7

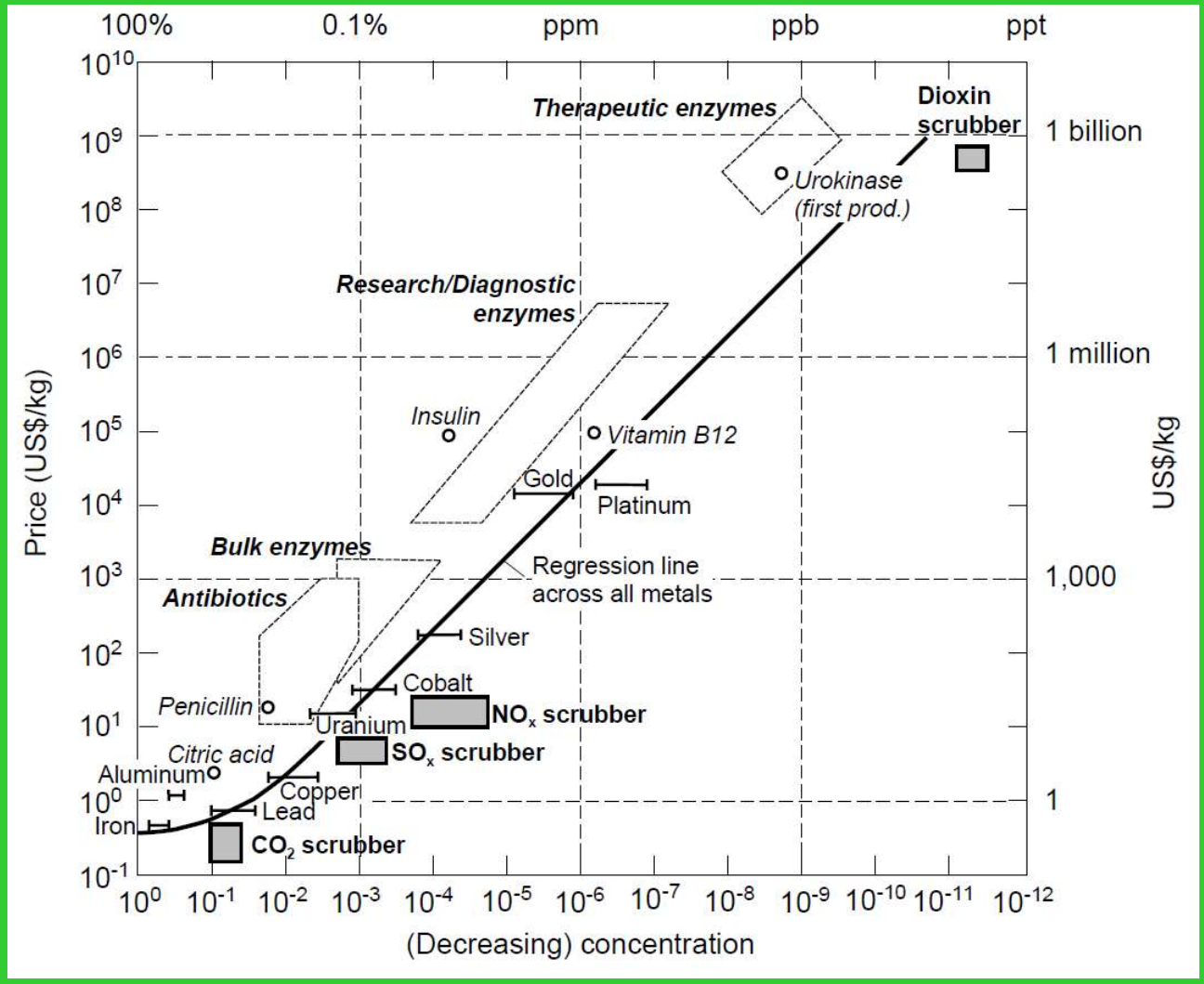
Case Study III

Industry: Do we “dematerialize”?

Industry: Some Basics

1. Price of materials/processing is a function of resource concentration and technological complexity
2. Organizational structure matters (impacts resource efficiency and transport)
3. Cost savings (labor, raw materials, energy..): “low hanging fruits” regrow
4. Money and time costly, so need to be “saved” as well

