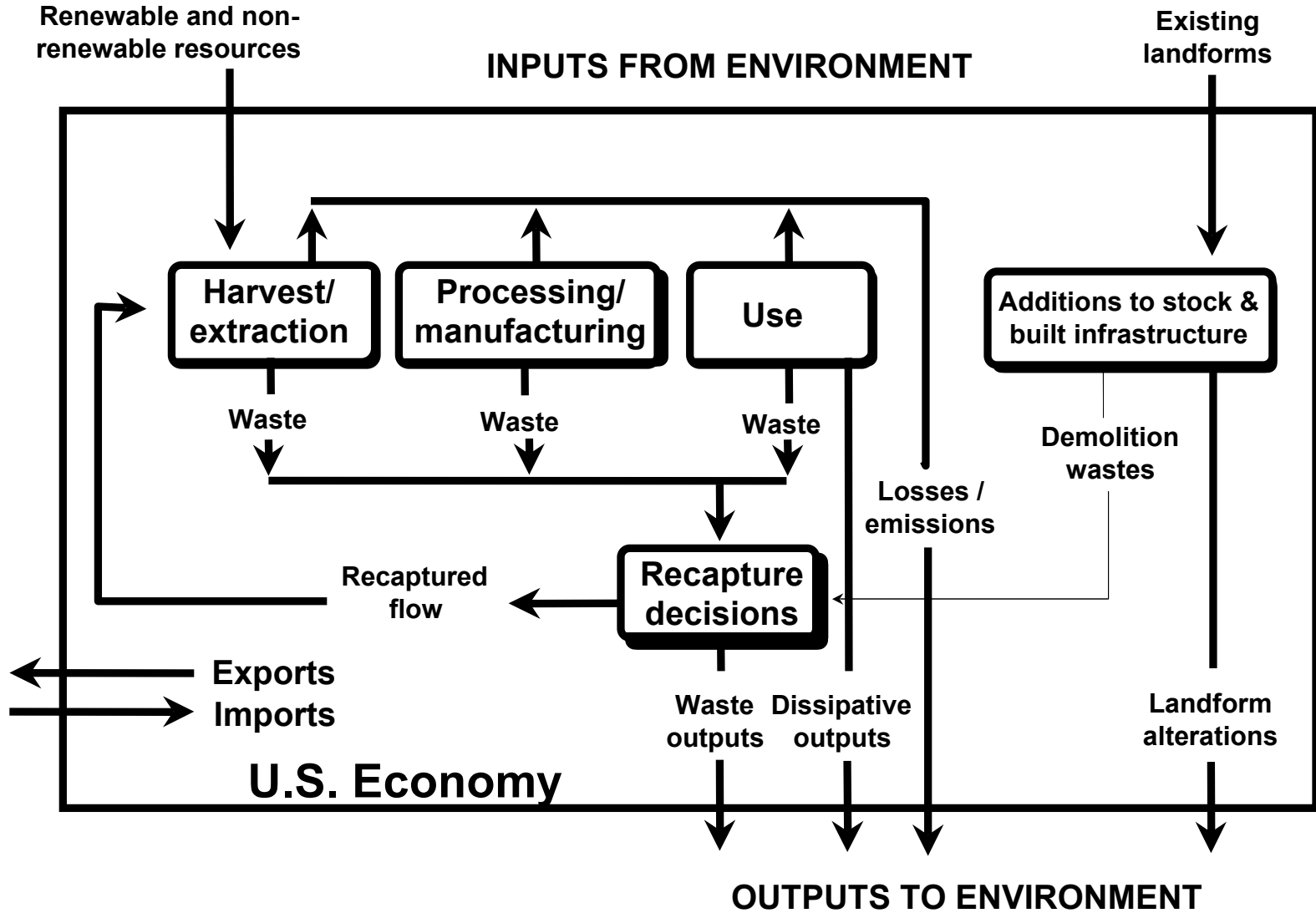


# Metals Use in Relation to Aggregate Material Flows and Sustainable Development

Donald G. Rogich

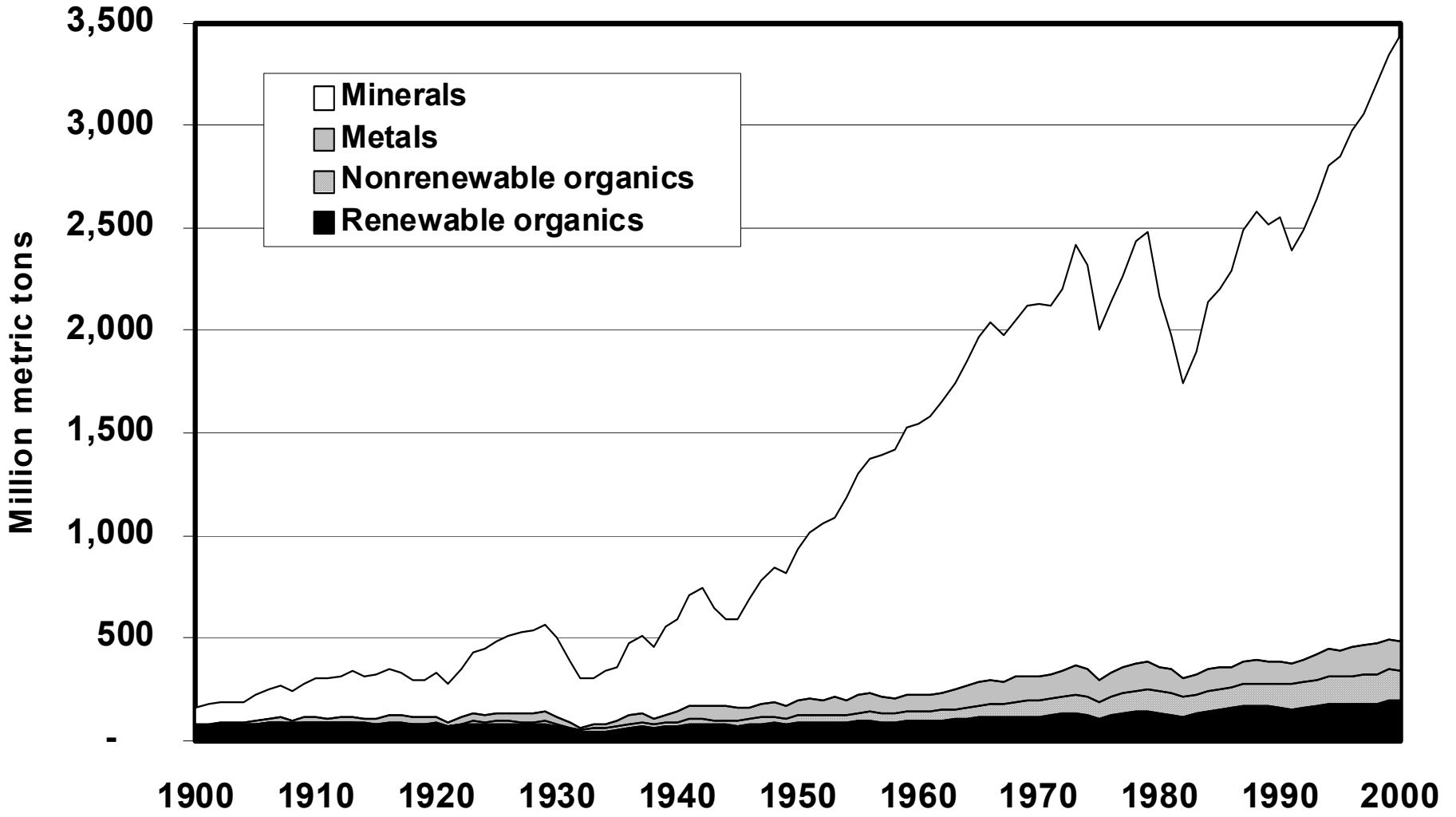
# *The Material Cycle*



# Human