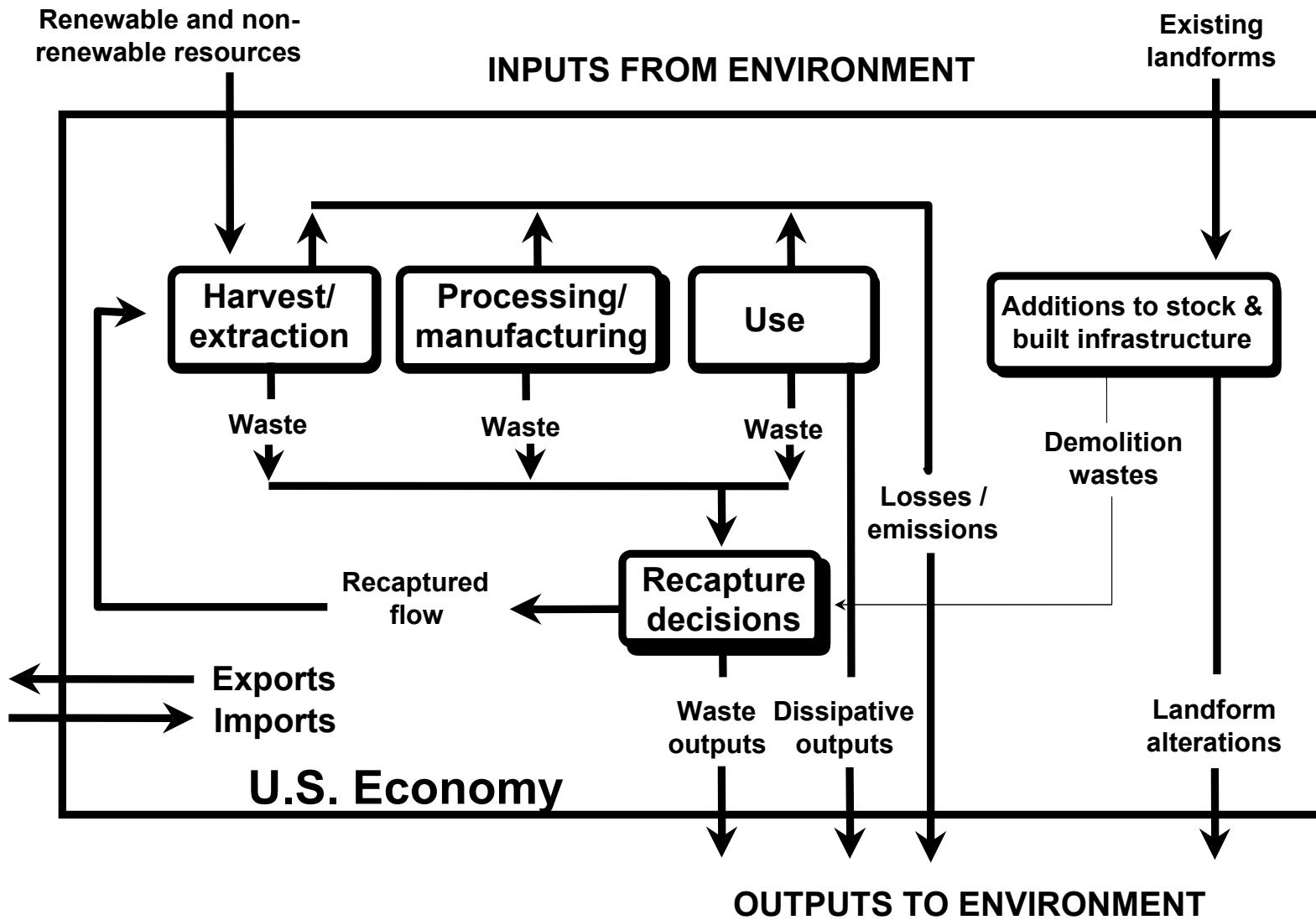


Metals Use in Relation to Aggregate Material Flows and Sustainable Development

Donald G. Rogich

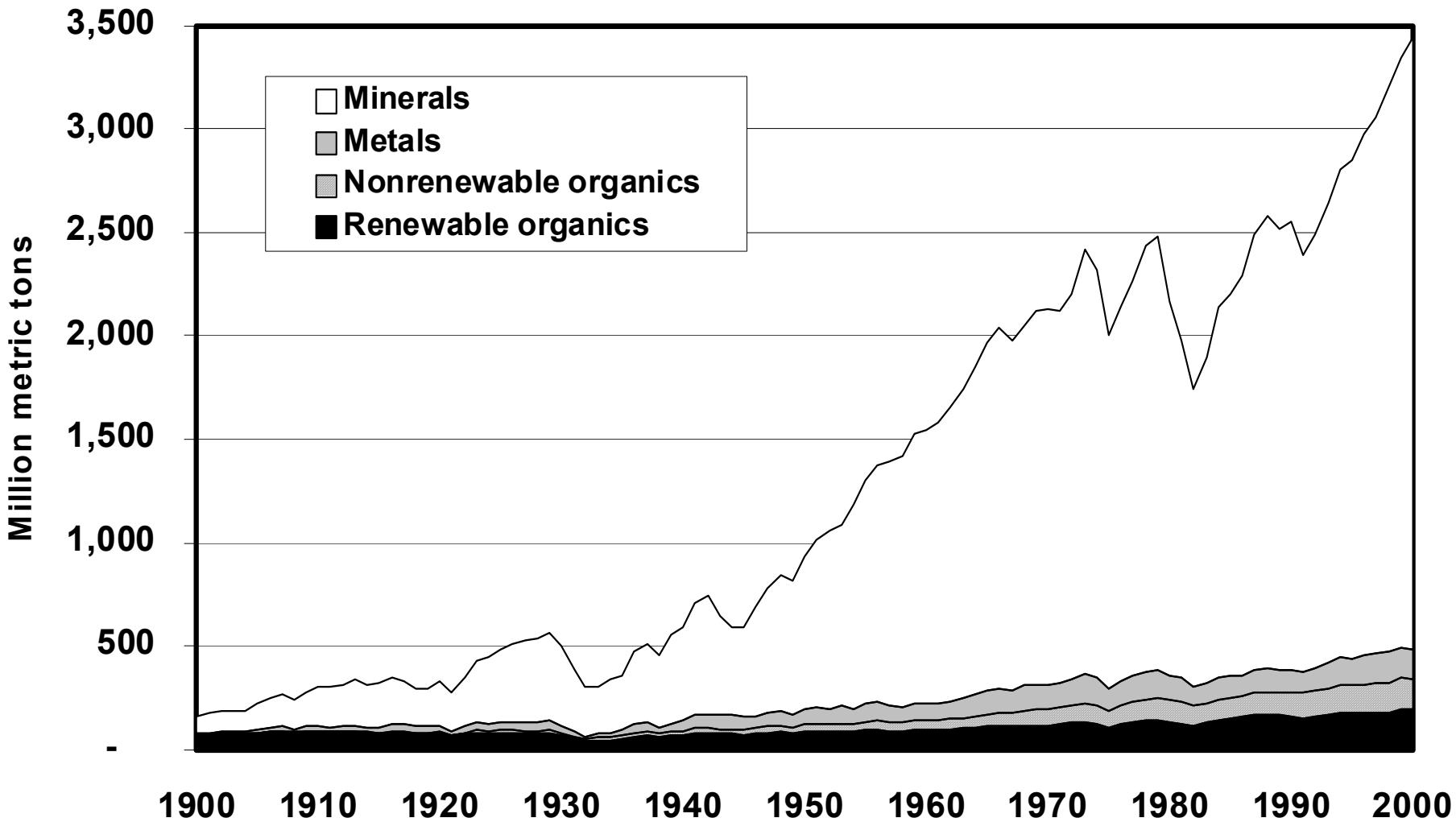
The Material Cycle



Human Induced Material Flows Associated With

- Food
- Physical goods
- Energy
- Construction and maintenance of built infrastructure

Processed Flows for Physical Goods in the United States During the Twentieth Century

