Supplementary Materials

Table S1: Copper contents of copper-containing products (adapted from [24])

SITC Rev.1	Items	Unit	Copper content	References
28311	Ores and concentrates of copper	t/t	0.272	AUDM, 1996 [30]
28312	Copper matte	t/t	0.625	NIRS, 2010 [31]
28402	Copper waste and scrap	t/t	0.750	METI, 2015 [32]
68211	Blister copper and other unrefined copper	t/t	0.9850	NIRS, 2010 [31]
68212	Refined copper including remelted	t/t	0.9999	
68213	Master alloys of copper	t/t	0.9999	
68221	Bars, rods, angles, shapes, wire of copper	t/t	0.9999	
68222	Plates, sheets, and strips of copper	t/t	0.9999	
68223	Copper foil	t/t	0.9999	
68224	Copper powders and flakes	t/t	0.9999	
68225	Tubes, pipes and blanks, hollow bars of copper	t/t	0.9999	
68226	Tube and pipe fittings of copper	t/t	0.650	RIETI, 1955 [33]
69212	Refined copper including remelted	t/t	0.9999	NIRS, 2010 [31]
69312	Wire, cables, ropes, etc. not insulated of copper	t/t	0.9999	
69332	Gauze, netting, grill, fencing wire of copper	t/t	0.9999	
69342	Expanded metal of copper	t/t	0.9999	
69412	Nails, tacks, staples, spikes, etc. of copper	t/t	0.65	RIETI, 1955 [33]
69422	Nuts, bolts, screws, rivets, washers of copper	t/t	0.65	
695	Tools of use in the hand or in machines	t/MY	0.006	NIES, 2000 [34]
696	Cutlery	t/MY	0.003	
69712	Domestic stoves, etc. of copper	t/t	0	METI, 2008 [35]
69722	Domestic utensils of copper	t/t	0.9999	NIRS, 2010 [31]
6979	Other household equipment of base metals	t/MY	0.002	NIES, 2000 [34]
6981	Locksmith wares	t/MY	0.003	
69862	Springs and leaves for springs of copper	t/t	0.9999	NIRS, 2010 [31]
6988	Miscell. articles of base metal	t/MY	0.004	NIES, 2000 [34]
69892	Articles of copper, n.e.s.	t/t	0.9999	NIRS, 2010 [31]
71	Machinery, other than electric	t/MY	0.006	NIES, 2000 [34]
72	Electrical machinery, apparatus, and appliances	t/MY	0.008	

73	Transport equipment	t/MY	0.009
81	Sanitary, plumbing, heating, and light fixtures	t/MY	0.012
82	Furniture	t/MY	0.001
86	Scientif & control instrum, photogr gds, clocks	t/MY	0.002
89	Miscellaneous manufactured articles, n.e.s.	t/MY	0.004
95	Firearms of war and ammunition therefor	t/MY	0.020

Table S2: Fabrication efficiency FE(t)

	Global market share (%) [36]	**Fabrication efficiency *FE(t')* (%) [37]**
Building and cconstruction	24	90
Infrastructure	17	88
Industrial	11	85
Transport	12	82
Other products	36	76

The average fabrication efficiency FE(t) was estimated by using following data (table) and equation:

$$\mathrm{FE(t')} = \frac{24\mathrm{x}90 + 17\mathrm{x}88 + 11\mathrm{x}85 + 12\mathrm{x}82 + 36\mathrm{x}76}{10000} = 0.84$$

Table S3: Determining the mean lifetime of copper products

	Country	**Average lifetime (years)**	**Cu Input from 1960 to 2022 (kt)**	**Ratio (%)**
1	Australia	22.33	8,183.00	0.02
2	Belgium	23.40	4,961.33	0.01
3	Germany	19.54	38,511.33	0.11
4	Italy	21.55	41,317.71	0.12
5	Japan	18.60	62,684.97	0.18
6	Korea	21.11	21,189.72	0.06
7	Spain	24.48	13,527.54	0.04
8	Sweden	23.39	6,714.38	0.02
9	The US	23.89	145,647.97	0.42
Total (kt)			**342,737.95**	**1.00**
Weighted Average		**21.95**		

Based on Maung et al. [24] and Yamamoto et al. [39], we updated the estimates of copper stocks and demands up to 2022 for 9 countries including: Australia, Belgium, Germany, Italy, Japan, Korea, Spain, Sweden, and the US. By using a solver function in MS Excel, we determined the mean lifetime of copper products so that the consistency between stocks and demands are kept during 1996-2022. Then, we determined the mean lifetime as a weighted average of 9 countries in terms of cumulative copper input during 1996 to 2022.