Induced Material Flows Associated With

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

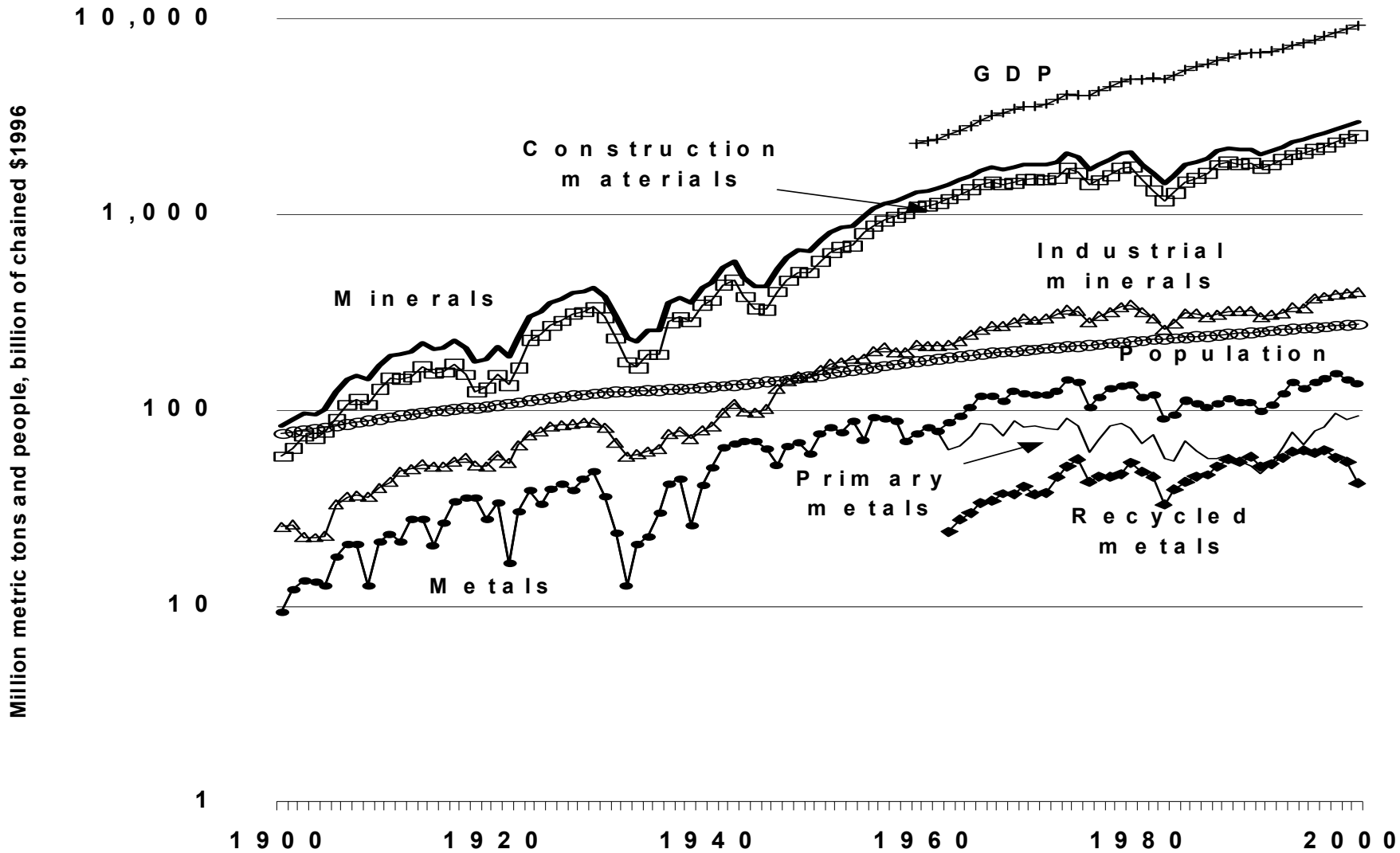
# Processed Flows for Physical Goods in the United States During the Twentieth Century