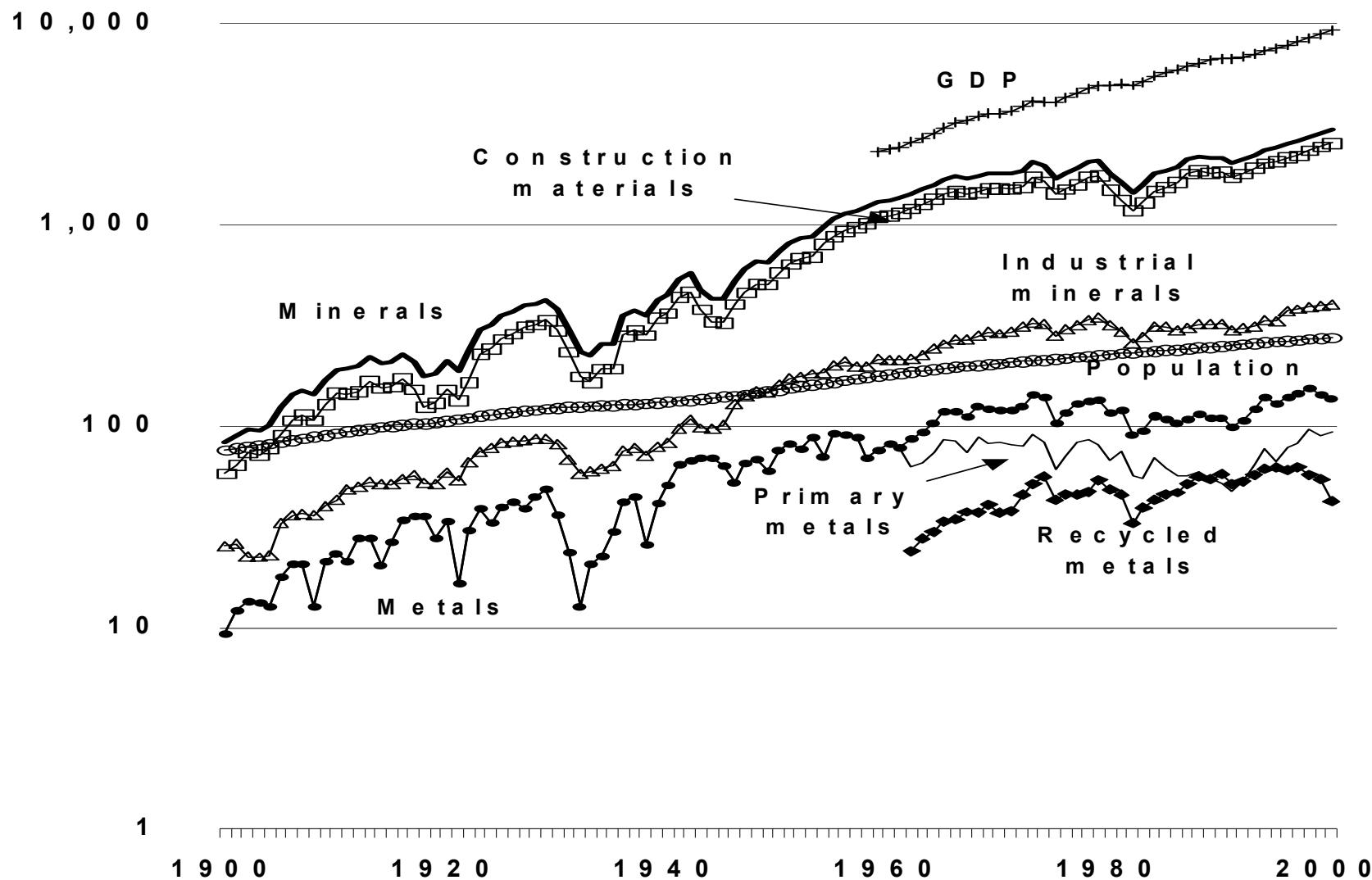


Material Flows for Physical Goods

- Minerals
- Metals
- Renewable organic material
- Nonrenewable organic material

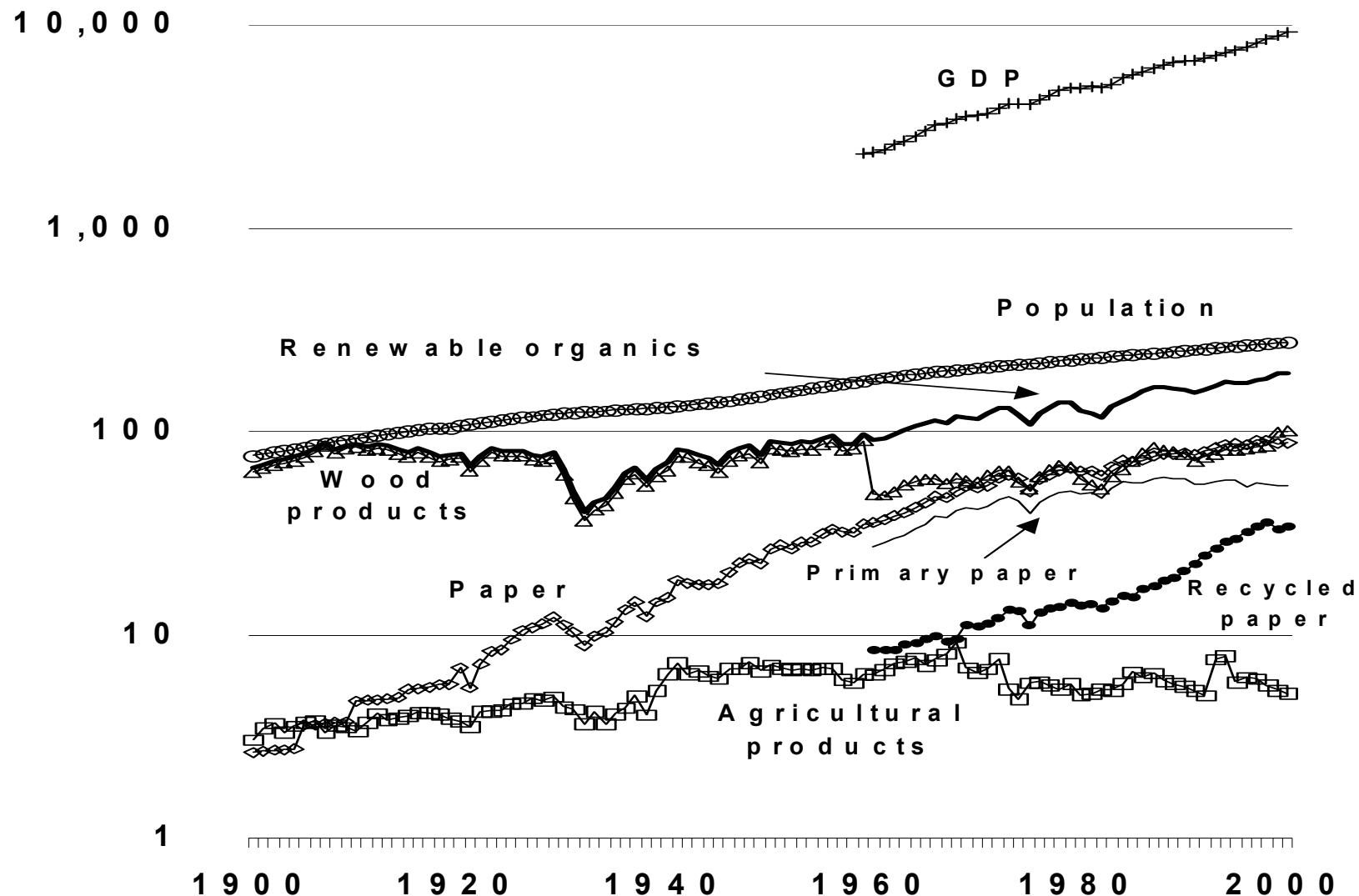
Physical Goods Derived from Metals and Minerals