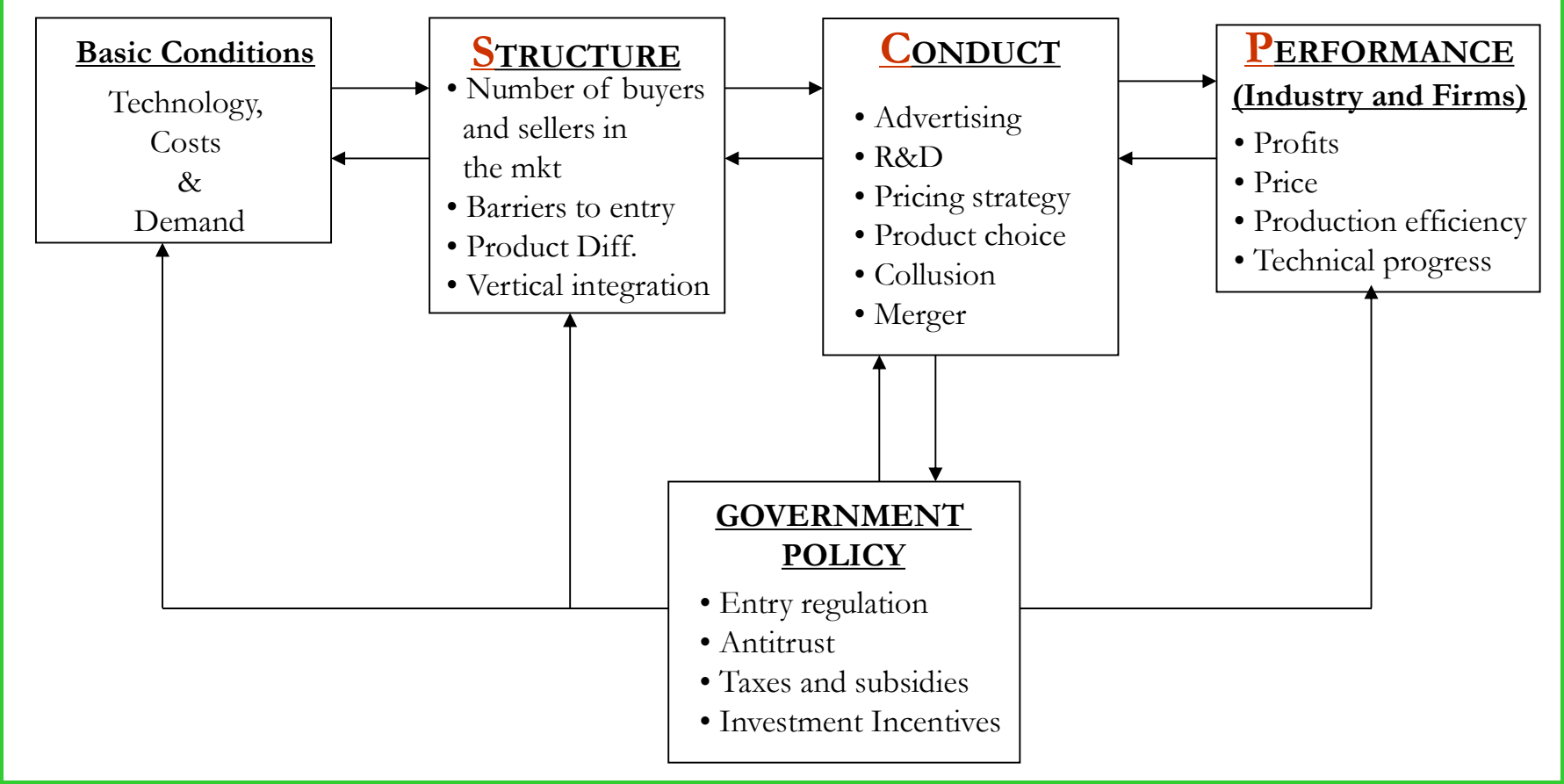
1. Price vs. Concentration of Materials



Technik & Umwelt

Arnulf Grübler

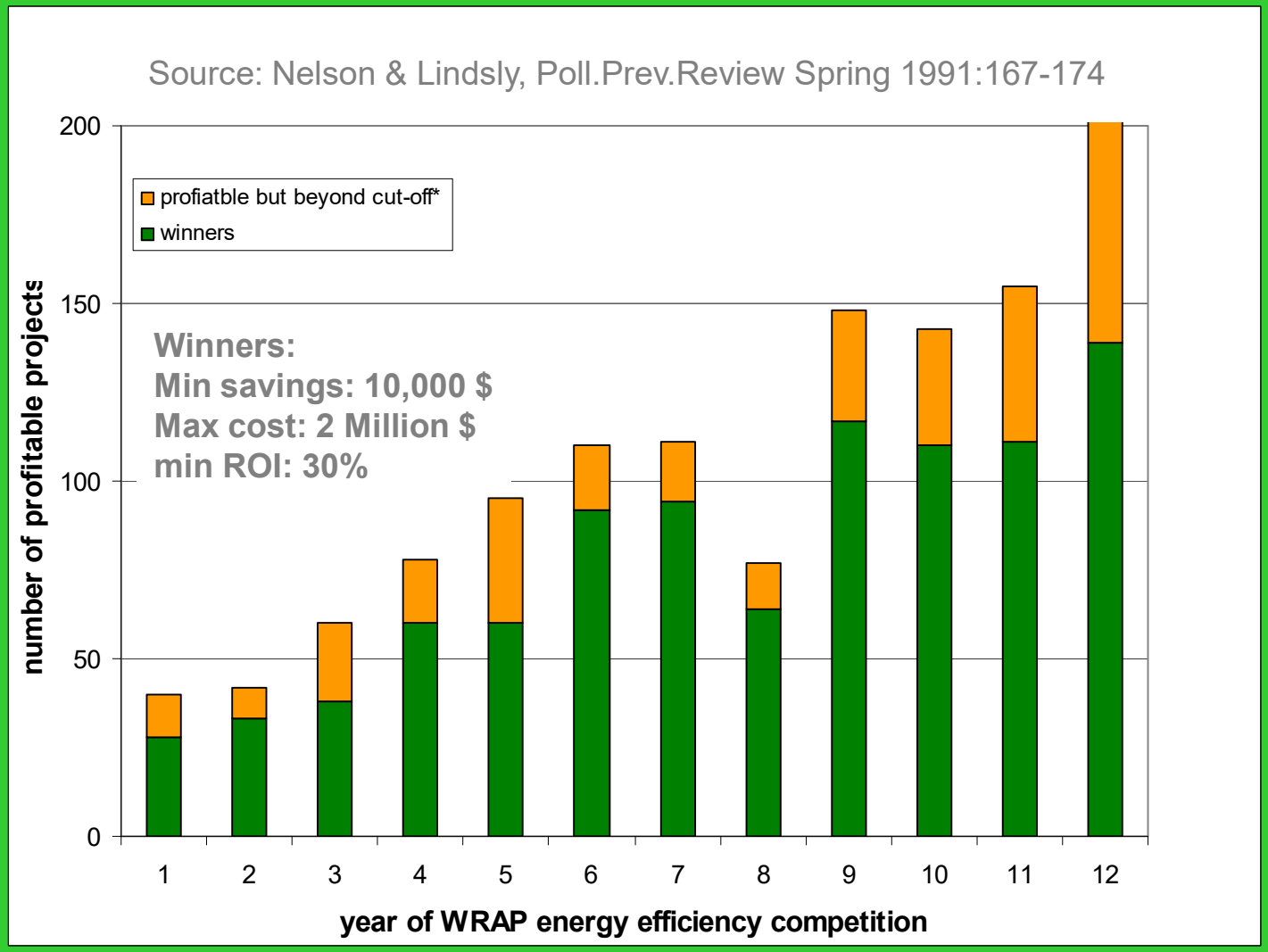
2. Industrial Organization



Key concepts:
Integration: vertical vs. horizontal
economies of scale vs. scope

3. “Low Hanging Fruit” Regrow:

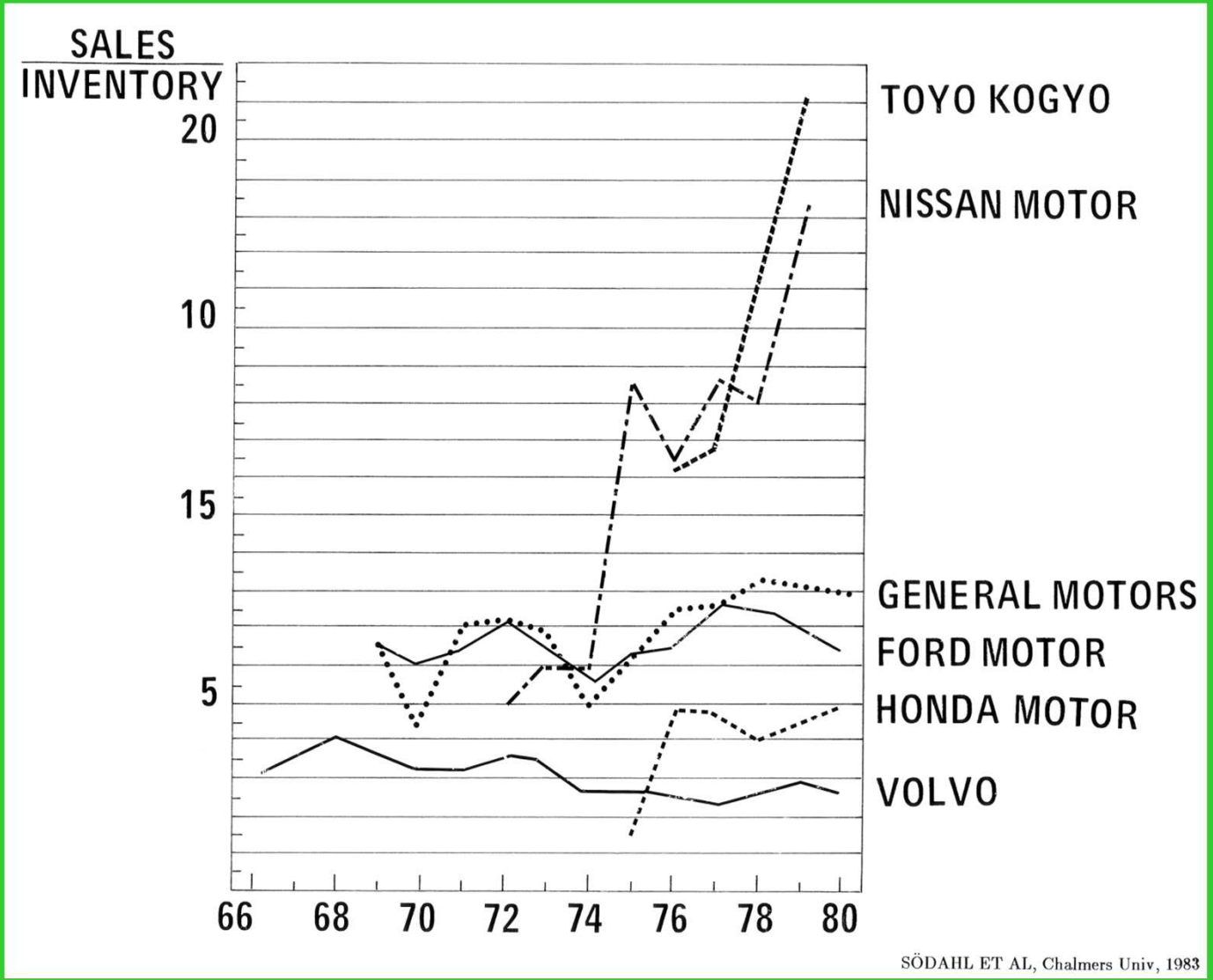
Winners in WRAP Energy Efficiency Contests of DOW Chemicals Lousiana