# Material Flows for Physical Goods

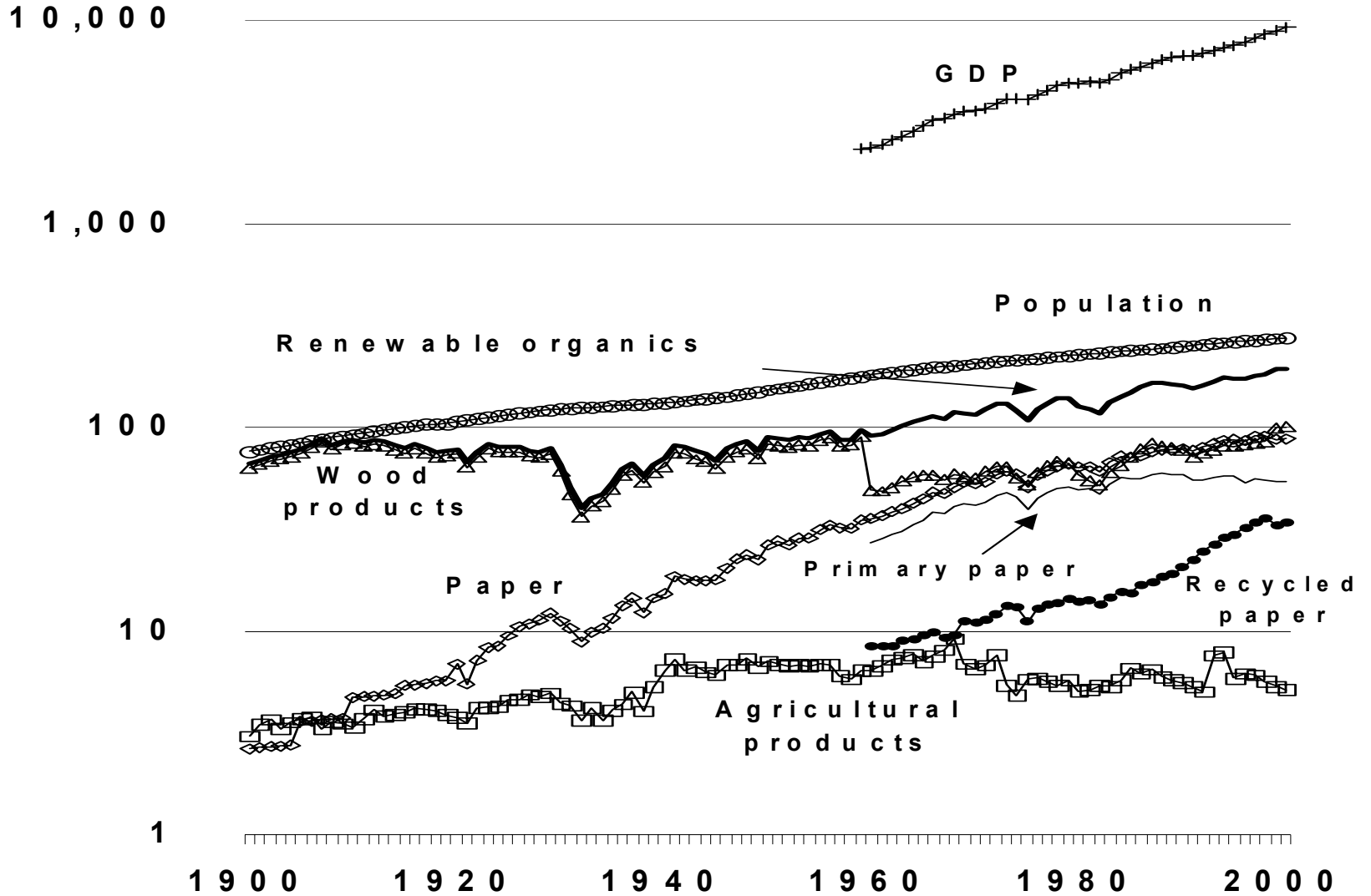
- Minerals
- Metals
- Renewable organic material
- Nonrenewable organic material