Million metric tons and people, billion of chained \$1996

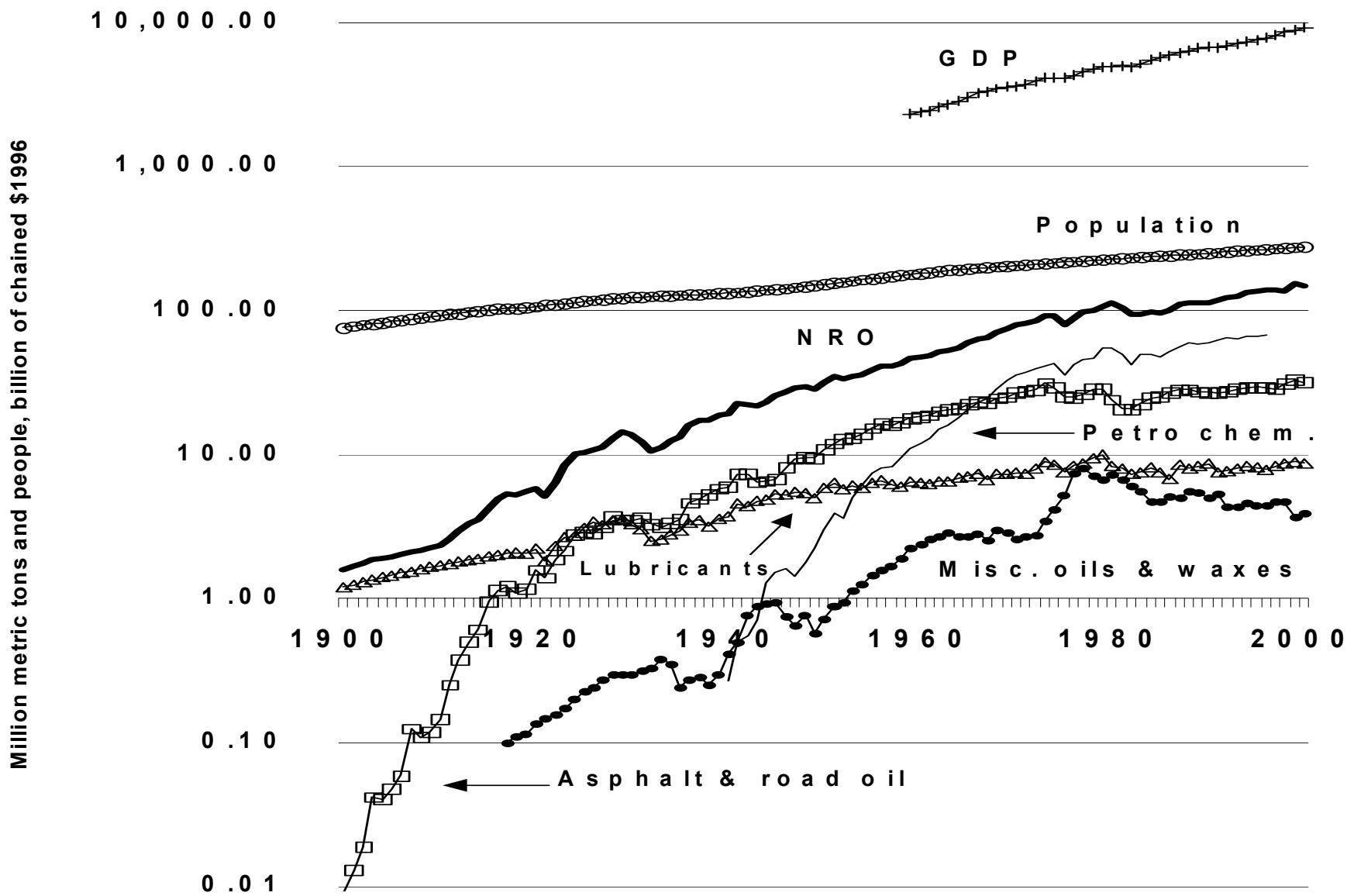


Physical Goods Derived from Renewable Organic Forest and Agricultural Sources

Million metric tons and people, billion of chained \$1996



Physical Goods Derived from Nonrenewable Organic Sources



Per Capita Sources of Physical Goods in the US, 1900 and 2000

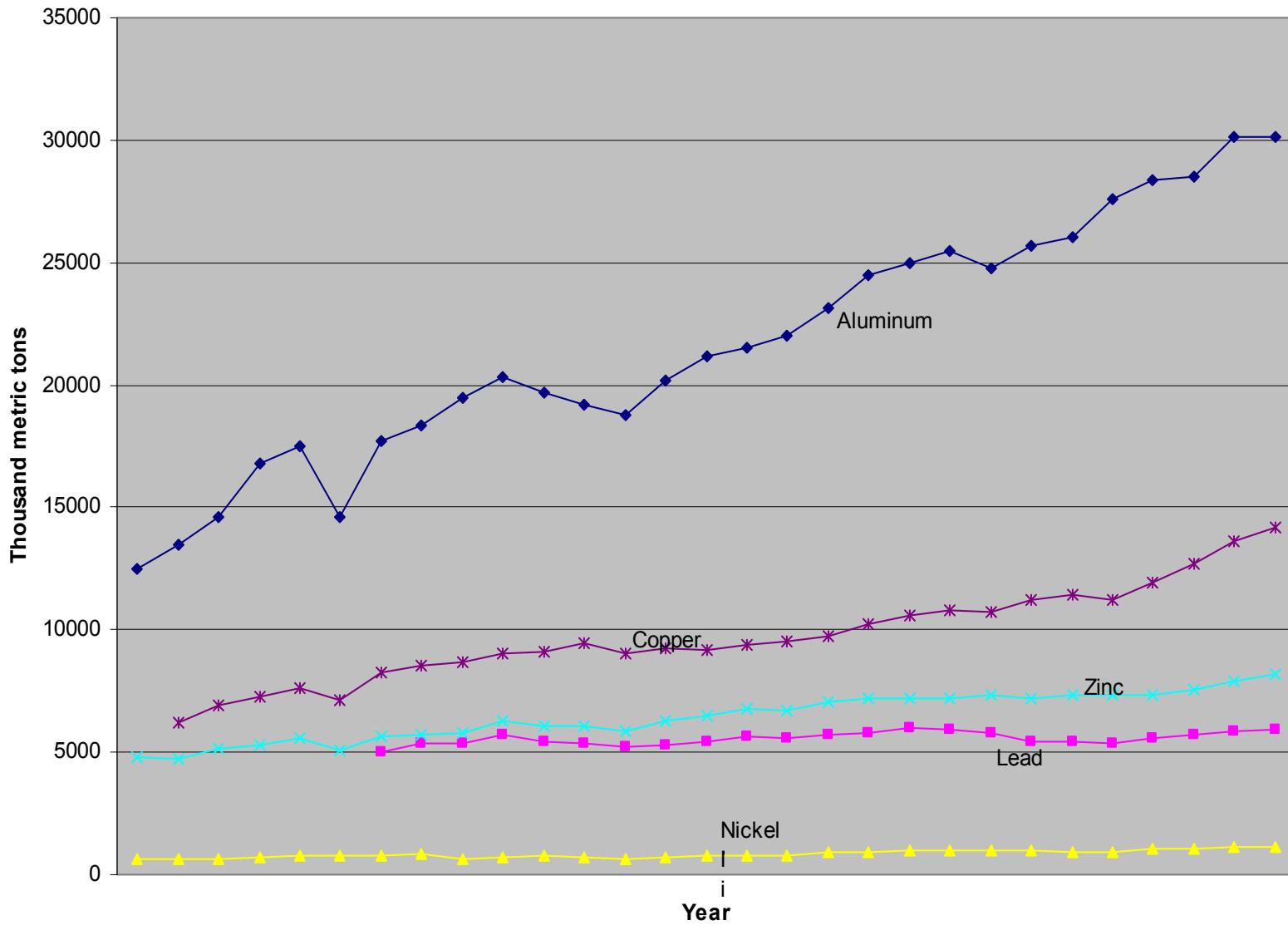