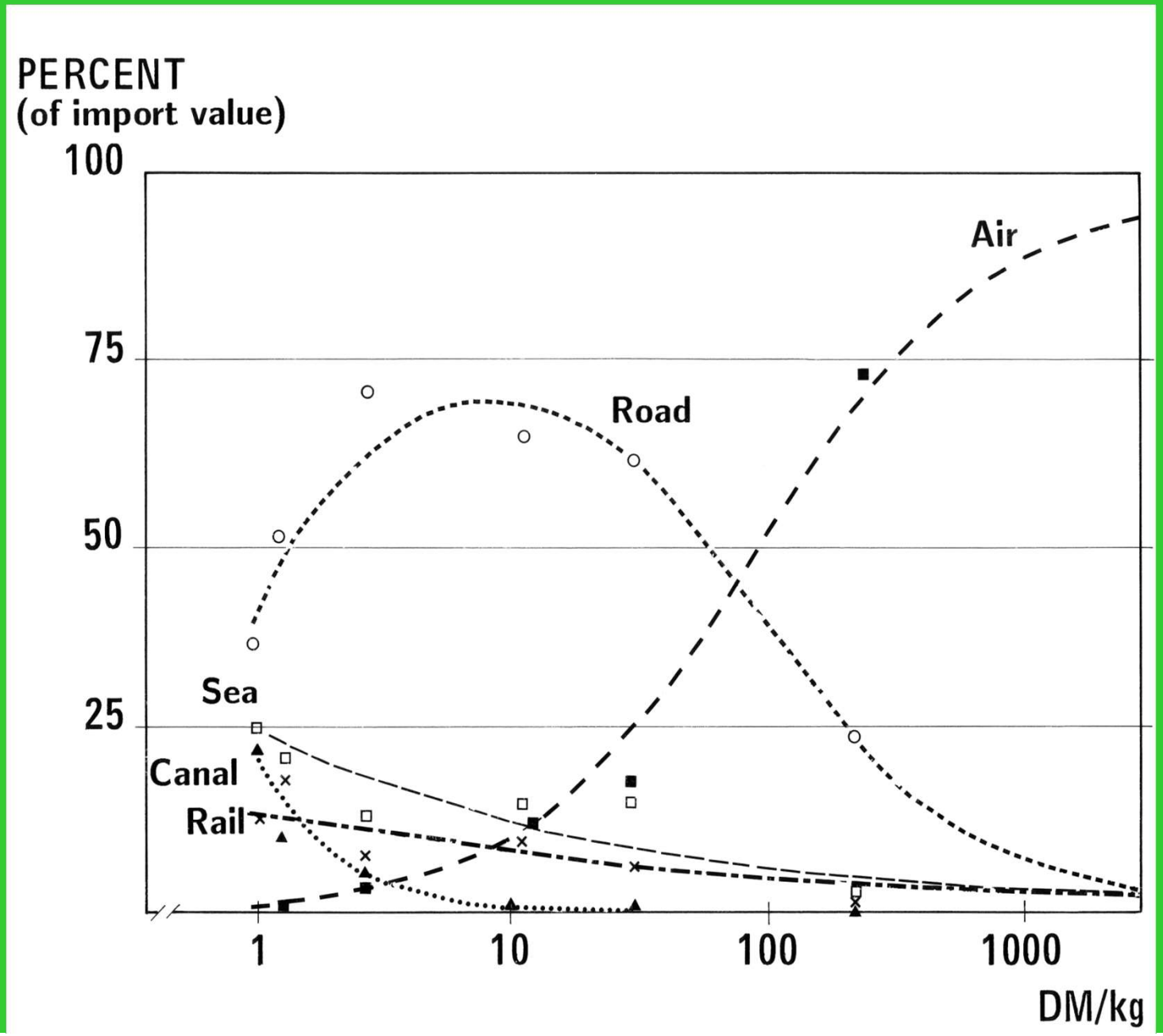
Technik und Umwelt **Arnulf Grübler**

4. Capital and Time are Costly:

Inventory Turnover, or the Birth of “just in time” Manufacturing



Germany: Goods Imported by Transport Mode versus Value Density



Industry: Scale of Activity

Basic Activity Data - World Industry	1990	2015/2017	*Factor increase*
People employed (10e6)	510	709	*1.4*
Value added (10e12 current US$)	7	20	*2.9*
7 Major commodities produced (10e9 tons)	2.5	6.6	*2.6*
Final energy use (EJ, industry+feedstock)	96	150	*1.6*
CO2 emissions (Gt CO2)			
direct industry, cement, + pro-rated electricty	7645	13451	*1.8*

Source: Updated (ILO, UNCTAD, IEA, IIASA) from Grubler, 1995

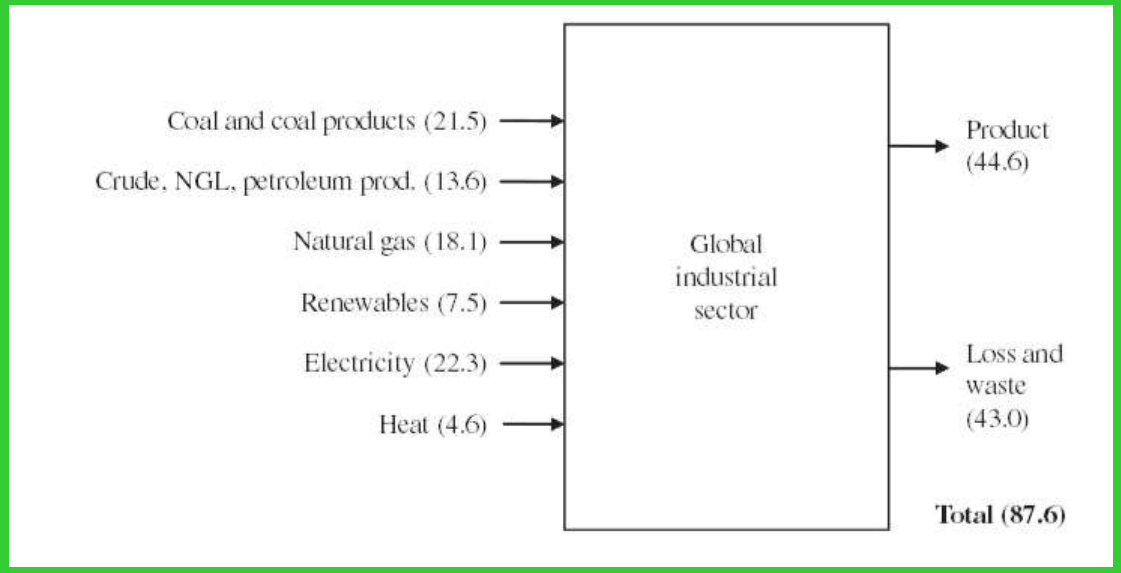
World Industrial Final Energy Use in 2017 (Mtoe, IEA, 2019)

