the specimen of bauxite in the laboratory. What other minerals do you see present in this Al-bearing ore?**

Price of Aluminum Ore

Like other commodities, the price of aluminum ore fluctuates daily on world financial markets. We have provided you information about domestic aluminum production and use in the United States (see the last few pages of this lab).

What was the average 1997 per kg price of ingot aluminum in the United States (note 2.205 lbs.=1 kg.)?

What percentage of the world's aluminum is produced in the United States?

Who is our biggest supplier of imported aluminum?

What percentage of our domestic aluminum production is from recycled scrap aluminum?

How much did the U.S. pay to other nations for its imported portion of (1 metric ton = 1000 kg) aluminum it consumed in 1997?

Energy Costs of Refining Aluminum

The aluminum in laterite and bauxite must still be separated from oxygen and hydrogen, and then purified. Although these bonds are quite weak individually, a large amount of electrical energy is required to refine any usable amount of aluminum. For example, processing 1 kg of aluminum from ore requires 15.55 kilowatt hours of electricity. Consequently, aluminum refining is profitable only where energy is inexpensive.

The most familiar use of aluminum is for beverage containers. The aluminum in soda cans was extracted, processed, and shipped simply to transport a drink from one place to another. **What are more efficient ways?**

One aluminum beverage can weighs 15 g. **At $0.09/kilowatt hour, what is the cost of refining the aluminum in one can?**

Using the approximation of 1 can/day per person, calculate the cost of the energy used in the refinement of aluminum cans consumed by the 45,000 students and faculty at the University of Washington in one year.

The U.S. consumed 6,900,000 metric tons of aluminum in 1997. **At the rate cited above, what was the cost of the energy required refine that portion of aluminum that was not recovered from recycled scrap (refer to the attached data sheet)?**

It takes only 6% as much energy to recycle aluminum as to produce raw ore. **If all the aluminum in the above question was recycled aluminum, what would have been the cost of energy used to produce it?**

**At present, only about 50% of all aluminum cans are recycled in the U.S.

Energy Resources

Most of the energy that we exploit originates as hydrocarbons. Hydrocarbons such as petroleum are formed principally of hydrogen and carbon. Together with oxygen, these elements are the main components of the organic portion of the earth.

Energy resources including petroleum, coal and natural gas are termed “fossil fuels” because the hydrogen and carbon that form them were derived from living organisms tens or hundreds of millions of years ago. Fossil fuels are non-renewable energy resources because the time required to form them from organic matter is, on a human time scale, essentially infinite.

Petroleum

Few discoveries have changed the course of human history more than the discovery of oil. Before the first successful oil well was drilled in 1859, world oil production was only a few barrels a day, all of it collected from “seeps” where oil came naturally to the surface. Today, world production exceeds 50,000,000 barrels daily (one barrel = 42 gallons).

The discovery of oil and the ability to tap it in large volumes allowed unprecedented breakthroughs in transportation, agriculture, heating, cooling, lighting and extraction of other Earth resources. It transformed humankind into a force capable of causing geologic change at rates far greater than natural processes. In this section of the laboratory you will examine the future of the resource that has shaped the modern age.

A Barrel's Worth

Given our society's heavy dependence on petroleum, its current value on the world market is unnaturally low when compared with other products we consume in our daily lives. In 1994, crude oil cost about $18 per barrel (42 gallons). **For comparison, estimate the "per barrel" cost of the following products.**

Table 7-3 Per Barrel Cost of Common Products

product	**per gallon**	**per barrel**	**product**	**per gallon**	**per barrel**
Gasoline			Bottled Water		
Milk			Beer		
Orange Juice			Wine		
Soda Pop			Perfume		

Do you think that the prices of the above products accurately reflect the cost associated with them? Consider which were locally produced, which are renewable, which require more processing.

Historical Petroleum Production

The petroleum we use accumulated in sedimentary rocks over the past half billion years, but it is quite possible that this 500-million-year legacy will be exhausted within your lifetime. Table 7-4 summarizes global production and consumption of petroleum since 1860.