	Per capita use 1900	Per capita use 2000
Minerals	1.1	10.5
Metals	0.1	0.5
NRO	0.0	0.5
Renewable org.	0.9	0.7
All sources	2.1	12.2

1996 US and World Use of Physical Goods by Source Category

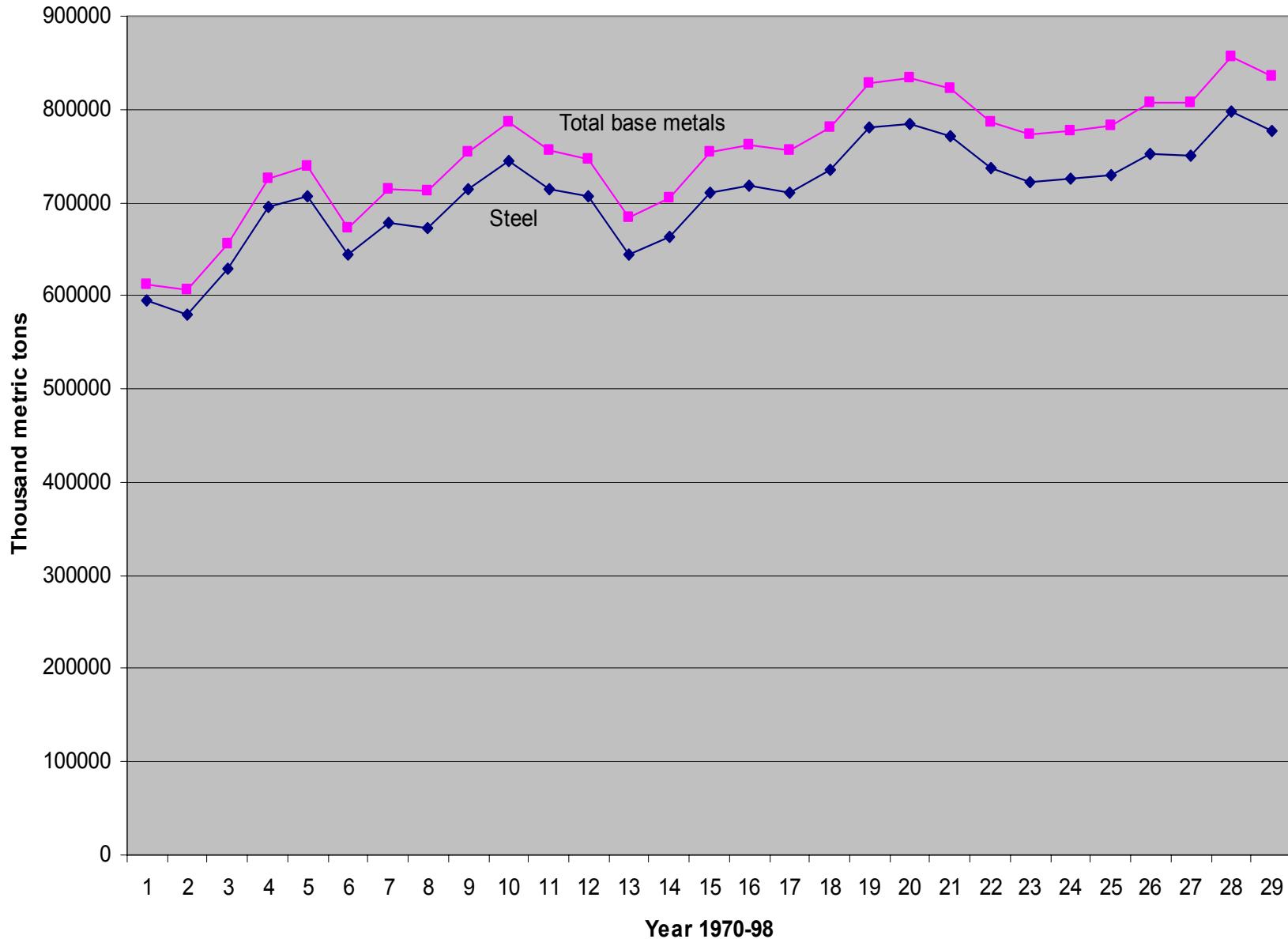
Mt per capita	Minerals	Metals	Forest	NRO	Agric.	Total
World	1.39	0.14	0.13	0.05	0.01	1.71
US	9.52	0.53	0.63	0.44	0.02	11.14
US/World	6.86	3.78	4.85	10.40	2.00	6.68