Million tonnes of oil equivalent

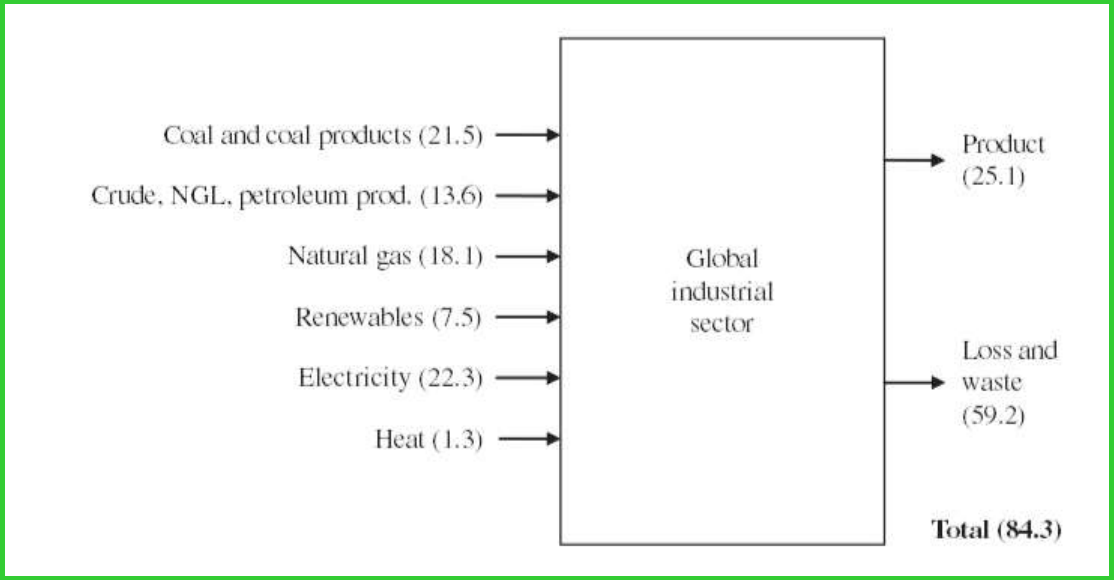
SUPPLY AND CONSUMPTION	Coal & peat	Crude oil	Oil products	Gas	Nuclear	Hydro	Geotherm. solar etc.	Combust. renew. & waste	Electricity	Heat	Total
INDUSTRY	**817.83**	**5.86**	**314.88**	**687.80**	**-**	**-**	**0.88**	**207.10**	**769.11**	**137.88**	**2320.89**
Iron and steel	313.42	0.00	6.98	55.41	-	-	0.00	3.64	97.74	13.82	491.01
Chemical and petrochemical	108.46	0.04	62.67	136.65	-	-	0.00	2.14	109.84	58.21	478.01
Non-ferrous metals	25.42	-	4.56	16.59	-	-	0.00	0.06	92.30	4.90	143.83
Non-metallic minerals	217.33	0.00	39.66	52.59	-	-	0.00	9.17	50.40	2.99	372.14
Transport equipment	2.31	-	2.11	12.48	-	-	0.00	0.02	25.52	3.88	46.32
Machinery	7.88	0.00	5.50	25.82	-	-	0.00	0.15	82.68	8.76	130.79
Mining and quarrying	6.09	-	23.66	8.07	-	-	0.00	0.22	31.46	2.10	71.60
Food and tobacco	27.80	0.01	9.47	47.53	-	-	0.00	36.79	44.00	11.67	177.27
Paper pulp and printing	16.25	0.01	3.72	24.59	-	-	0.00	65.55	39.68	12.25	162.05
Wood and wood products	1.28	-	2.19	2.96	-	-	0.00	7.72	9.90	2.37	26.41
Construction	4.06	-	31.40	8.69	-	-	0.00	0.53	16.22	0.99	61.89
Textile and leather	10.10	0.01	3.41	8.54	-	-	0.00	3.14	27.36	9.64	62.20
Non-specified	77.25	5.78	119.65	167.67	-	-	0.96	77.98	142.00	6.09	597.36
NON-ENERGY USE	**60.82**	**8.70**	**833.61**	**136.98**	**-**	**-**	**-**	**-**	**-**	**-**	**978.78**
In industry/transf./energy	50.33	8.70	588.30	135.96	-	-	-	-	-	-	833.29
of which: chem./petrochem.	*2.96*	*5.62*	*443.96*	*134.97*	*-*	*-*	*-*	*-*	*-*	*-*	*640.50*
In transport	-	-	11.02	-	-	-	-	-	-	-	11.02
In other	0.30	-	34.19	-	-	-	-	-	-	-	34.48

Non-energy Feedstocks (for chemicals)>Other>Steel>(petro-)Chemicals>Minerals

Global Industry: Energy & Exergy Flows (GEA KM8, 2012)

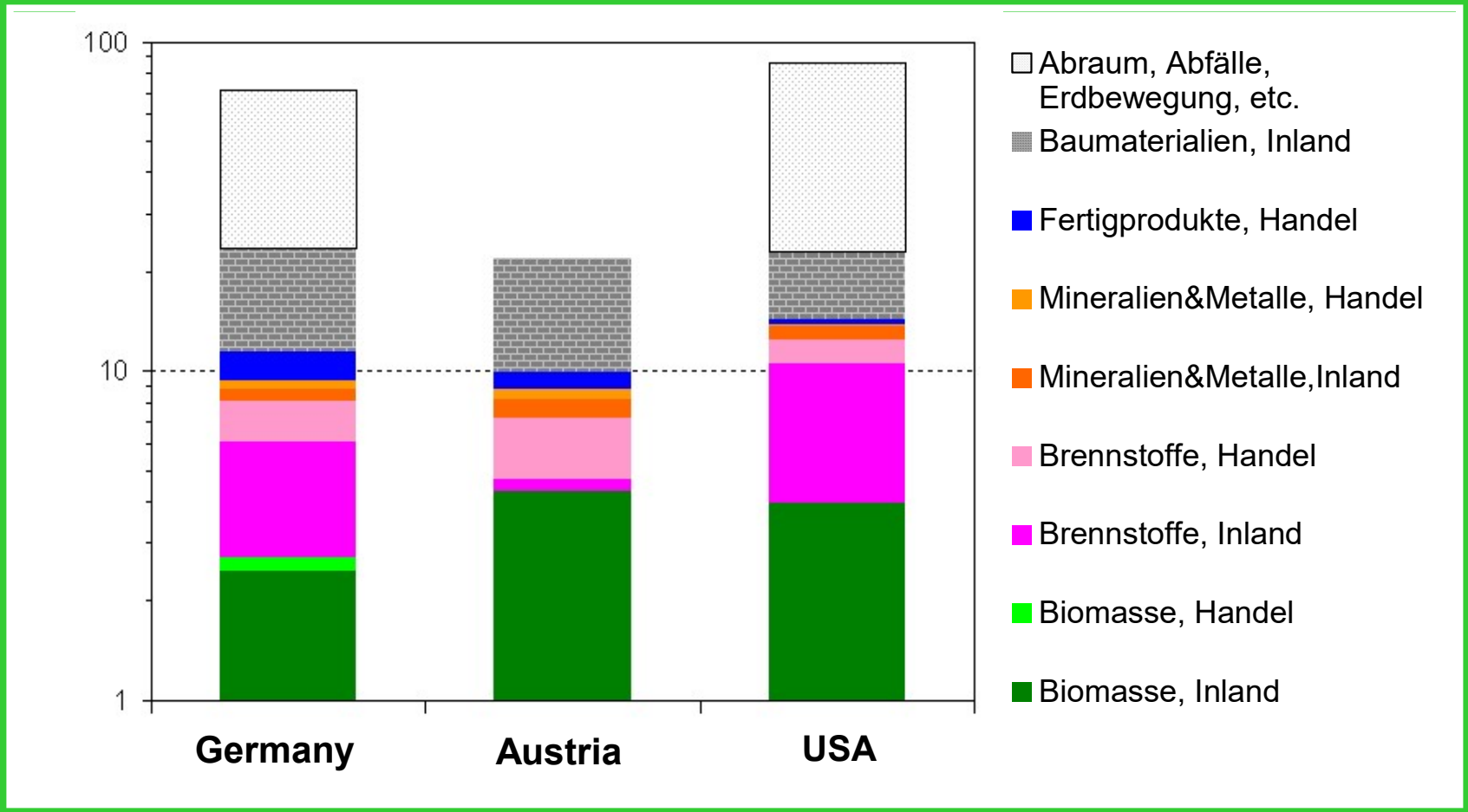


Energy: 51%



Exergy: 30%

Per Capita Materials Mobilization (log scale)



Source: Adriaanse et al. (1997), W. Hüttler et al. (1996), Wagner & Nötstaller (1997).

Global Materials Mobilization

Billion tons per year. AD 2000

	Fossil energy	Metals	Industrial raw materials	Constr. materials	Earth moved	Food & fibers	**Total**
Mining/ harvesting	10	>5	2.5	~16	- -	>5	**>40**
Overburden, wastes	>20	>15?	<1	>1	>50	<5	**>100**

Source: Argawal (1991), Grübler (2001), Nötstaller (1998).