Table 7-4 Global Petroleum Production Since 1860

Decade	Global Production (Million of Barrels)	Cumulative Global Production (Million of Barrels)
1860	29	29
1870	119	148
1880	409	557
1890	1033	1590
1900	2186	3776
1910	4282	8058
1920	10,567	18,625
1930	16,617	35,242
1940	26,410	61,652
1950	53,689	115,341
1960	109,297	224,638
1970	200,388	425,026
1980	203,754	628,780
1990	250,000	878,780
2000 (predicted)	288,000 (predicted)	

What percent of total global petroleum consumption through 1999 occurred in the five decades between 1860 and 1909?

What percent of total global petroleum consumption through 1999 occurred in the five decades between 1910 and 1959?

What percent of total global petroleum consumption through 1999 occurred in the five decades between 1950 and 1999?

Describe the overall trend in petroleum consumption indicated by your calculations. How can you account for this pattern of consumption?

Future Petroleum Production

How much longer can petroleum resources last? One of the earliest attempts to predict future petroleum production was made in the mid-1950's by geologist M. King Hubbert for the American Petroleum Institute. Hubbert used the "integral technique of prediction", which suggests that production rises from the time of resource discovery, through a maximum, then declines again to zero production. In a sense, this is an inverted form of the uniformitarian principle; future resource availability is predicted from the past production.

On the graph provided in Figure 7-1, plot decadal global production since 1860 using the data in Table 7-4. Note that the vertical axis is in billions of barrels.

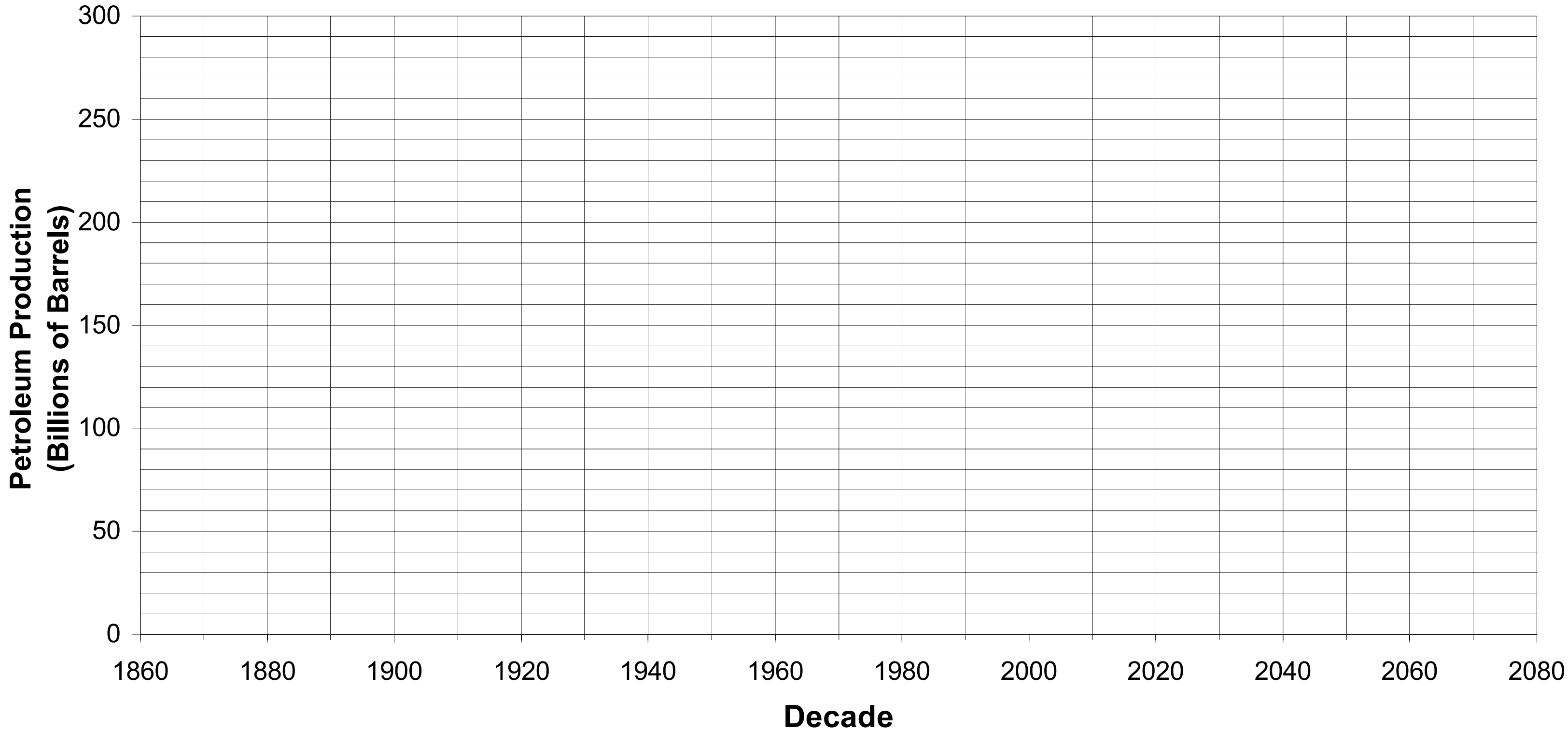
Describe how the rate of production changed over the period from 1960 to 1989. If you only had data through 1989 to work with, when would you predict petroleum production to reach its peak?