Hidden and Processed Material Flows in the United States											
(000) metric tons and metric tons per capita											
Years	Population			Hidden Flows							
		Total Hidden Flows	Total MFA/Capita	Hidden flows per capita	Minerals, mining overburden and waste	Coal, mining overburden and waste	Earth moving for infrastructure creation	Dredging	Erosion	Other	
1975	215,973	17,192,354	97	80	6.5	23.4	18.3	2.6	25.6	3.3	
1976	218,035	17,539,492	99	80	6.6	24.2	18.9	2.4	25.1	3.3	
1977	220,239	17,662,095	99	80	6.0	26.6	17.3	2.3	24.6	3.5	
1978	222,585	17,093,056	96	77	6.6	25.7	14.6	2.2	24.1	3.5	
1979	225,055	17,450,954	97	78	7.0	25.3	15.7	2.2	23.6	3.8	
1980	227,726	17,385,206	94	76	6.2	26.0	15.3	2.2	23.1	3.4	
1981	229,966	17,520,339	92	76	6.6	26.0	15.7	2.6	22.7	2.5	
1982	232,188	16,857,076	87	73	4.4	25.2	14.9	2.1	22.3	3.8	
1983	234,307	15,759,806	83	67	4.8	22.1	14.4	2.1	21.1	2.7	
1984	236,348	16,786,692	87	71	5.1	24.8	15.1	2.4	20.1	3.6	
1985	238,466	15,910,969	83	67	5.1	22.7	13.9	2.2	19.1	3.8	
1986	240,651	15,928,483	83	66	4.9	23.2	14.3	2.2	18.1	3.5	
1987	242,804	15,780,427	82	65	5.4	23.3	13.3	1.9	17.9	3.3	
1988	245,021	15,824,197	82	65	7.0	23.9	11.9	2.0	17.0	2.7	
1989	247,342	16,616,678	85	67	8.0	24.0	13.4	2.3	16.2	3.2	
1990	249,913	16,765,680	84	67	8.9	24.1	13.3	1.9	15.4	3.4	
1991	252,650	16,176,599	80	64	9.1	22.8	12.2	2.0	14.7	3.2	
1992	255,419	16,504,327	81	65	9.3	22.6	13.0	1.7	14.4	3.6	
1993	258,137	15,727,375	78	61	9.0	22.0	11.5	1.8	13.7	2.9	
1994	260,660	16,050,117	79	62	9.2	22.7	10.9	2.0	13.1	3.7	
1995	263,034	15,904,228	78	60	9.4	22.4	11.0	1.7	13.0	3.1	
1996	265,455	16,332,950	79	62	9.3	22.6	11.7	1.7	12.8	3.3	
Processed Flows											
Years	Total processed flows	processed flows per capita	Fuels all types	Physical goods	Agricultural flows						
1975	3,703,891	17	7.4	9.0	0.7						
1976	3,963,850	18	7.8	9.6	0.8						
1977	4,076,242	19	7.8	10.0	0.7						
1978	4,282,562	19	7.9	10.7	0.7						
1979	4,320,089	19	7.9	10.6	0.7						
1980	3,956,883	17	7.5	9.1	0.7						
1981	3,739,530	16	7.2	8.4	0.7						
1982	3,459,020	15	6.9	7.4	0.7						
1983	3,609,936	15	6.8	7.9	0.7						
1984	3,883,918	16	7.0	8.8	0.7						
1985	3,955,657	17	7.0	9.0	0.7						
1986	4,039,204	17	7.1	9.1	0.7						
1987	4,243,577	17	7.3	9.6	0.6						
1988	4,380,729	18	7.6	9.6	0.7						
1989	4,286,094	17	7.6	9.1	0.6						
1990	4,188,495	17	7.2	8.9	0.6						
1991	3,953,315	16	7.2	7.8	0.6						
1992	4,205,100	16	7.3	8.5	0.6						
1993	4,339,536	17	7.2	8.9	0.6						
1994	4,589,761	18	7.8	9.2	0.7						
1995	4,625,867	18	7.8	9.1	0.7						