Dematerialization

- Economic structural change
- Change in materials composition
- Demand growth and saturation

- Questions/Paradoxes:
  -- Interplay between variables?
  -- No example of absolute dematerialization documented
  -- Patterns: Convergence vs. path dependency

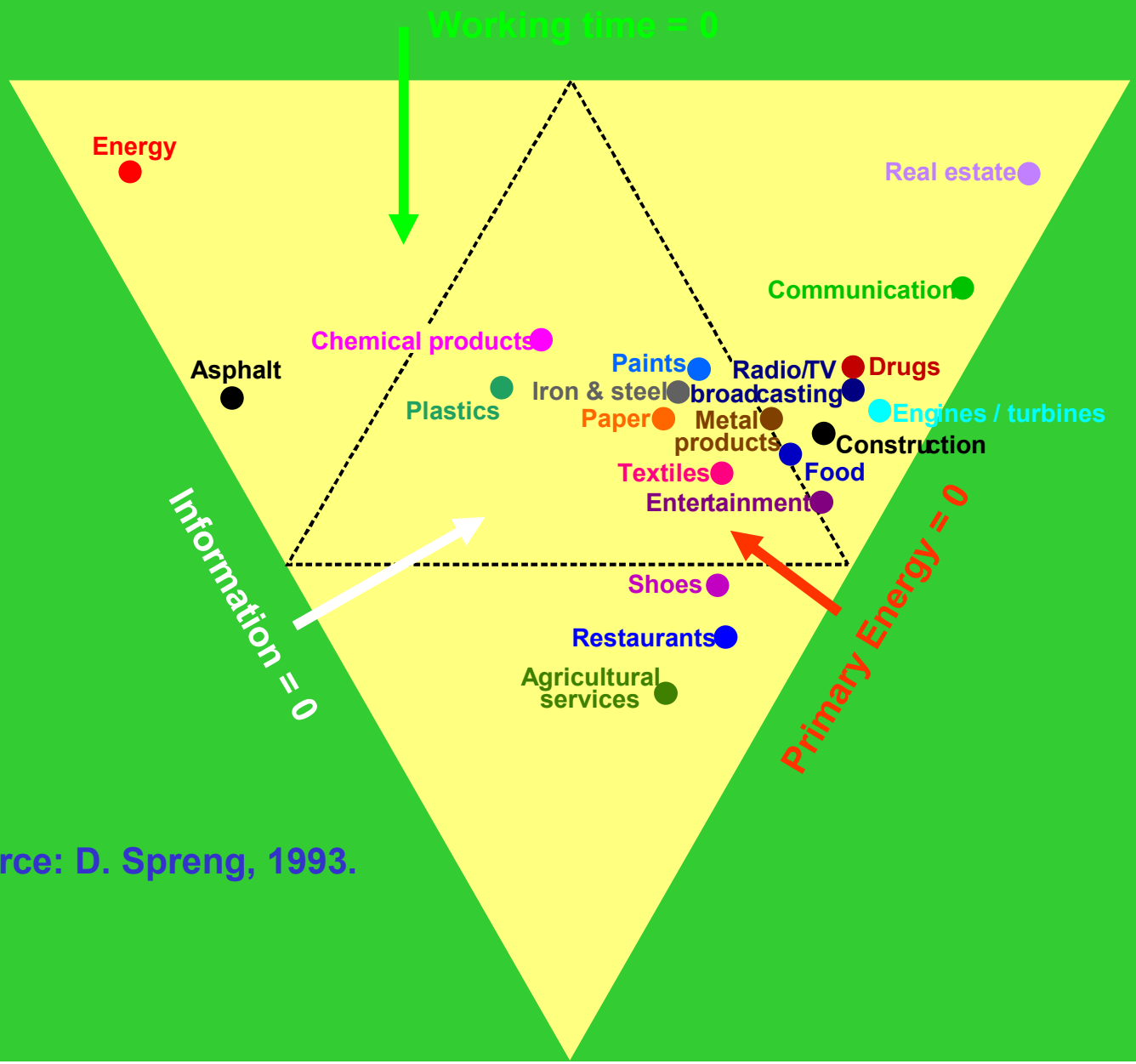
Arnulf Grübler

Technik & Umwelt

Structural and Technological Change

- Decompositional analysis
  IPAT framework, Divisa indexes, etc.
- Ex: Industrial CO2 emissions
- Influence of output growth, economy structure, intra-sectorial structure, intensity, decarbonization
- Not yet available for non-energy

Energy – Time – Information: Intensity of Products/Activities



Source: D. Spreng, 1993.

Energy Intensity & Industry Structural Change in EU 2000-2007 (GEA KM8, 2012)

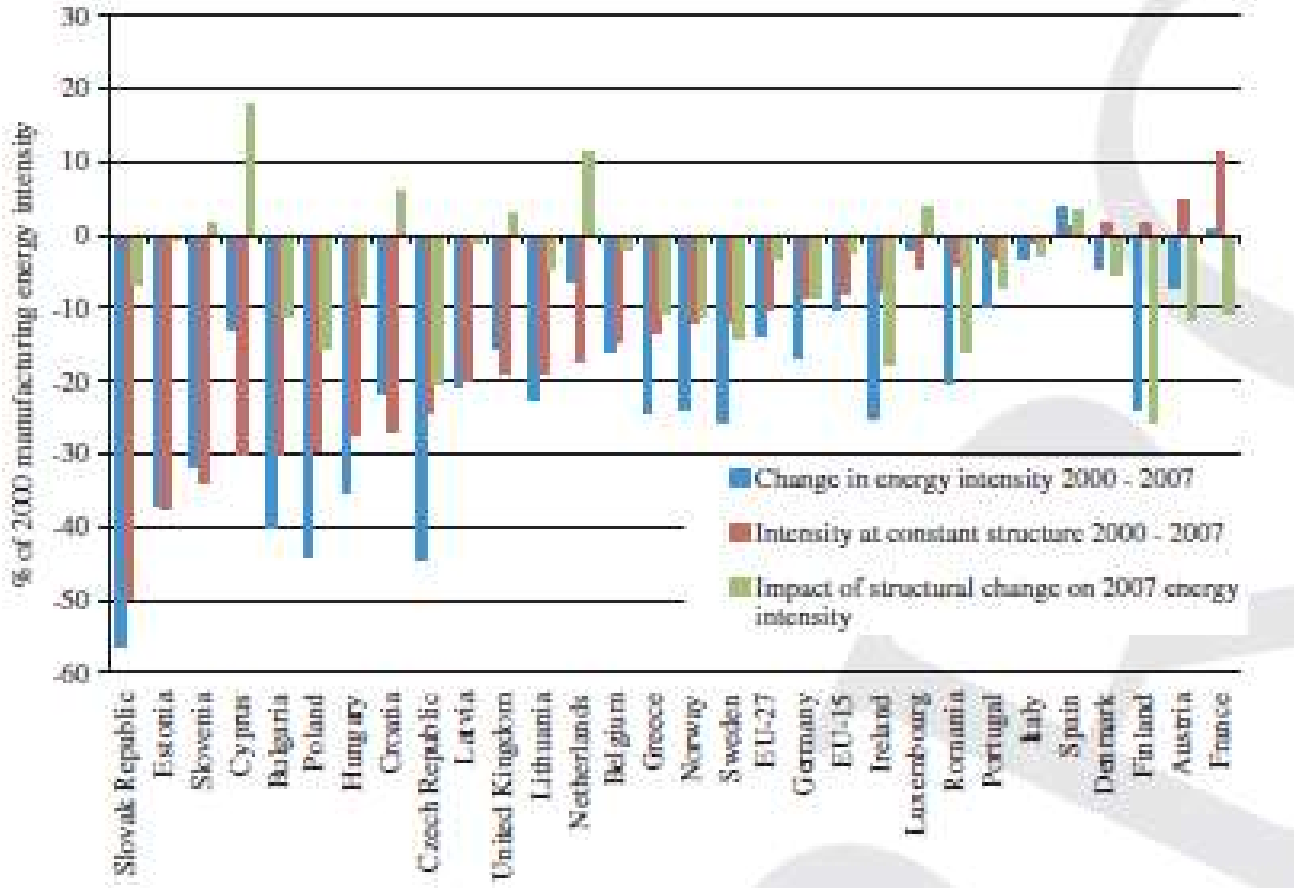


Figure 8.6 | Structural change impact for the EU. Source: Odyssee, 2009.