Does the prediction you made in the previous question hold true?

Current estimates indicate that global oil production will peak between 2000 and 2009. Using a different color or symbol on your graph, project your production curve into the future by assuming that production in coming decades will be the mirror image of that in the past-- i.e., that the curve will be symmetric about its maximum. On the timelines *below* the chart, shade in areas corresponding to the lifetimes of your grandparents, your parents and yourself. (You can approximate the times by assuming 30 years between generations and lifespans of 80 years).

According to your plot, during what decade will global production fall to the level of 1960? How old will you be then?

Figure 7-1: Global Petroleum Prodcution by Decade (Historical and Projected)



Your life span	
Parents’ life span	
Grandparents’ life span	

ALUMINUM[1]

(Data in thousand metric tons of metal, unless otherwise noted)

Domestic Production and Use: In 1997, 13 companies operated 22 primary aluminum reduction plants. Montana, Oregon, and Washington accounted for 40% of the production; Kentucky, North Carolina, South Carolina, and Tennessee, 20%; other States, 40%. Based on published market prices, the value of primary metal production in 1997 was $5.9 billion. Aluminum consumption, by an estimated 25,000 firms, was centered in the East Central United States. Transportation accounted for an estimated 32% of domestic consumption in 1997; packaging, 26%; building, 16%; electrical, 8%; consumer durables, 8%; and other, 10%.

Salient Statistics—United States:	1993	1994	1995	1996	1997[e]
Production: Primary	3,695	3,299	3,375	3,577	3,600
Secondary (from old scrap)	1,630	1,500	1,510	1,570	1,700
Imports for consumption	2,540	3,380	2,970	2,810	3,100
Exports	1,210	1,370	1,610	1,500	1,600
Shipments from Government stockpile excesses	—	—	—	—	57
Consumption, apparent[2]	6,600	6,880	6,320	6,620	6,900
Price, ingot, average U.S. market (spot), cents per pound	53.3	71.2	85.9	71.3	75
Stocks: Aluminum industry, yearend	1,980	2,070	2,000	1,830	1,800
LME, U.S. warehouses, yearend	168	16	14	12	10
Employment, primary reduction, number	18,800	17,800	17,800	18,200	18,000
Net import reliance[3] as a percent of apparent consumption	19	30	23	22	23

Recycling: Aluminum recovered in 1997 from purchased scrap was about 3.5 million tons, of which about 50% came from new (manufacturing) scrap and 50% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 25% of apparent consumption.