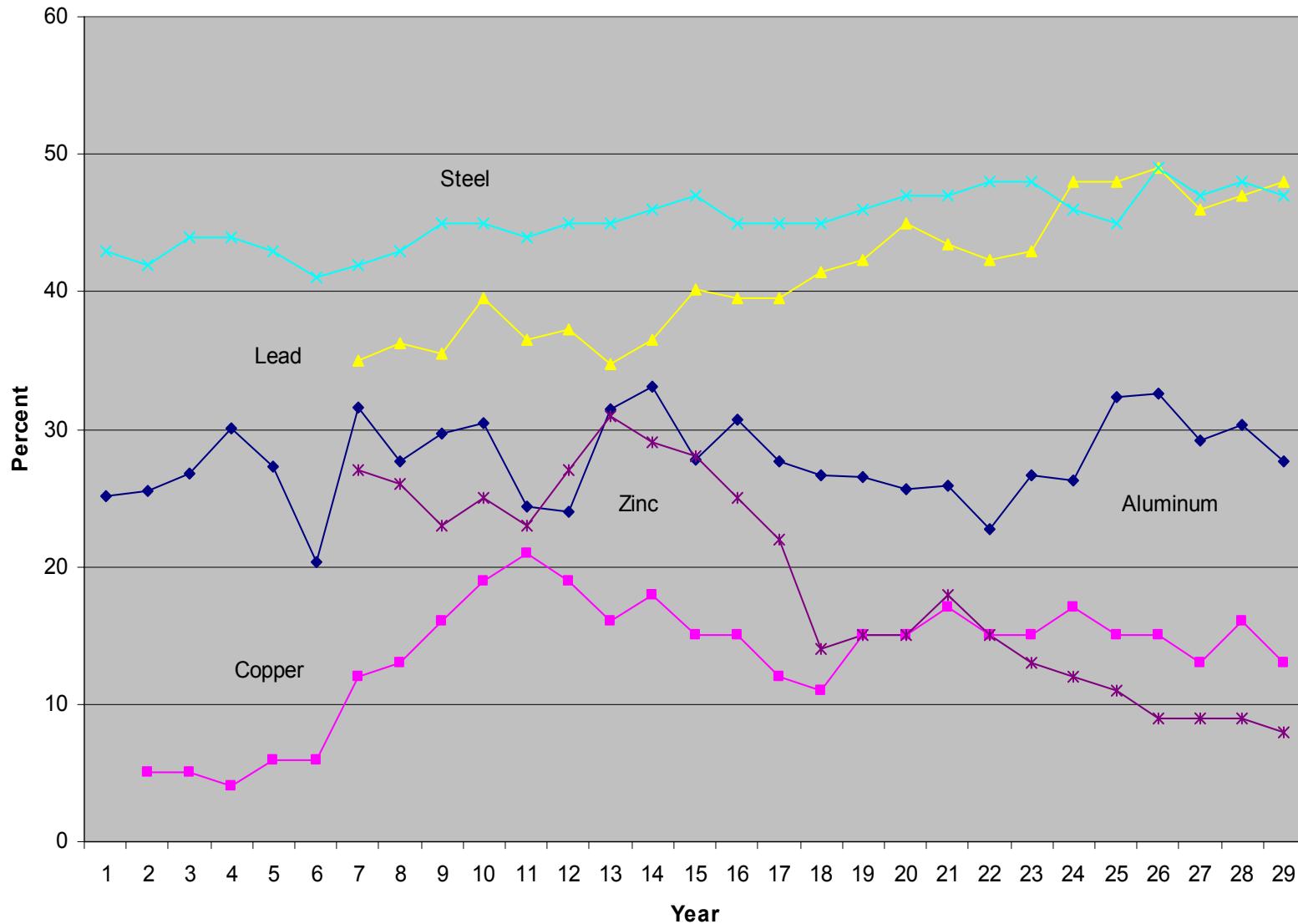
World Production of Base Metals from Primary and Secondary Resources



