

## *Supplementary Information*

# **Estimating the Evolution of Urban Mining Resources in Hong Kong, Up to the Year 2050**

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Table S1 HKHS code of studied EEE in the Hong Kong Merchandise Trade Statistics Classification

<b>EEE</b>	<b>HKHS code</b>	<b>EEE</b>	<b>HKHS code</b>
<b>RF</b>	84182100	MPh	85171200
<b>WM</b>	84501110, 84501120, 84501200	Laptop	84715000
<b>AC</b>	84151000	Desktop	84713010
<b>TV-CRT</b>	85287290	RH	84146000
<b>TV-LCD</b>	85287210	PFCM	84433110, 84433120, 84433190, 84433210, 84433220, 84433290,
<b>Mon-CRT</b>	84284900		84433910
<b>Mon-LCD</b>	85285100		84433910
<b>GWH</b>	84191910	EWH	85161000

Note: data source from (HKCSD, 2018)<sup>1</sup>

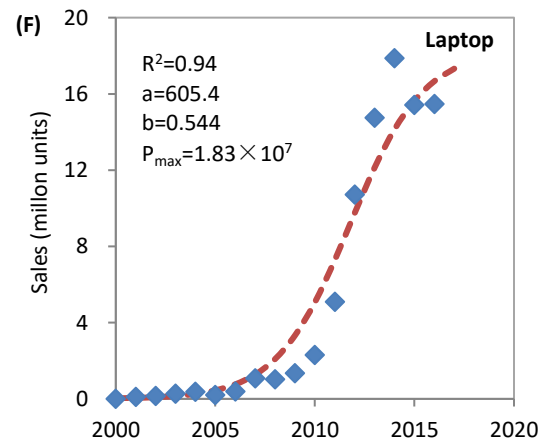
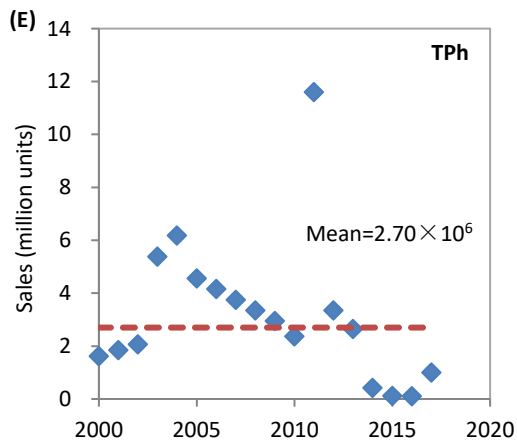
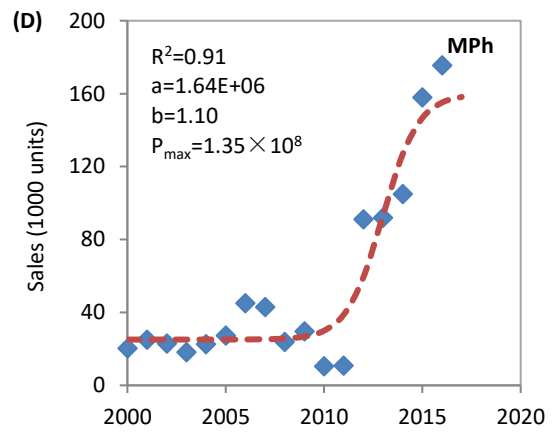
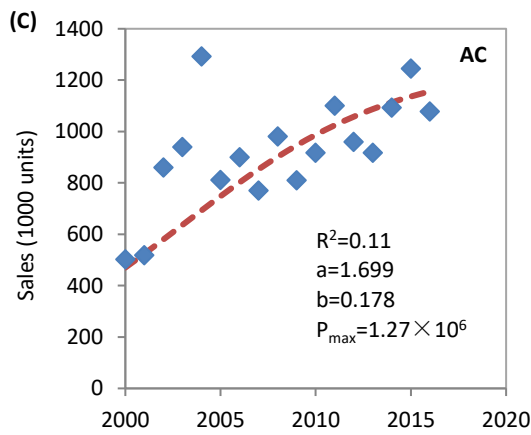
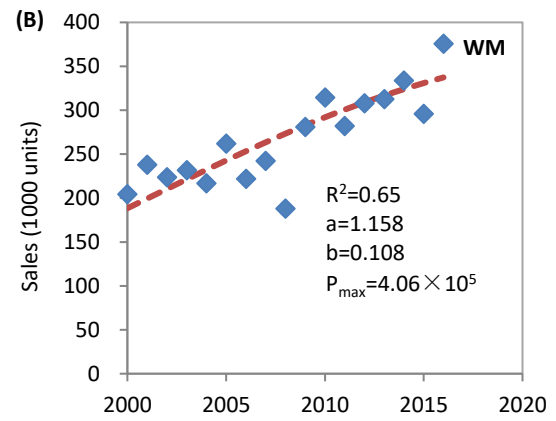
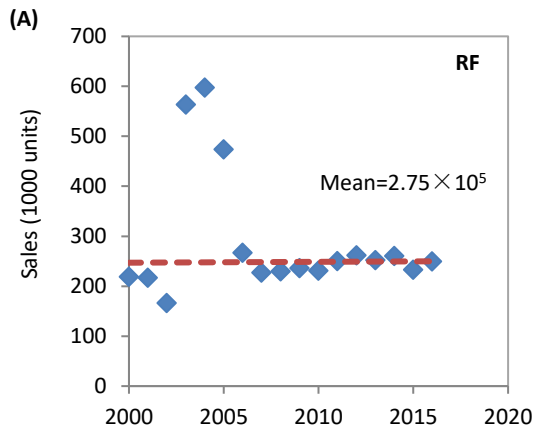
Table S2 Sale data of EEE in Hong Kong