# Physical Goods Derived from Metals and Minerals

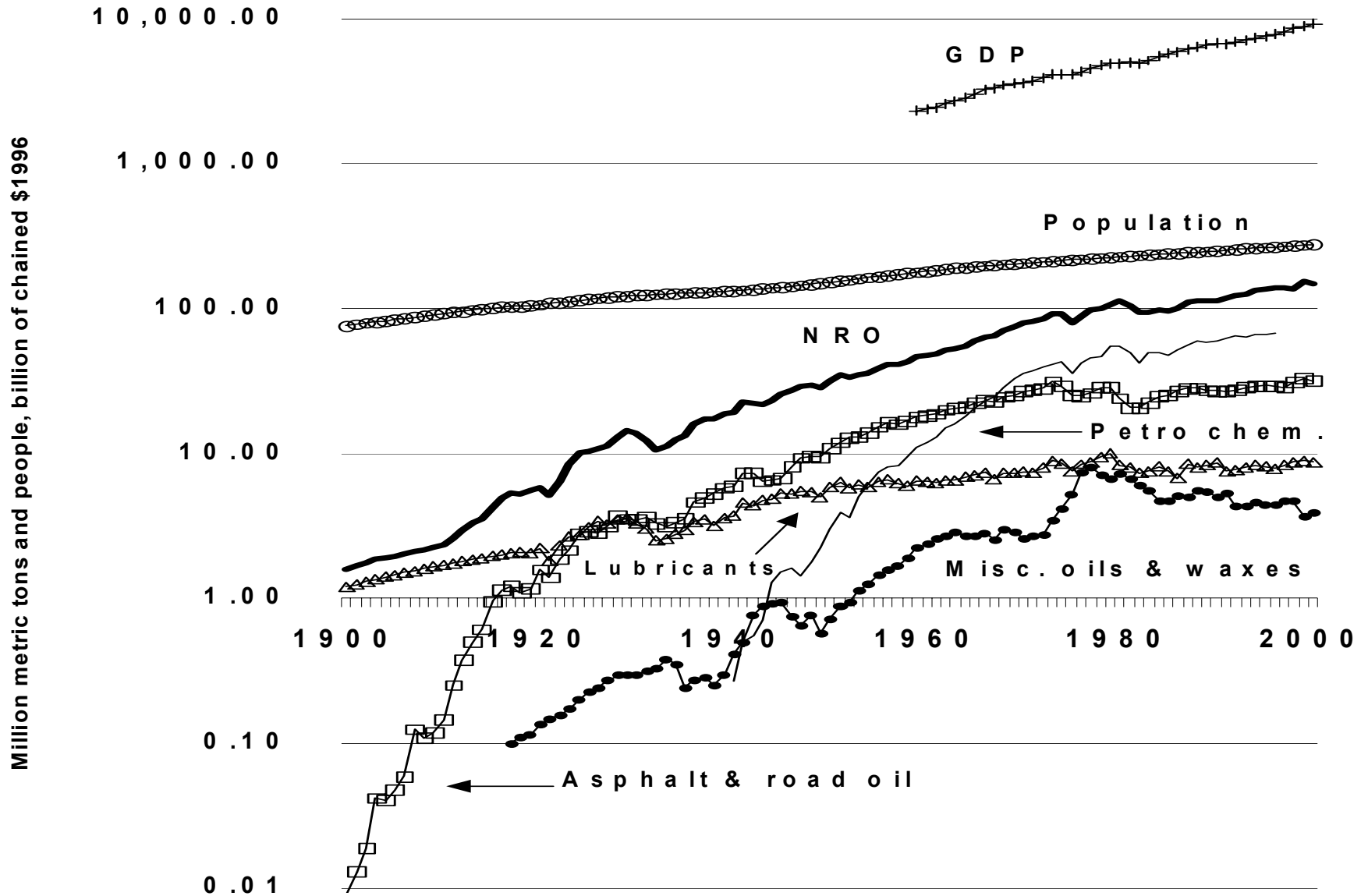


# Physical Goods Derived from Renewable Organic Forest and Agricultural Sources

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