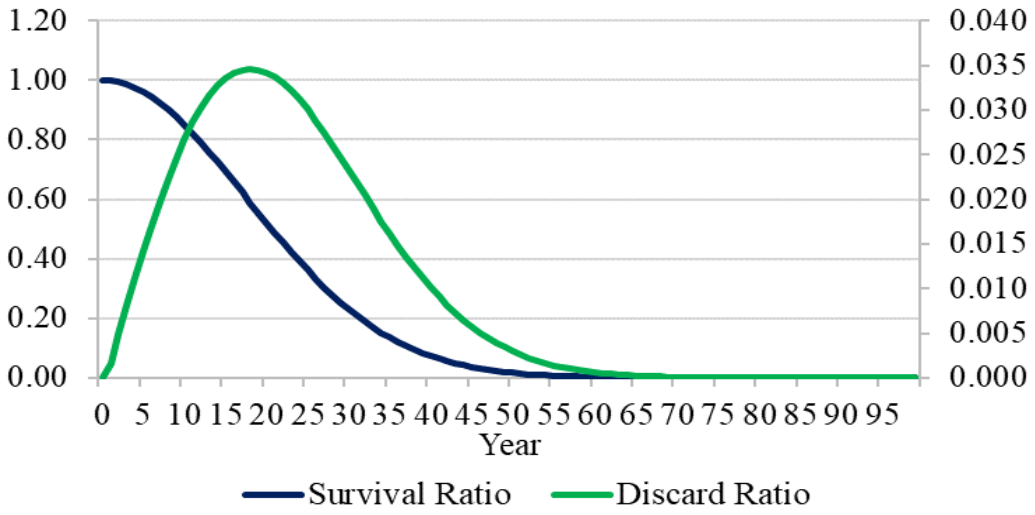

Figure S1: Survival ratio SR(t) and discard ratio DR(t)

The average mean lifetime (21.95 years) was used for determining SR(t) and DR(t).

Table S4: Saturation value of the per-capita copper stock (Ssat)

Country/region	Stock saturation	α	β
Japan	184.3	3.55	0.21
Korea	234.2	3.55	0.24
Germany	222.7	3.41	0.18
Spain	178.3	4.46	0.23
USA	224.7	4.12	0.16
Minimum	**178.3**	**4.46**	**0.23**
Average	**210.9**	**3.54**	**0.17**
Maximum	**234.2**	**3.55**	**0.24**

Historical statistical data for 5 developed countries were collected from [39] to determine the minimum, average, and maximum copper stock saturation values as shown inTable S4.

We assumed that Vietnam would follow the stock model of developed countries, and Vietnam's copper saturation will be reached when copper stock per capita equals 90% of the developed countries' stock saturation value. Using two points, A1 (copper stock in 2022, GDP/cap in 2022) and A2 (90% copper stock saturation, corresponding GDP/cap when Vietnam copper stock equals 90% copper stock saturation), we determine the corresponding α and β for each stock saturation value.

Table S5: α and β

	S_{sat} (kg/capita)	α	β
Minimum	178.3	2.69	0.14
Average	210.9	3.01	0.15
Maximum	234.2	3.21	0.16

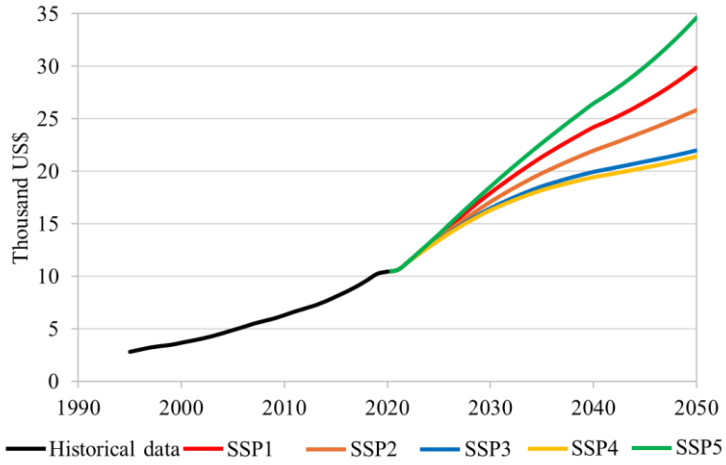

Figure S2: Per-capita GDP, GDP(t) (constant 2017 $) (our calculation based on [43])

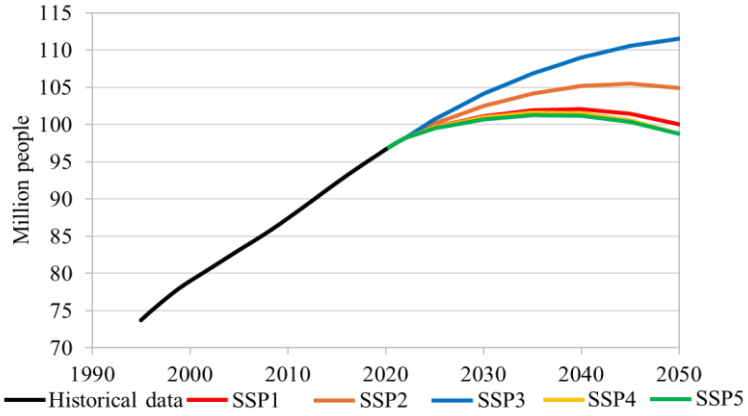

Figure S3: Population, POP(t) (our calculation based on [43])