Year	WM	AC	MPh*	Laptop	Desktop	LCD TV	CRT TV	LCD	CRT	Printer/Copier	EWH	GWH	RH
1993		237481	418384657				1008000						
1994		295447	407351104				1911528						
1995	125348	259121	502332085				2314778						
1996		264743	316414918				2050083						
1997		312627	263887747				1035547						
1998	86144	375612	194348117				704533						
1999		374903	239115859				730661						
2000	204482	502870	91950822	268	623051		854447	86253	159823	1775000	596623	161535	117607
2001	238082	519122	105049553	111815	496584		479675	258513	339959	1972987	134137	143782	57537
2002	223867	860358	157971384	159777	244779		304186	457610	451854	809061	629101	150849	202854
2003	231717	940089	175592479	269510	212389		818530	370114	432390	1146501		106882	123752
2004	216957	1293182	140412416	379243	338997	809690	1409242	373076	984913	365716		105139	141827
2005	262155	811678	159240555.7	200054	333112	1274488	1458439	805807	160079	961242		125438	49213
									6				
2006	221891	900765	159594082.7	386228	427822	2248095	11886972	968023	237928	4560928		111225	389544
									5				
2007	242426	770495	159711900	1088121	1076661	4925294	575848	2547852	695777	851795		120195	164451
2008	188146	981370	159751072.3	1031169	943618	5721308	290637.7	1112199	39676	801762		144880	87154
								9					
2009	280993	810527	159764086.3	1357503	2027342	3694990	144423.8	4364406	43879	682951		129212	53447

								4					
2010	314657	917920	159768408.8	2303408	398551	1069901	70713.44	1538532	56006	879911		124033	49405
2011	282185	1100259	159769844.3	5091614	1217904	2426265	34153.47	923034	47185	173794	122702	125833	45363
2012	308199	959930	159770321.1	10718610	1754245	2784875	16294.47	1232952	41412	203270	183533	118131	48873
2013	312609	917610	159770479.4	14749179	2431900	1388808		1472059	32486	1220342	531532	124885	24464
2014	334003	1092913	159770532	17869986	1717787	773875		1852788	26866	281926	552797	123907	50128
2015	295947	1245342	159770549.4	15423487	1319169	1172541		1734719		409955		103716	3676
2016	375696	1078525	159770555.2	15478954	1537402	647030		488181		331214		128527	39058
2017	343303.8	1173373	159770557.1	17323601	1621502	3412956		693249.9		625783.767		134943.2	79232.76
2018	348864	1188136	159770557.8	17730240	1655074	2179122		758088.4		643751.6714		134945.9	79977.78
2019	354009.5	1200782	159770558	17975006	1682191	2207152		824061.9		656461.1194		134947.9	80680.69
2020	358758.2	1211575	159770558.1	18120119	1703926	2229435		890390		665318.0278		134949.3	81343.08
2021	363129.6	1220759	159770558.1	18205379	1721240	2247062		956275.2		671426.2668		134950.4	81966.59
2022	367144.4	1228554	159770558.1	18255208	1734967	2260952		1020941		675608.6757		134951.2	82552.89
2023	370823.7	1235155	159770558.1	18284239	1745806	2271863		1083668		678458.3544		134951.7	83103.65
2024	374189	1240735	159770558.1	18301123	1754340	2280415		1143825		680393.4631		134952.2	83620.55
2025	377261.5	1245444	159770558.1	18310931	1761042	2287104		1200888		681704.5241		134952.5	84105.26
2026	380062.2	1249414	159770558.1	18316626	1766295	2292329		1254457		682591.4107		134952.7	84559.4
2027	382611.3	1252755	159770558.1	18319932	1770407	2296405		1304260		683190.7303		134952.9	84984.57
2028	384928.2	1255566	159770558.1	18321850	1773622	2299583		1350141		683595.4378		134953	85382.35
2029	387031.4	1257929	159770558.1	18322962	1776133	2302057		1392059		683868.5975		134953.1	85754.24
2030	388938.7	1259913	159770558.1	18323608	1778093	2303984		1430064		684052.9087		134953.2	86101.71

2031	390666.3	1261578	159770558.1	18323983	1779621	2305483	1464284	684177.2433	134953.2	86426.19
2032	392229.9	1262976	159770558.1	18324200	1780814	2306650	1494904	684261.106	134953.2	86729.01
2033	393643.8	1264148	159770558.1	18324326	1781743	2307557	1522150	684317.6651	134953.3	87011.49
2034	394921.4	1265130	159770558.1	18324399	1782467	2308262	1546273	684355.8075	134953.3	87274.87
2035	396075.1	1265954	159770558.1	18324441	1783031	2308810	1567539	684381.5287	134953.3	87520.32
2036	397116.1	1266644	159770558.1	18324466	1783471	2309237	1586211	684398.8733	134953.3	87748.98
2037	398055.1	1267222	159770558.1	18324480	1783813	2309568	1602552	684410.569	134953.3	87961.91
2038	398901.5	1267707	159770558.1	18324489	1784080	2309825	1616810	684418.4555	134953.3	88160.12
2039	399664.2	1268112	159770558.1	18324493	1784287	2310025	1629217	684423.7734	134953.3	88344.57
2040	400351.2	1268452	159770558.1	18324496	1784449	2310181	1639989	684427.3592	134953.3	88516.16
2041	400969.7	1268737	159770558.1	18324498	1784575	2310302	1649324	684429.7771	134953.3	88675.74
2042	401526.4	1268975	159770558.1	18324499	1784673	2310396	1657400	684431.4074	134953.3	88824.11
2043	402027.3	1269175	159770558.1	18324499	1784750	2310469	1664375	684432.5068	134953.3	88962.03
2044	402477.9	1269342	159770558.1	18324500	1784809	2310525	1670393	684433.248	134953.3	89090.2
2045	402883.1	1269481	159770558.1	18324500	1784855	2310569	1675579	684433.7479	134953.3	89209.28
2046	403247.5	1269599	159770558.1	18324500	1784891	2310604	1680044	684434.0849	134953.3	89319.9
2047	403575.1	1269697	159770558.1	18324500	1784919	2310630	1683884	684434.3122	134953.3	89422.64
2048	403869.5	1269779	159770558.1	18324500	1784941	2310651	1687186	684434.4654	134953.3	89518.04
2049	404134.1	1269847	159770558.1	18324500	1784958	2310667	1690022	684434.5687	134953.3	89606.61
2050	404371.8	1269905	159770558.1	18324500	1784971	2310680	1692458	684434.6384	134953.3	89688.84

Note: The data from 1993 to 2017 are real value from UN Comtrade Database and the data from 2018 to 2050 are predicted value using Figure S1. \*data for the year of 1993-1999 belong to mobile phone (MPh) and single-machine phone (TPh).