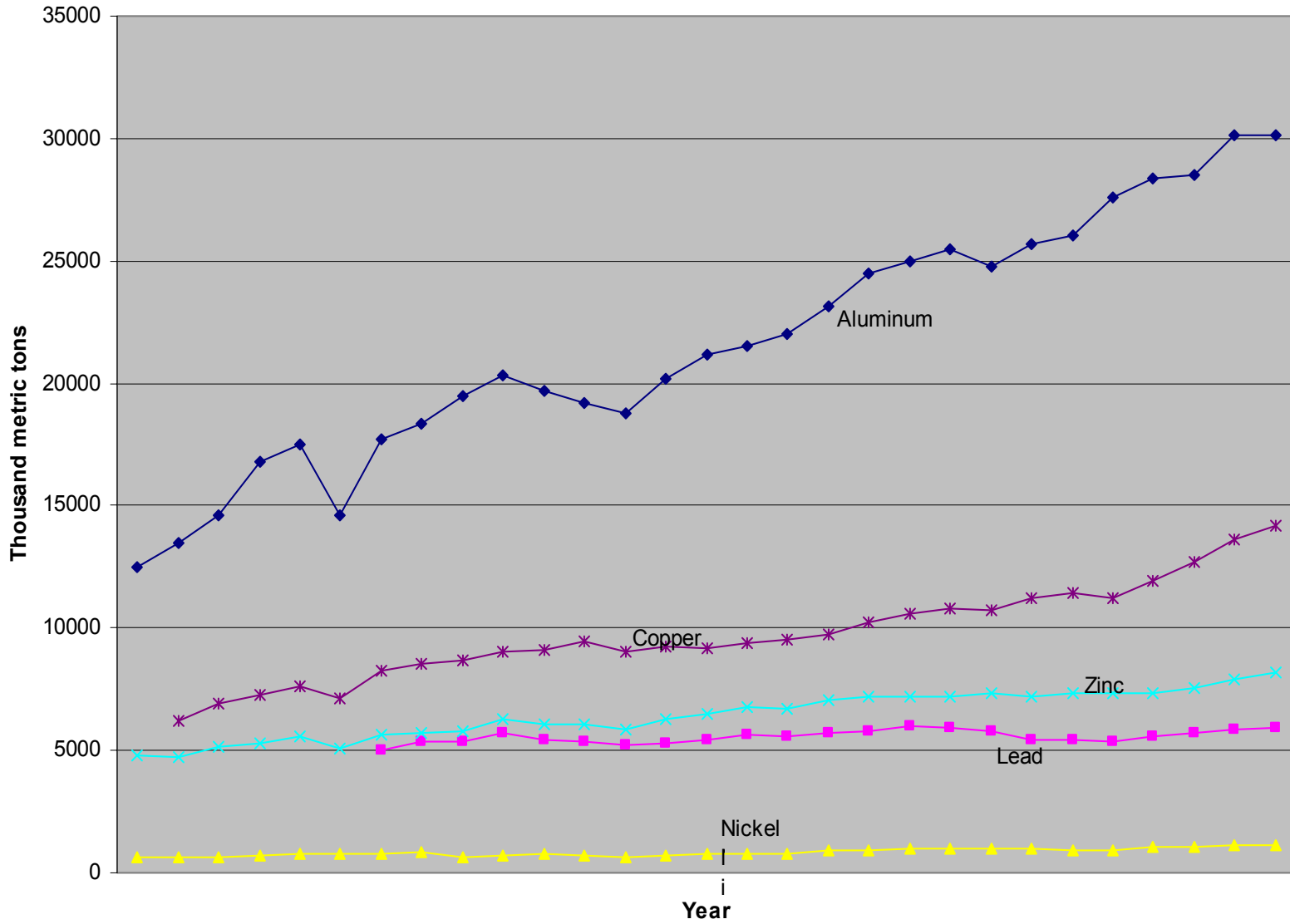
	Per capita use 1900	Per capita use 2000
Minerals	1.1	10.5
Metals	0.1	0.5
NRO	0.0	0.5
Renewable org.	0.9	0.7
All sources	2.1	12.2