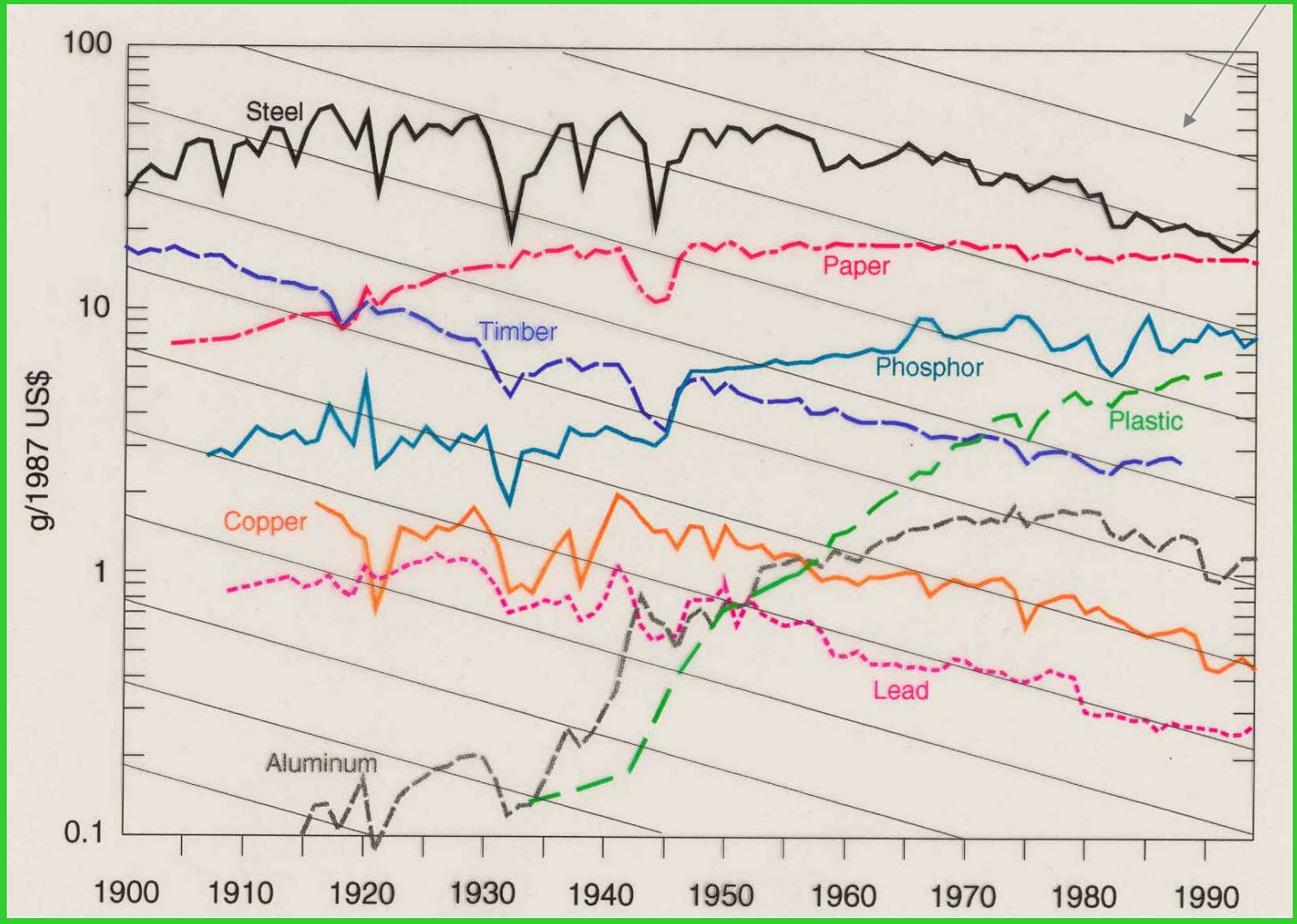
Dematerialization

- Change in material/energy intensity per unit of output
  -- physical
  -- economic (VA, or GDP)
- Drivers:
  -- structural change
  -- new technologies (process and products)
  -- prices
  -- regulation

US Materials Intensity

(Data: Wernick, 1996)

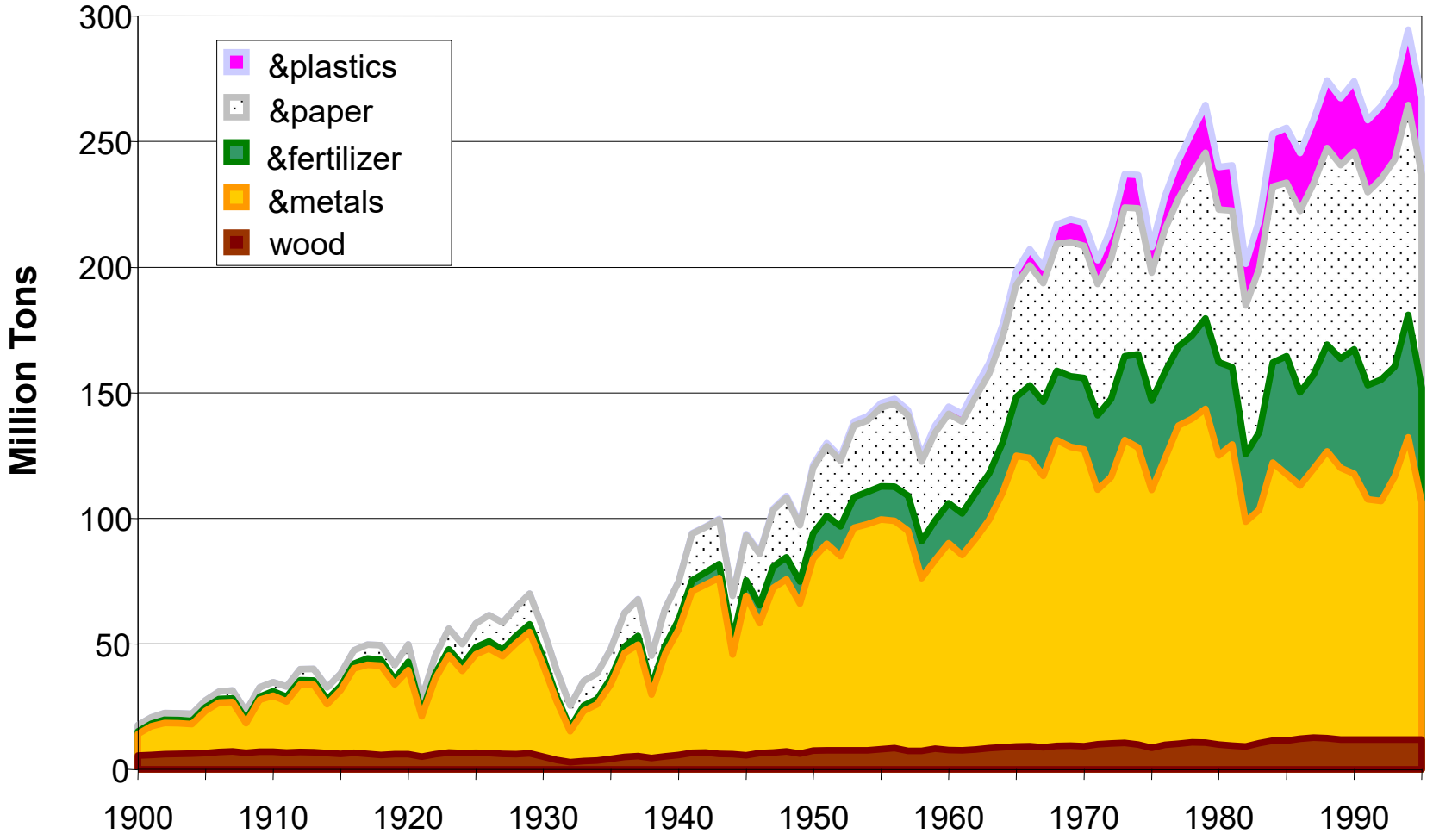
Isolines of –3%/yr
(GDP growth rate)