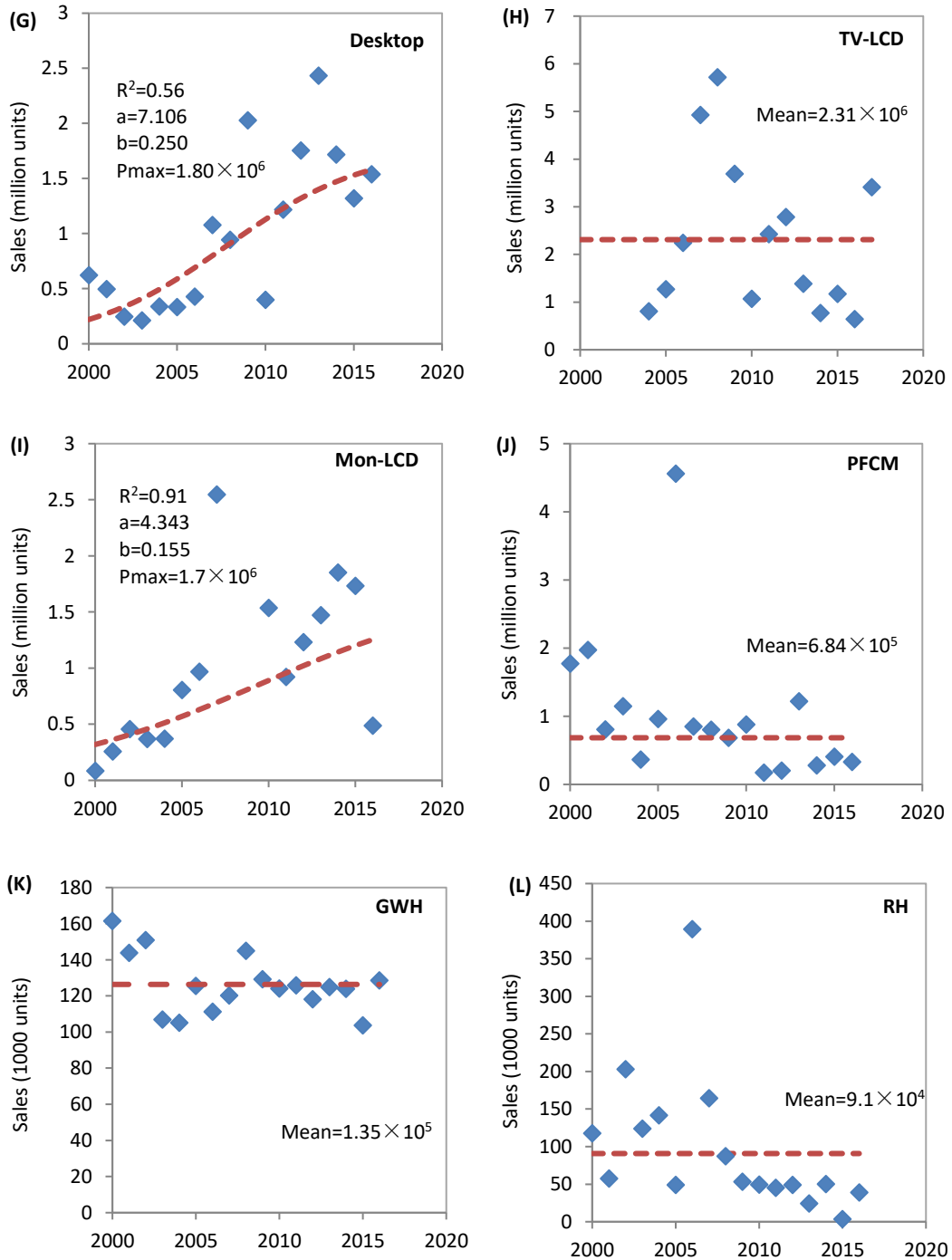


Figure S1 Regression for EEE sales data

(A) Refrigerator; (B) washing machine; (C) air conditioner; (D) mobile phone; (E) single telephone; (F) laptop; (G) desktop; (H) television-LCD; (I) monitor-LCD; (J) printing, faxing and copying machine; (K) gas water heater; (L) range hood.

Note: a and b are parameters for logistic model;  $P_{\max}$  is the maximum sales of the product; for (B)(C)(D)(F)(G)(I), a logistic curve simulation is adopted; for (A)(E)(H)(J)(K)(L), the sales amount is assumed as the mean. Here CRT products and EWH are not simulated because the formers have been completely substituted by LCD products and the latter is lack of robust data.

Table S3 Average weight of various EEEs

EEE	Average weight (kg/unit)	EEE	Average weight (kg/unit)
RF	40.09	TPh	0.6
WM	18.00	Desktop computer	13.88
AC	44.90	Laptop computer	1.86
TV-CRT	27.81	PCFM	10.0
TV-LCD	12.6	RH	23.57
Mon-CRT	13.45	GWH	12.42
Mon-LCD	4.89	EWH	24.36
MPh	0.1		

Note: data source from (Zeng et al., 2016)<sup>2</sup> and the weight data is obedient to Beta distribution.