# 1996 US and World Use of Physical Goods by Source Category

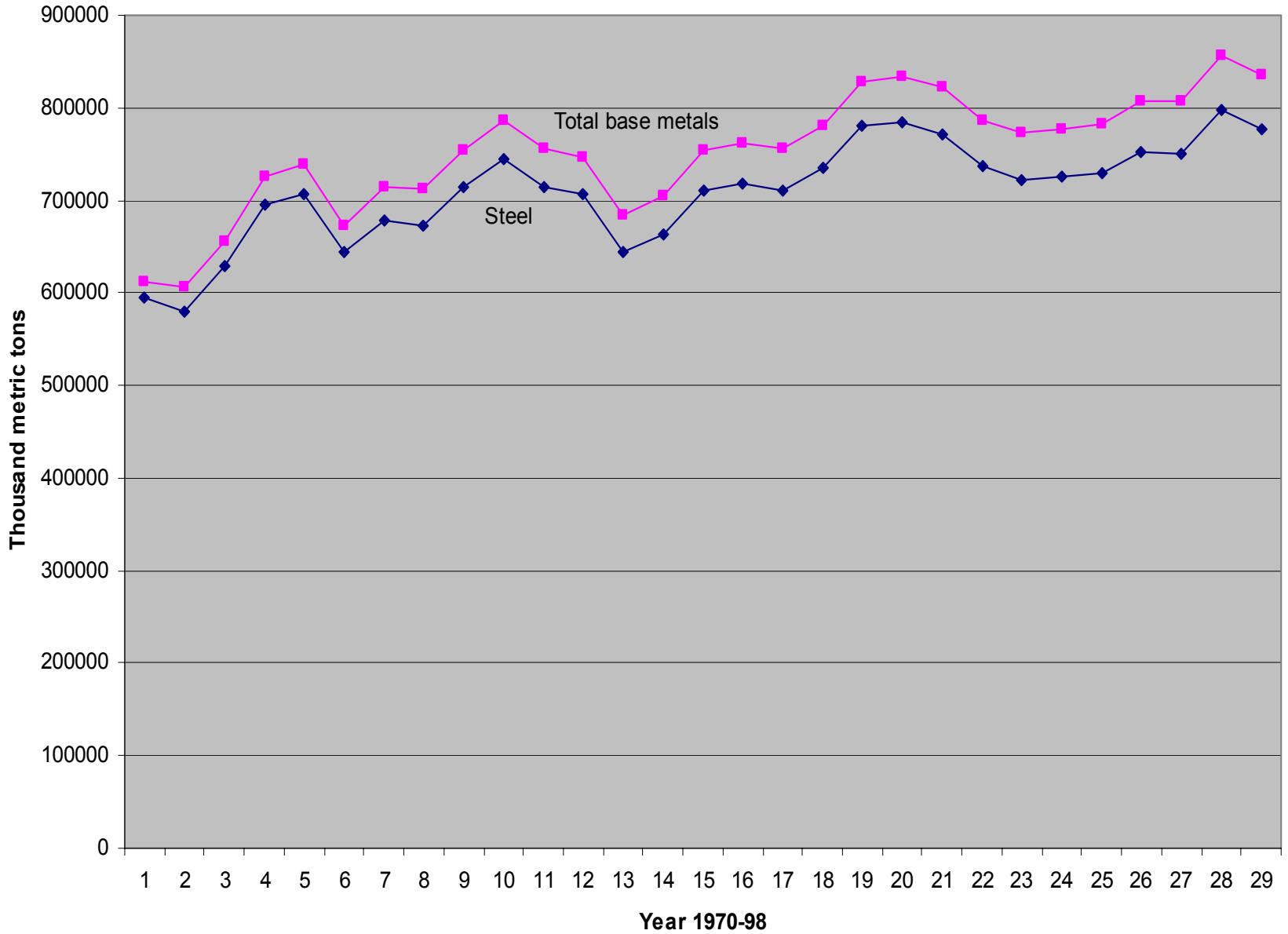
Mt per capita	Minerals	Metals	Forest	NRO	Agric.	Total
World	1.39	0.14	0.13	0.05	0.01	1.71
US	9.52	0.53	0.63	0.44	0.02	11.14
US/World	6.86	3.78	4.85	10.40	2.00	6.68