Technik & Umwelt

Arnulf Grübler

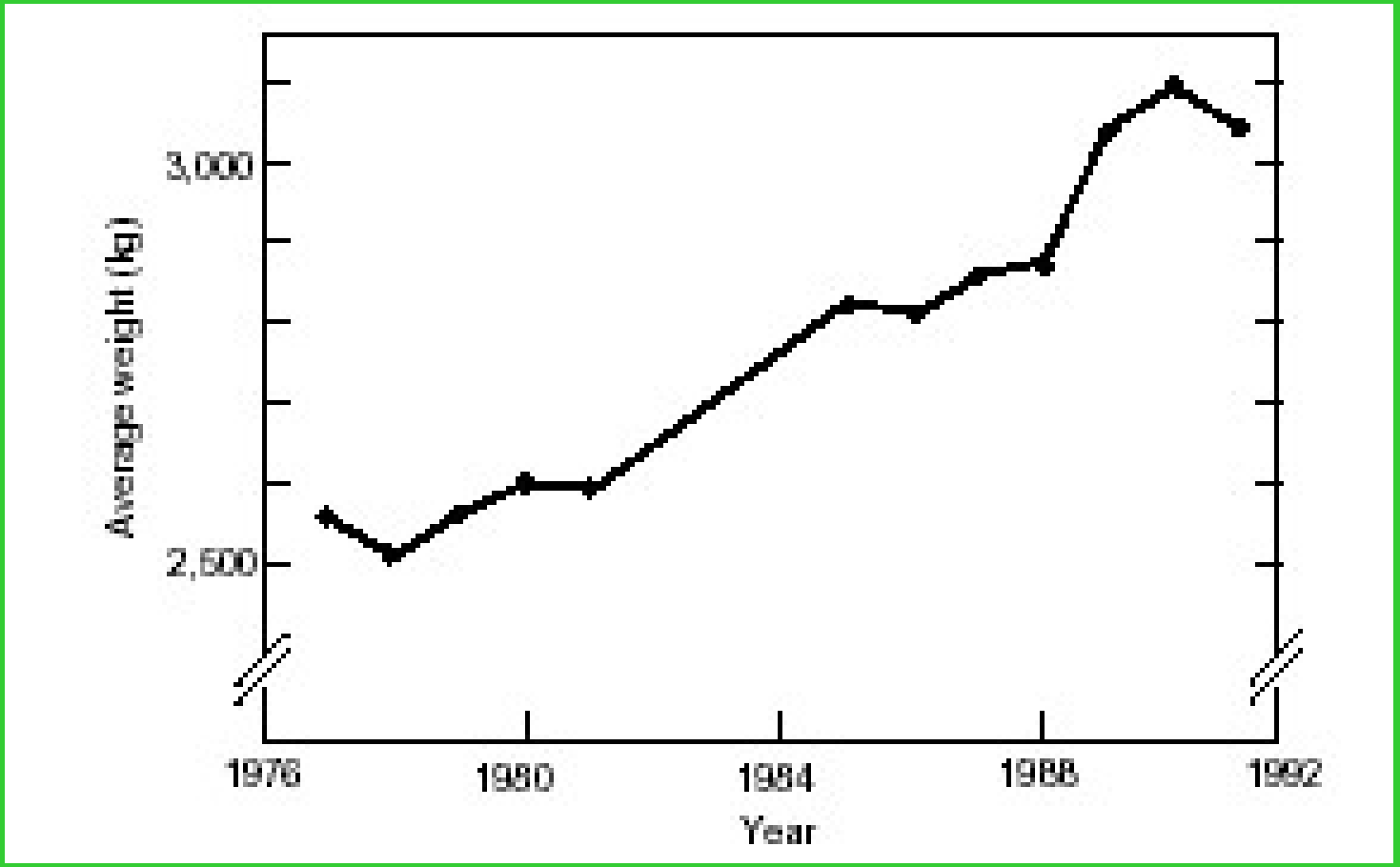
USA – Materials Use (cumulative)



Source: adapted from Wernick & Ausubel (1995).

USA – Weight Transported per Household Move (excl. Vehicles).

Data: Courtesy I. Wernick, 1997.