Table S4 Weibull function parameters for various EEEs

Products	$\beta$	$\eta$	Products	$\beta$	$\eta$
RF	16.5	2.6	MPh	7.6	0.7
WM	13.9	2.2	TPh	6.5	2.1
AC	12.3	2.8	Desktop	9.6	2.1
TV-CRT	12.6	2	Laptop	5.2	1.5
TV-LCD	12	2.1	PFCM	10.1	1.7
Mon-CRT	8.5	2.2	RH	13.5	2
Mon-LCD	7.5	2.5	EWH / GWH	7.9	1.8

Note: data source from (Baldé et al., 2017)<sup>3</sup>.



Table S5 Content of resources in various categories of EEE

EEE	Base metals (%)			Precious metals (10 <sup>-6</sup> )			Rare metals (10 <sup>-6</sup> )			Rare earth (10 <sup>-6</sup> )		Plastic (%)
	Cu	Al	Fe	Au	Ag	Pd	In	Co	Nd	Y	Eu	
RF	3.4	1.1	50	0	0	0	0	0	0	0	0	43.3
WM	4	3	53	0	0	0	0	0	0	0	0	26
AC	18.5	7	45.9	0	0	0	0	0	0	0	0	17.5
TV-CRT	3	2	10	1.4	19.6	0.7	0	0	0	67.51	5.47	23
TV-LCD	1	4	30	0	0	0	102	0	0	0	0	40
Mon-CRT	6.5	2	26	46	207	18.4	0	0	170	4.40×10 <sup>-5</sup>	3.56×10 <sup>-6</sup>	23
Mon-LCD	7.2	3.6	18	60	300	25	40	0	270	0	0	4.3
MPh*	2.8	2.7	3.4	30	2000	1700	1102	10788	0	0	0	25.6
TPh	2	2	1	2.2	30.8	1.1	10000	0	0	0	0	69
Desktop	7.2	3.6	18	60	300	25	40	0	0	0	0	4.3
Laptop	5.7	1.5	20	32	190	19	140	10700	360	0	0	16
PCFM	0.5	18	32	0	0	0	0	0	0	0	0	40
RH	10	8	30	0	0	0	0	0	0	0	0	5
GWH	8	10	30	0	0	0	0	0	0	0	0	5
EWH	5	10	35	0	0	0	0	0	0	0	0	5

Note: \*data source from (Chen et al., 2018; Singh et al., 2018)<sup>4</sup> and other data source from (Zeng et al., 2016)<sup>2</sup>. The content data is obedient to normal distribution.

Table S6 Vehicle classification in Hong Kong

Vehicle	Average Weight (t)	Range	Impact factor on vehicle amount
Motorcycle	0.11	[0.10, 0.12]	Household income
Private Car	1.25	[1, 1.5]	Household income
Taxi	1.25	[1, 1.5]	Population
Light bus	3	[2,4]	Population
Franchised, non-franchised and private bus	Single deck: 8; Double deck: 14	Single deck: [4; 11] Double deck: [11,16]	Population
Government and special purpose vehicle	2.75	1.1. [0, 5.5]	1.2. GDP
Light goods vehicle	1.3. 2.75	1.4. [0, 5.5]	1.5. GDP
Medium goods vehicle	1.6. 14.75	1.7. [5.5, 24]	1.8. GDP
Heavy goods vehicle	1.9. 30.00	1.10. [24, 38]	1.11. GDP

Table S7 Average content of resources in vehicles (g/unit)

Resource	Content	Resource	Content	Resource	Content
Fe	806,144	Co	36.2	La	4.04
Al	110,544	Nd	162	Pr	16.53
Cu	28,500	Y	0.41	Dy	14.7
Au	3.08	Eu	0.23	Plastic	6,000
Ag	17.5	Zn	1,000	Tire and rubber	3,420
Pd	1.24	Rh	0.01	Glass	2,700
In	0.38	Ce	46.95		

Note: all the average contents were calculated from all the available data<sup>5-12</sup> and are obedient to normal distribution.

Table S8 The mean and error of market value of various resources (US\$/t)

Resource	Mean	Error	Resource	Mean	Error	Resource	Mean	Error
Al	2100	±650	Au	46.3×10 <sup>6</sup>	±11.6×10 <sup>6</sup>	Ce	12570	±5580
Co	48400	±26600	Pd	25.4×10 <sup>6</sup>	±9.6×10 <sup>6</sup>	La	14330	±5470

<b>Cu</b>	7300	±2900	Nd	5.11×10 <sup>6</sup>	±2.00×10 <sup>5</sup>	Pr	52900	±2000
<b>Fe</b>	250	±74	Y	5.55×10 <sup>4</sup>	±0.25×10 <sup>4</sup>	Dy	235500	±250
<b>In</b>	24×10 <sup>6</sup>	±11×10 <sup>6</sup>	Eu	6.85×10 <sup>5</sup>	±0.25×10 <sup>5</sup>	Plastic	890	±140
<b>Ag</b>	7.57×10 <sup>5</sup>	±7.43×10 <sup>5</sup>	Rh	80.5×10 <sup>6</sup>	±18.1×10 <sup>6</sup>			

Note: data source from (Zeng et al., 2016; Balde et al., 2015; Portal, 2018) <sup>2, 13, 14</sup>.