		Hidden and Processed Material Flows in the United States										
		(000) metric tons and metric tons per capita										
				Hidden Flows								
Years	Population	Total HiddenFlows	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	Agri-cultural 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							

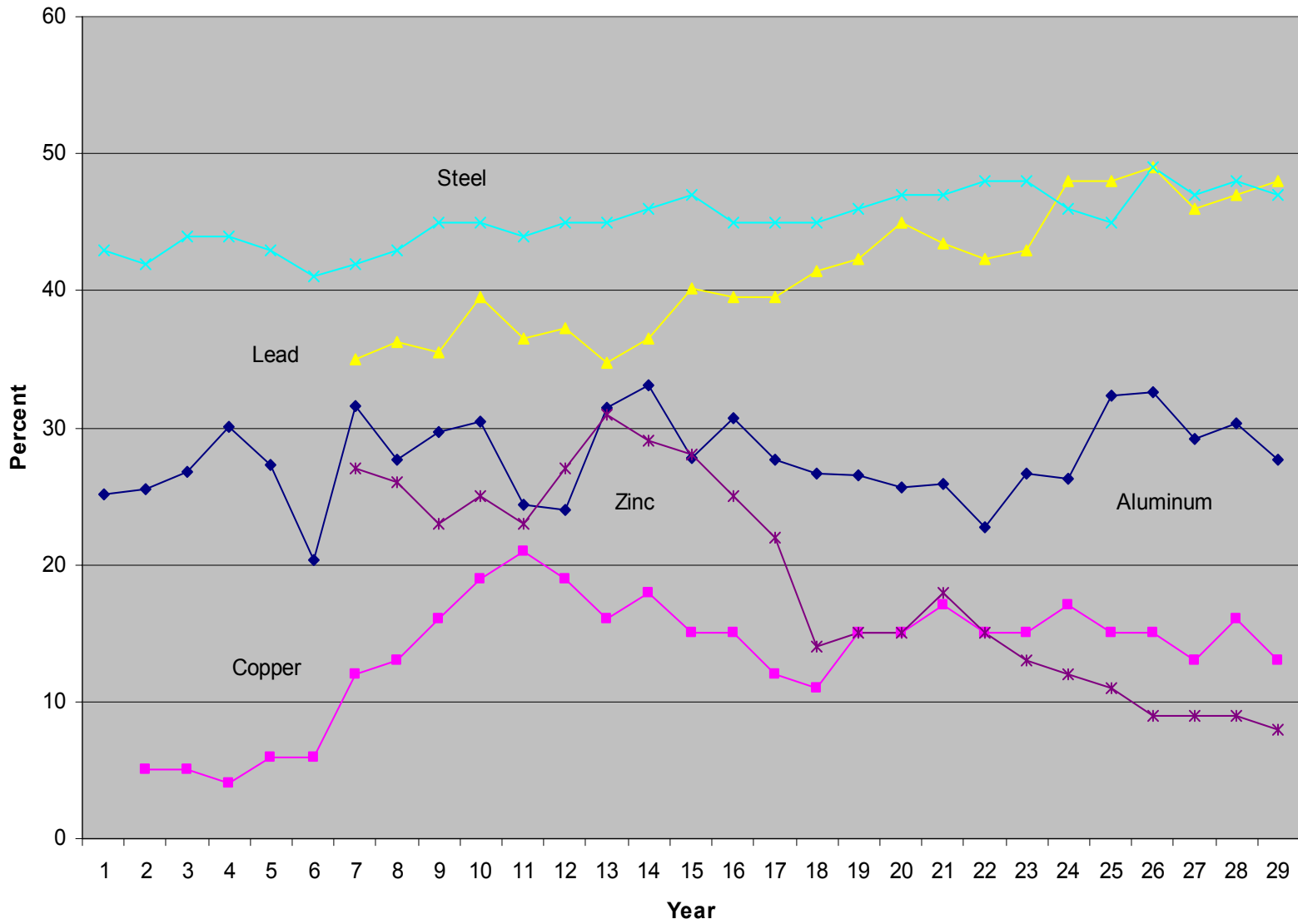
# World Production of Base Metals from Primary and Secondary Resources