Import Sources (1993-96): Canada, 62%; Russia, 18%; Venezuela, 5%; Mexico, 3%; and other, 12%.

Tariff: Item	Number	Most favored nation (MFN) 12/31/97	Non-MFN[4] 12/31/97
Unwrought (in coils)	7601.10.3000	2.6% ad val.	18.5% ad val.
Unwrought (other than aluminum alloys)	7601.10.6000	Free	11.0% ad val.
Waste and scrap	7602.00.0000	Free	Free.

Depletion Allowance: None.[1]

Government Stockpile:

Stockpile Status—9-30-97[5]

Material	Uncommitted inventory	Committed inventory	Authorized for disposal	Disposal plan FY 1997	Disposals FY 1997
Aluminum	9	5	9	57	48

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ALUMINUM

Events, Trends, and Issues: Domestic primary aluminum production remained relatively stable in 1997. Domestic smelters continued to operate at about 85% of engineered or rated capacity.

U.S. imports for consumption increased in 1997, reversing the downward trend that began in 1995. Although Russia remained second only to Canada as a major shipper of aluminum materials to the United States, the level of its shipments has declined over the last few years from the record high level reached in 1994 and appears to have stabilized at about 400,000 tons of aluminum per year.

The 1997 Defense Authorization Act authorized the Defense Logistics Agency to sell the entire inventory of 57,045 tons (62,882 short tons) of aluminum metal from the National Defense Stockpile. Sales began on April 15, and, by the end of October, the entire inventory had been sold.

The price of primary aluminum ingot in the United States fluctuated within the range of 75 to 80 cents per pound during most of the year. In January, the average monthly U.S. market price for primary ingot quoted by Platt's Metals Week was 76.1 cents per pound; by August the price had risen to 80.1 cents per pound. However, there were indications that the price would turn downward again in September. Prices on the London Metal Exchange (LME) followed the trend of the U.S. market prices. The monthly average LME cash price for August was 77.6 cents per pound. Prices in the aluminum scrap markets paralleled the general trend of primary ingot prices. The buying price for aluminum used beverage can scrap, as quoted by American Metal Market, increased from a 53- to 54-cent-per-pound range in January to a 59- to 60-cent-per-pound range at the end of August.

World production increased as producers continued to bring back on-stream primary capacity that had been temporarily idled and to start-up new capacity expansions. Inventories of metal held by producers, as reported by the International Primary Aluminium Institute, declined slightly during the first half of 1997. Inventories of metal held by the LME also declined during the same period before beginning to increase in August.

World Smelter Production and Capacity:

	Production		Yearend capacity	
	1996	1997[e]	1996	1997[e]
United States	3,577	3,600	4,200	4,200
Australia	1,372	1,390	1,450	1,570
Brazil	1,190	1,200	1,210	1,220
Canada	2,282	2,300	2,280	2,290
China	1,780	1,800	1,750	1,800
France	365	400	430	430
Norway	874	880	924	953
Russia	2,800	2,880	2,970	2,970
South Africa	620	670	578	666
Venezuela	600	630	635	638
Other countries	5,210	5,400	6,450	6,650
World total (rounded)	20,700	21,200	22,900	23,400

World Resources: Domestic aluminum requirements cannot be met by domestic bauxite resources. Potential domestic nonbauxitic aluminum resources are abundant and could meet domestic aluminum demand. However, no processes for using these resources have been proven economically competitive with those now used for bauxite. The world reserve base for bauxite is sufficient to meet world demand for metal well into the 21st century.

Substitutes: Copper can replace aluminum in electrical applications; magnesium, titanium, and steel can substitute for aluminum in structural and ground transportation uses. Composites, wood, and steel can substitute for aluminum in construction. Glass, plastics, paper, and steel can substitute for aluminum in packaging.

[e]Estimated.
[1]See also Bauxite.
[2]Domestic primary metal production + recovery from old aluminum scrap + net import reliance.
[3]Defined as imports - exports + adjustments for Government and industry stock changes.
[4]See Appendix B.
[5]See Appendix C for definitions.