Table S9 Average e-waste generation in many countries and regions

Country/Region	Year	Generation (kt)	Average (kg/cap)	E-waste scope
Hong Kong (this study)	2015	185	25.3	14 types
	2050	187	23.0	
Hong Kong <sup>15</sup>	2010	81	11.5	TV, RF, WM, AC, &
Macau <sup>16</sup>	2010	5.2	9.17	PC
China Mainland <sup>2</sup>	2010	4630	3.46	14 types
	2030	28400	20.6	
Netherland <sup>17</sup>	2010	392	23.7	25 types
Denmark <sup>18</sup>	2015	81	14.3	Large & small
Switzerland <sup>19</sup>	2009	113	~15	household appliance, and ICT equipment
India <sup>20</sup>	2014	None	1.3	WEEE directive
Brazil <sup>21</sup>	2015	None	6.5	WEEE directive
Mexico <sup>21</sup>	2014	None	8.2	WEEE directive
South Africa <sup>21</sup>	2014	None	6.6	WEEE directive
Russia <sup>21</sup>	2014	None	8.7	WEEE directive

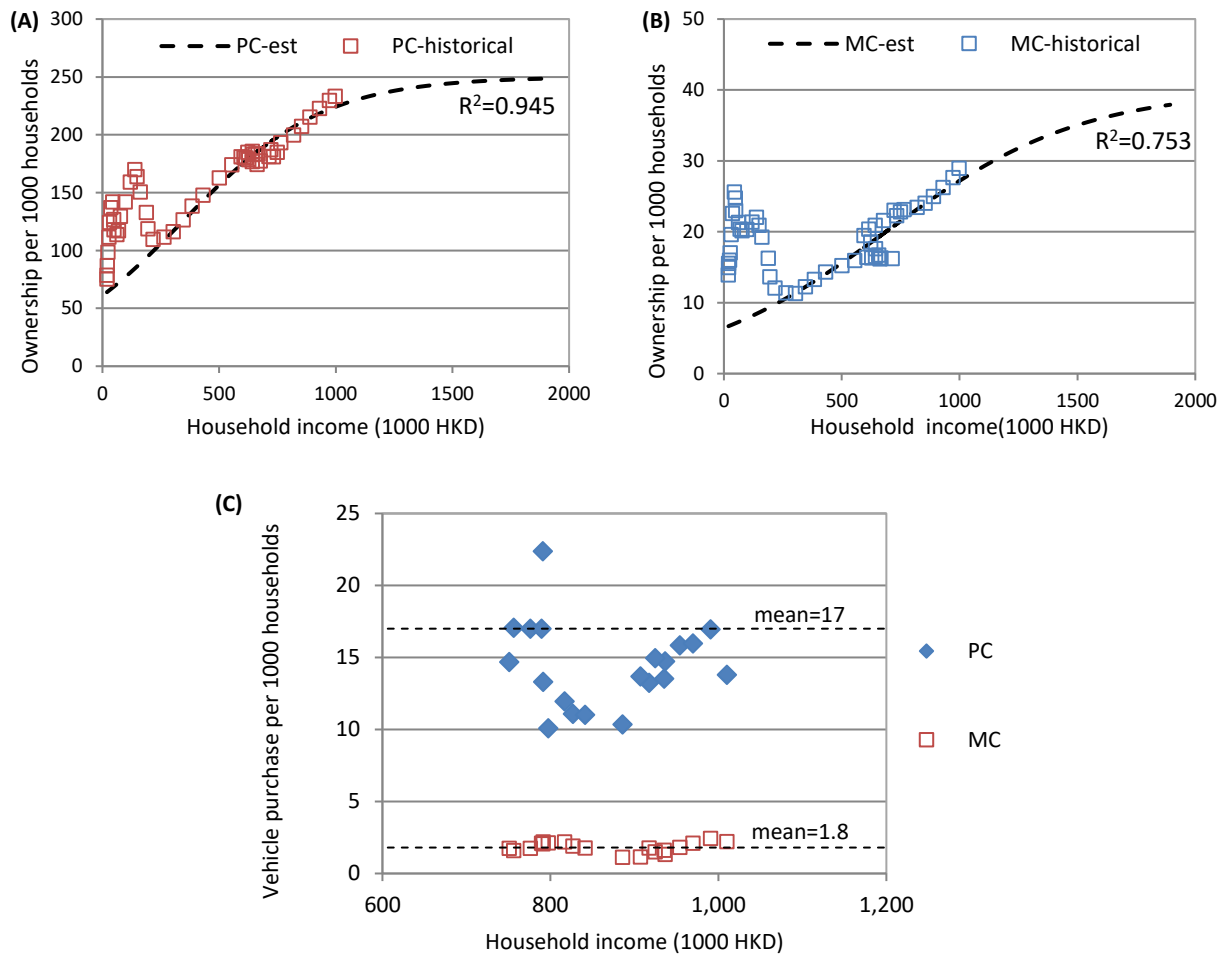


Figure S2 Historical data for private vehicles and their regression  
 (A) Passenger cars; (B) Motorcycles; (C) sales data of vehicles