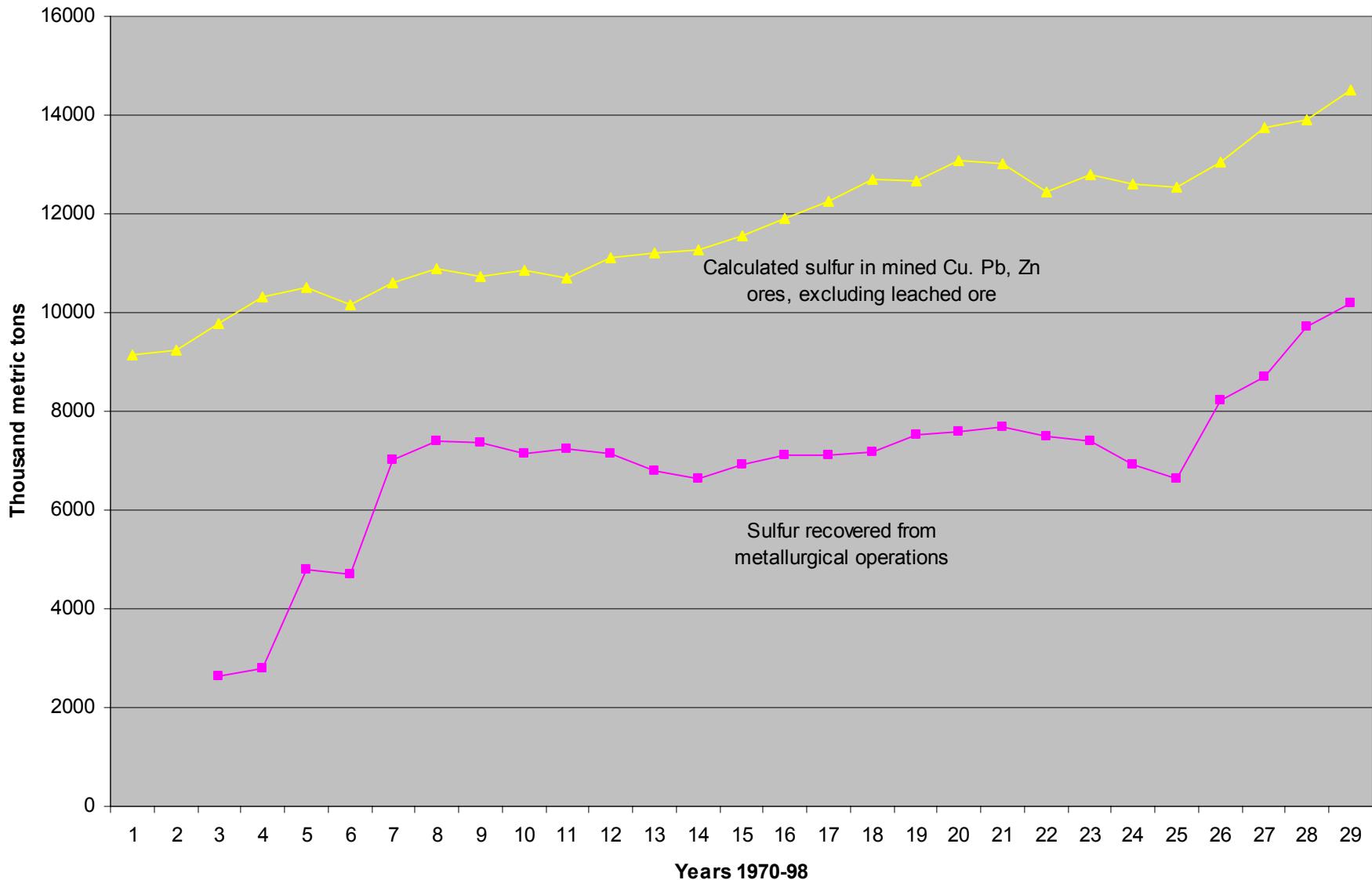
World Production of Base Metals from Primary and Secondary Resources



Calculated World Production from Secondary Resources



World Recovery of Sulfur From Nonferrous Ores



Estimated World Base Metal Hidden Flows, (tons/ton 1998)

Metal	Over-burden Dev. rock	Milling	Smelting	Refining	Total
Al	4		3	1	8
Cu	208	123	2.7	0.01	334
Pb	2	7	1		10
Ni	10.2	38.7	6.5		55
Fe	4	1	1		6
Zn	4	19	1		24

Table

Base Metals Use 1970 and 1998

	Per capita								Per capita	Per capita		
	Consumption	tons	1970							tons	ratio	
	mt (1000)	per 1000								mt (1000)	per 1000	US/World
	US	US								World	World	
Aluminum	4425	21.6								12503	3.4	6.4
Copper	1860	9.1								6100	1.6	5.5
Lead*	1272	6.2								5043	1.4	4.6
Nickel	149	0.7								628	0.2	4.3
Steel	107850	526.1								594415	160.7	3.3
Zinc	1074	5.2								4827	1.3	4.0
Total	116630	568.9								623516	168.5	3.4
Population millions		205									3700	
Lead data are for 1976												
	Consumption		1998							Per capita	Per capita	
	Consumption	mt (1000)	Per capita mt per 1000							mt (1000)	mt/1000	ratio
	US	US	Canada	France	Germany	Japan	U.K.			World	World	US/World
Aluminum	7090	26.3	27.6	16.4	24.0	25.7	16.3			30106	5.1	5.1
Copper	3030	11.2	8.0	10.0	13.9	10.0	6.5			14200	2.4	4.7
Lead	1630	6.0	2.0	4.2	4.4	2.6	4.8			5940	1.0	6.0
Nickel	186	0.7	0.3	0.9	1.1	1.2	0.5			1130	0.2	3.6
Steel	138700	513.7	500.0	297.7	436.5	558.4	252.9			776000	131.5	3.9
Zinc	1580	5.9	5.5	4.9	7.0	5.2	3.3			8160	1.4	4.2
Total	152216	563.8	519.5	334.1	486.9	603.1	284.3			835536	141.6	4.0
		152216.0	15897.7	19644.8	39972.5	75926.9	16402.3					
Population millions		270	30.6	58.8	82.1	125.9	57.7				5900	

Finished steel consumption from International Iron and Steel Institute

Al, Cu, Pb, Ni, Zn consumption from Metalgesellschaft

Base Metals and Sustainability

- Global production continues to increase
- The percentage of supply derived from secondary resources appears to be decreasing
- Hidden flows are large and may increase if grades decline
- Considerable amounts of sulfur are still being released to the environment.
- Global consumption equity is not improving
- Global populations continue to increase
- Metals are the most recyclable materials we have