Waste Generation and Recycling

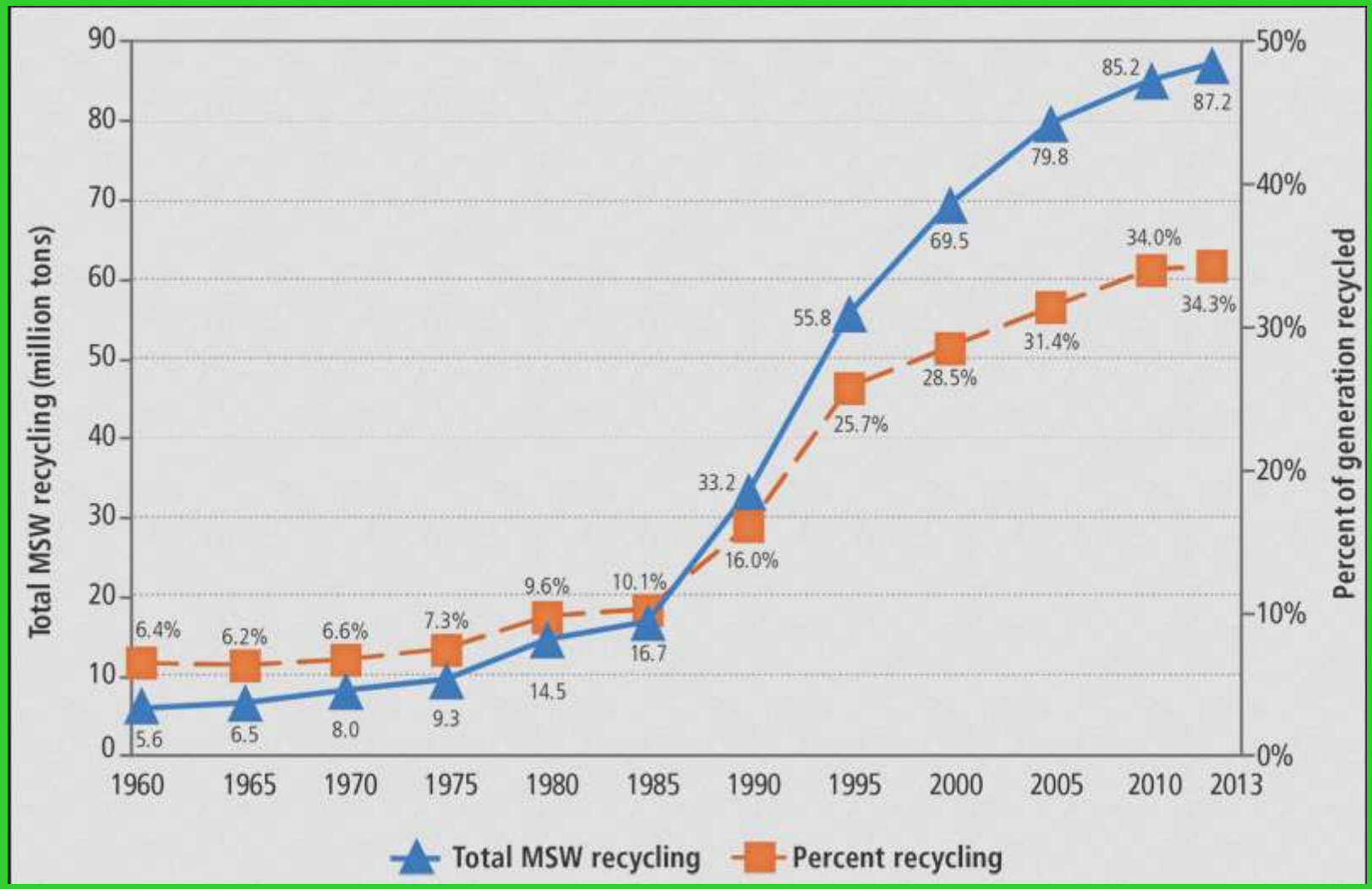
The aftermath of industrial metabolism

Technik & Umwelt

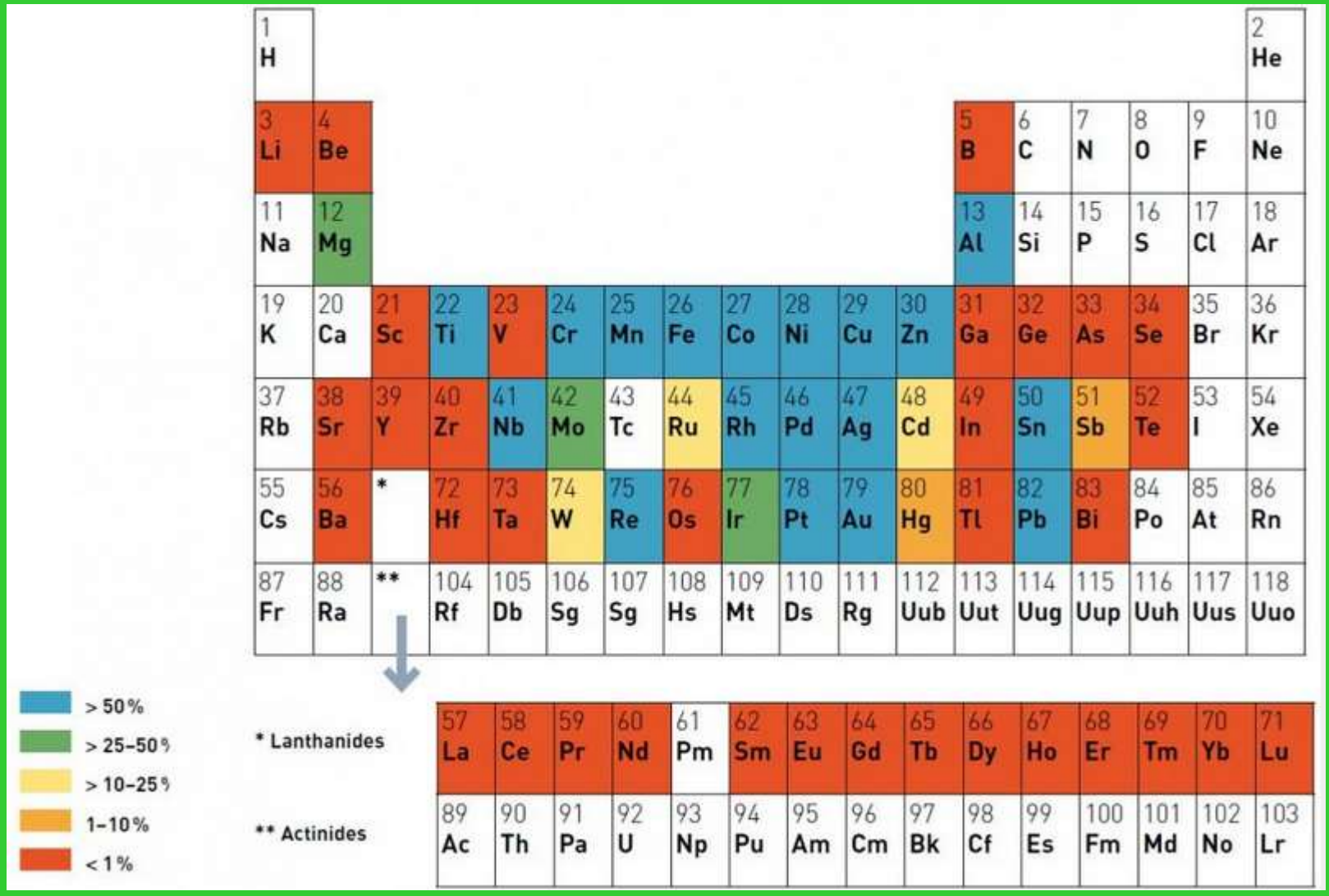
Arnulf Grübler

US: Municipal Waste Generation
(Source EPA, 2017)

US Municipal Waste: Recycling Tonnage and Percent
(Source: EPA, 2017)



Recycling Rates for 60 Metals in EU (EC, 2013)



Technik & Umwelt

Arnulf Grübler

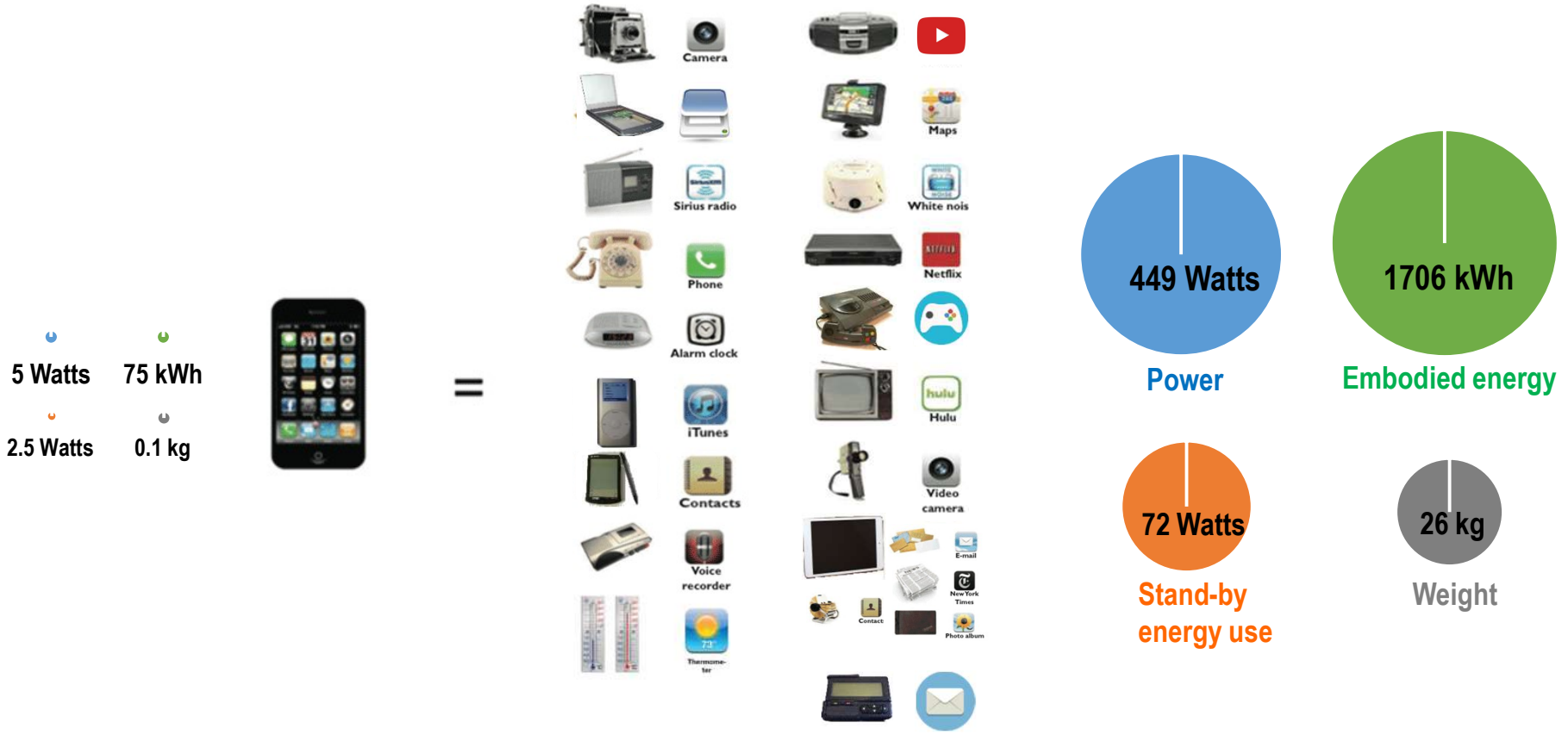
Materialization amidst Dematerialization

- Saturating absolute materials use
- But: ever higher wastes and recycling
- Increasing stocks with:
  -- multiple stacks of artifacts
  (PCs on shelf, fridges in basement)
  -- shorter cycling times?
  -- heavier products?
  -- other factors?

Materials Use: The Long-term Picture

- No theory
- Increasing weight of DCs, but based on what development model?
- Largest “wildcard”: Digitalization
- Technological “denudation” (H. Brown, 1956)
- Increasing waste streams: mining, processing, deposition, scrubbing of effluents

Impacts of Digital Convergence



Operational Peak Power / 90

Weight /260

Operational Energy /30

Embodied Energy /23

Summary Block 7
(Industry)

- **orders of magnitude of industrial activities (0.7 billion employment, 20 trillion $ value added, >7 Gt commodities produced and 14 Gt CO2 emitted)**
- **global materials mobilization (>40 Gt plus >100 Gt wastes)**
- **problems of quantity and quality (toxidity, "area of ignorance")**
- **increasing decoupling of output and impacts**
- **materials intensity: non linear trends (e.g. S-curves), geographical shifts**
- **materials use per GDP: decoupling: max of GDP growth = stabilization of materials use at high levels**
- **dematerialization: ambiguous trends (+/-)**
- **environmental strategies:**
  -- efficiency improvements
  -- materials substitution
  -- recycling (30 to 50 percent recycling rates for most materials)