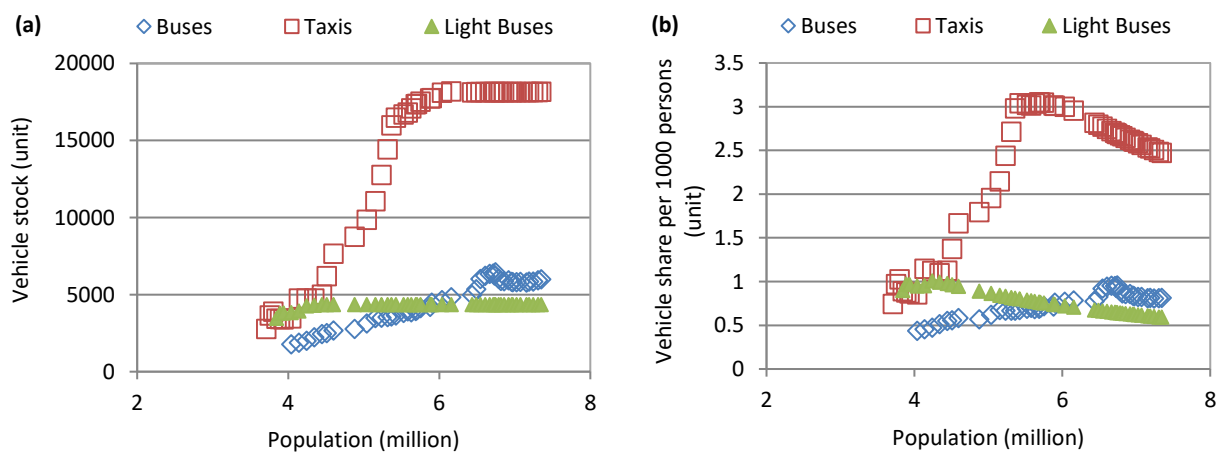


Figure S3 Public transport vehicle share subject to population

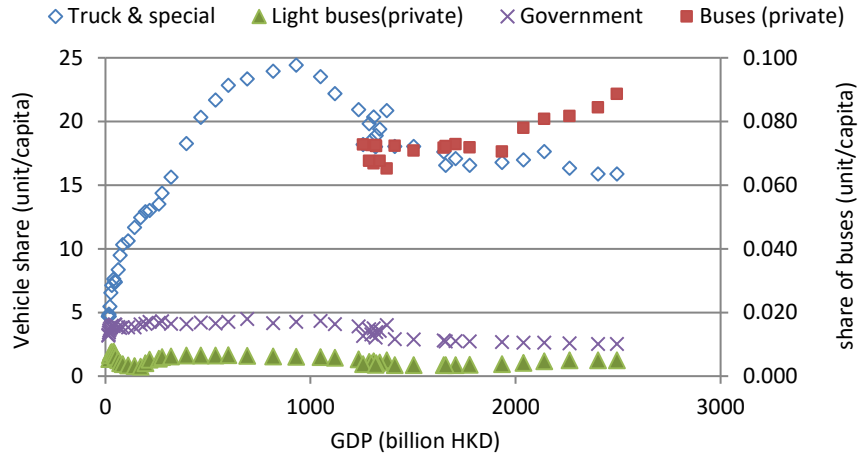


Figure S4 Commercial- and social-use vehicle share in relation to GDP

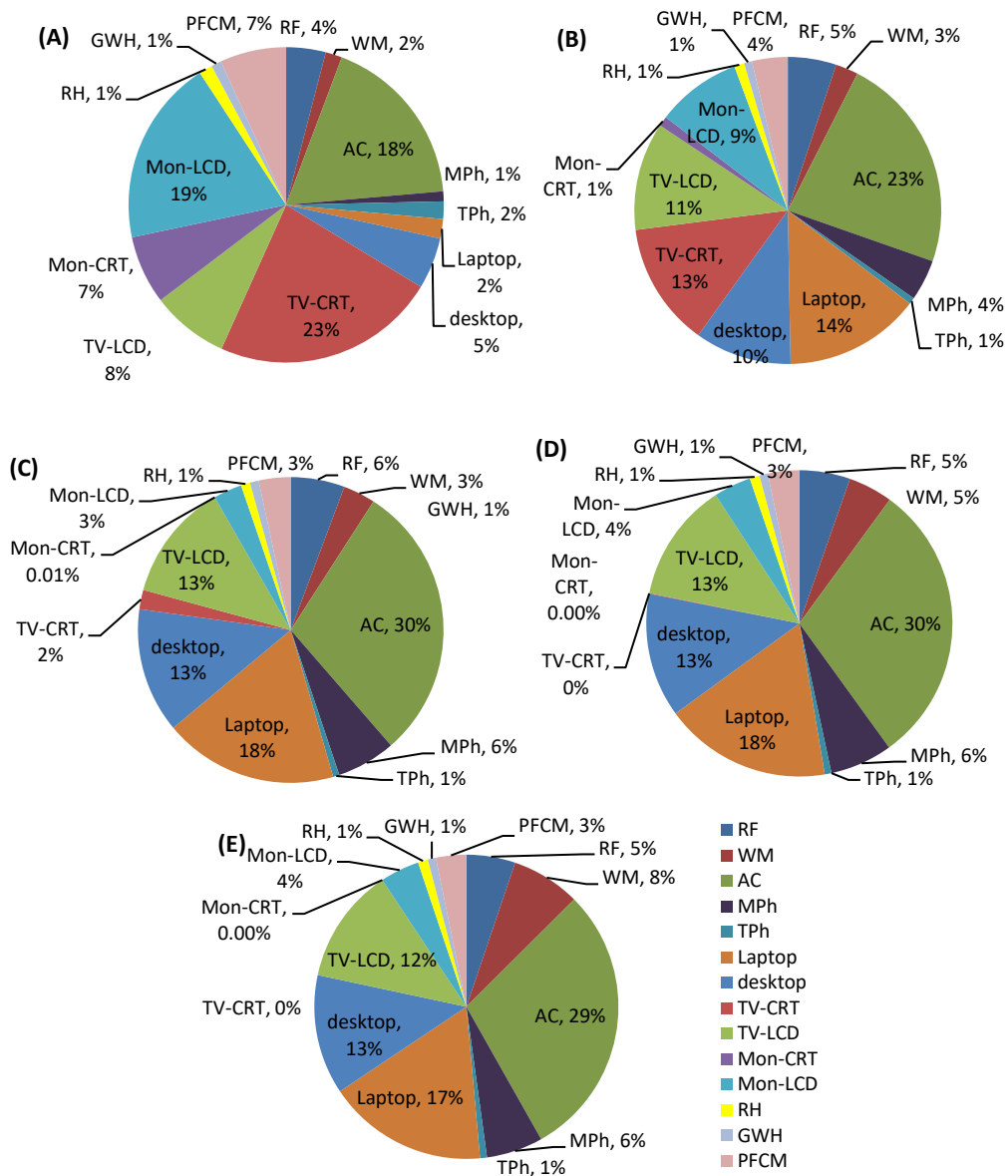


Figure S5 Weight Structure of the generated e-waste in Hong Kong