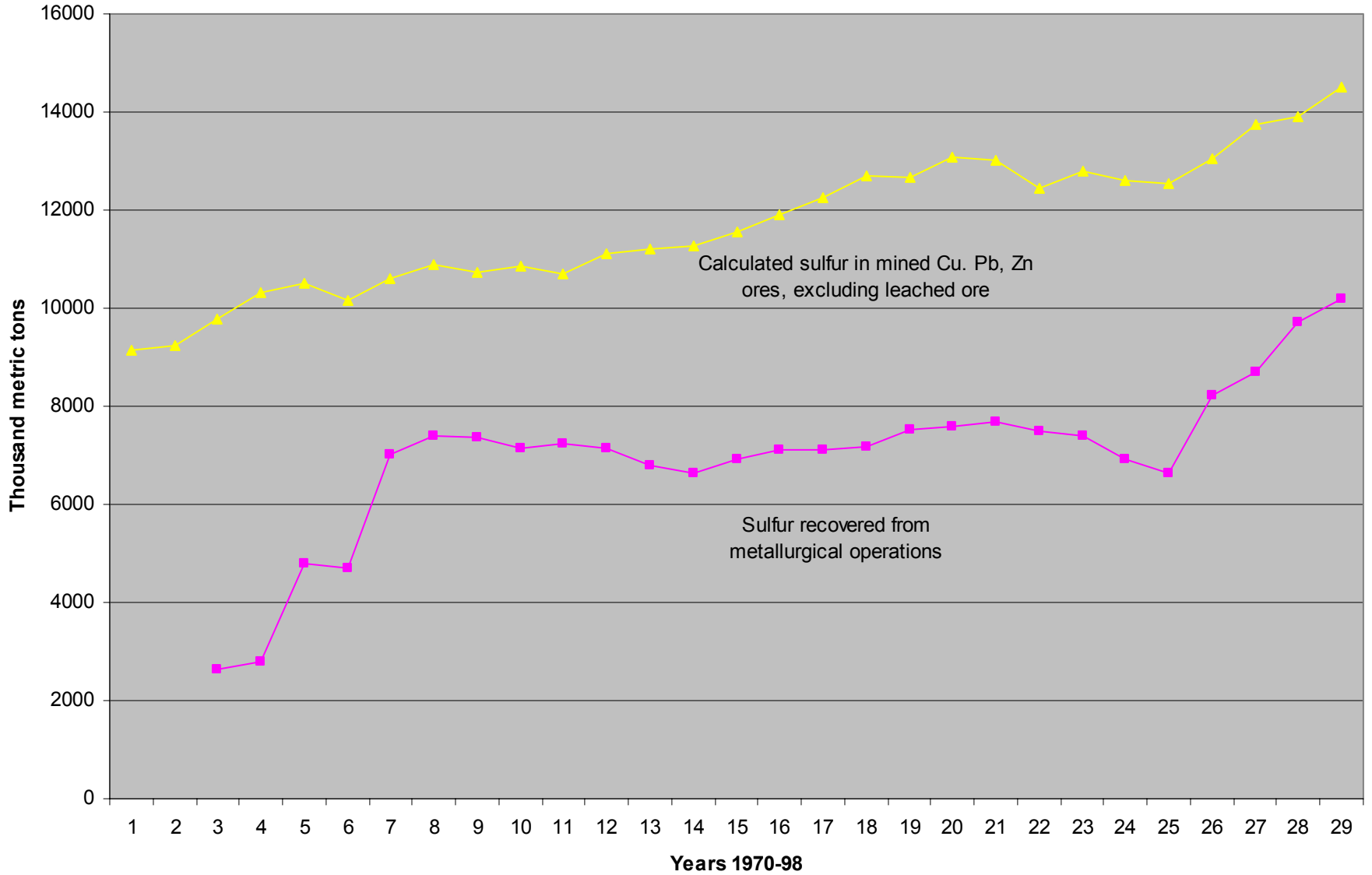
# World Production of Base Metals from Primary and Secondary Resources



### 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





# 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