(A) 2012; (B) 2020; (C) 2030; (D) 2040; (E) 2050

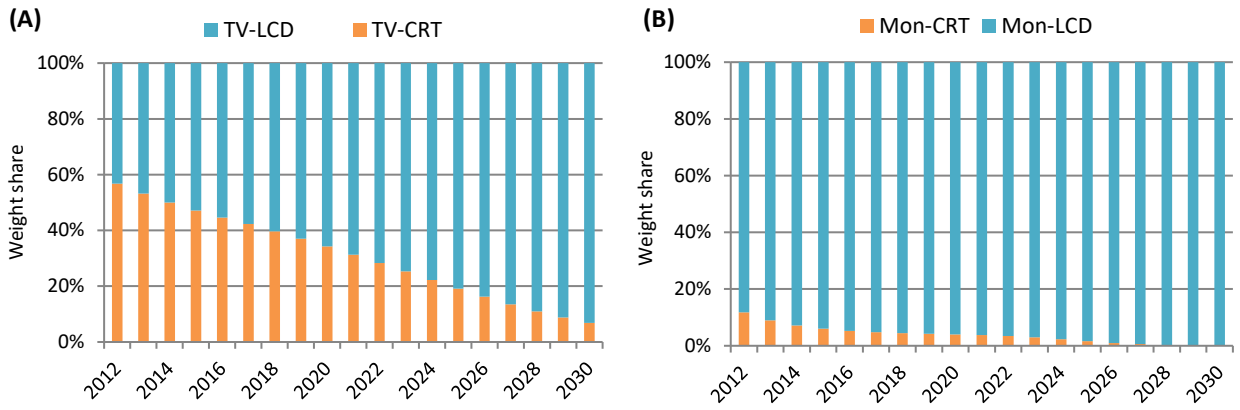


Figure S6 Weight share interchanges between CRT and LCD products  
 (A) TVs; (B) monitors

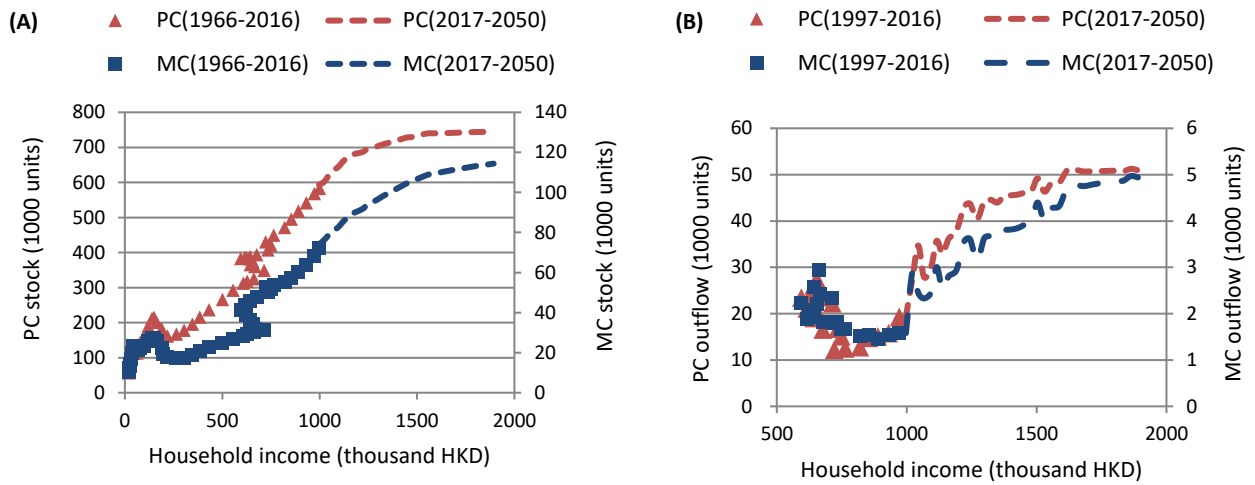
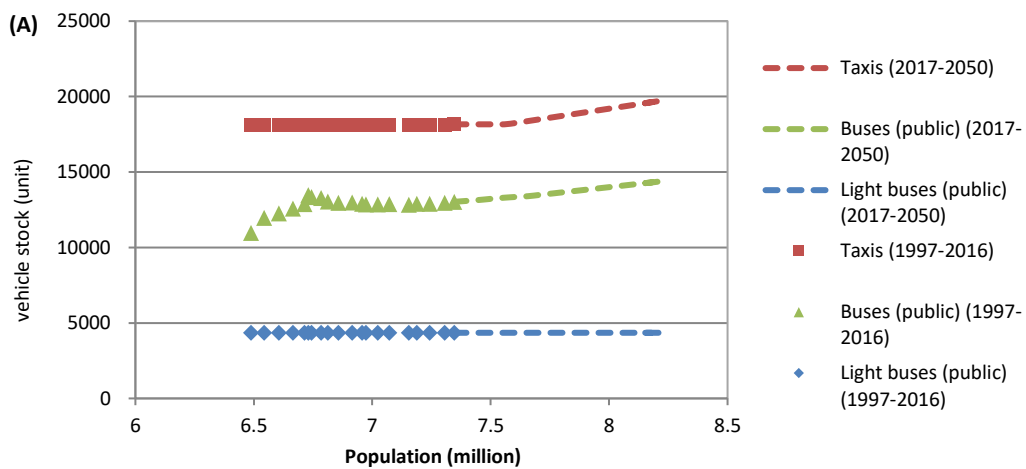


Figure S7 Predicted amount of passenger car and motorcycle  
 (A) in-use stock; (B) ELV



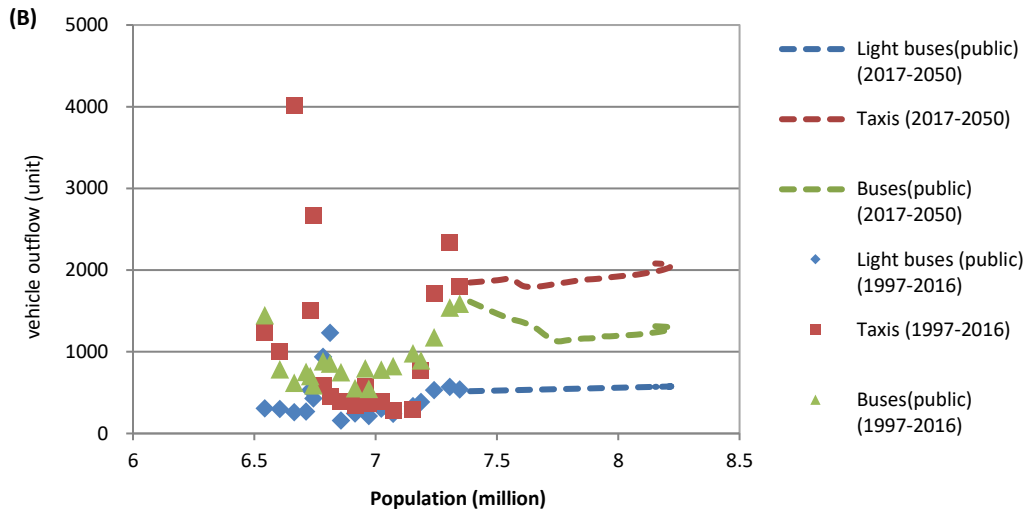
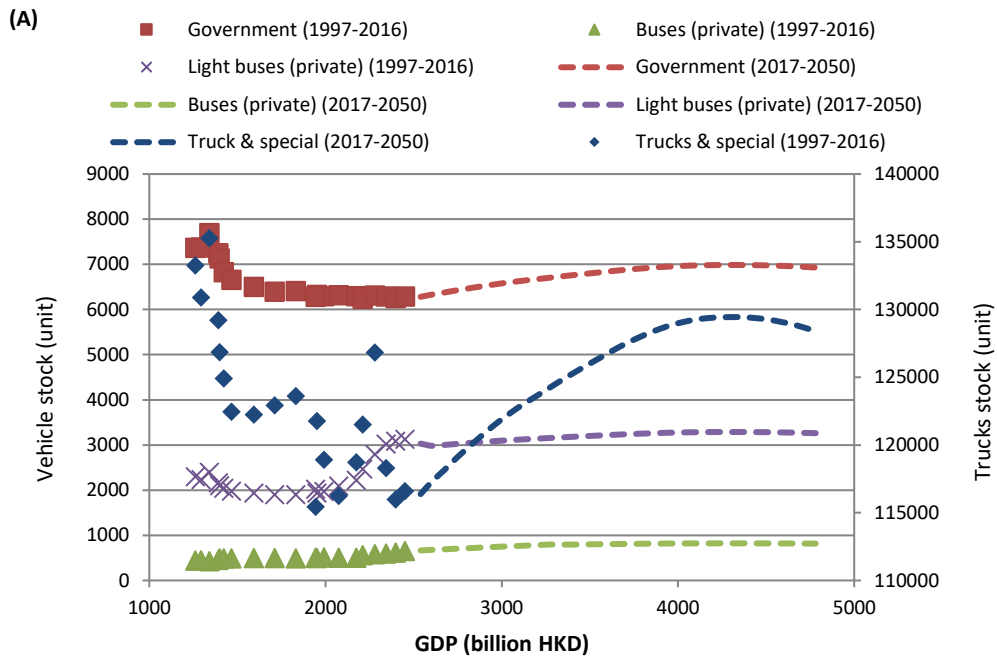


Figure S8 Predicted amount of public transport in relation to population

(A) in-use stock; (B) ELV



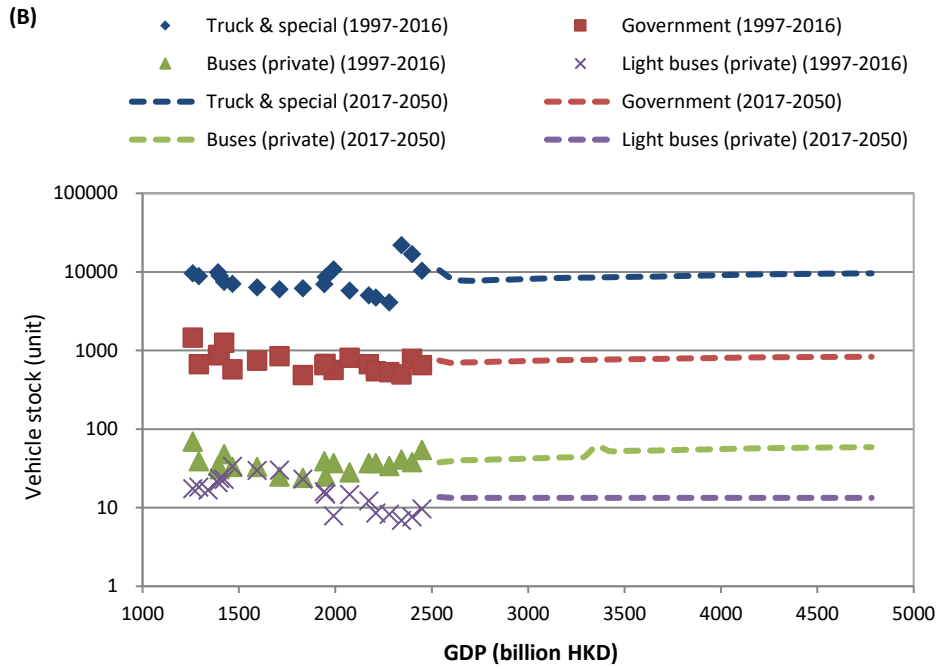


Figure S9 Predicted amount of Commercial- and social-used vehicles (A) in-use stock; (B) ELV

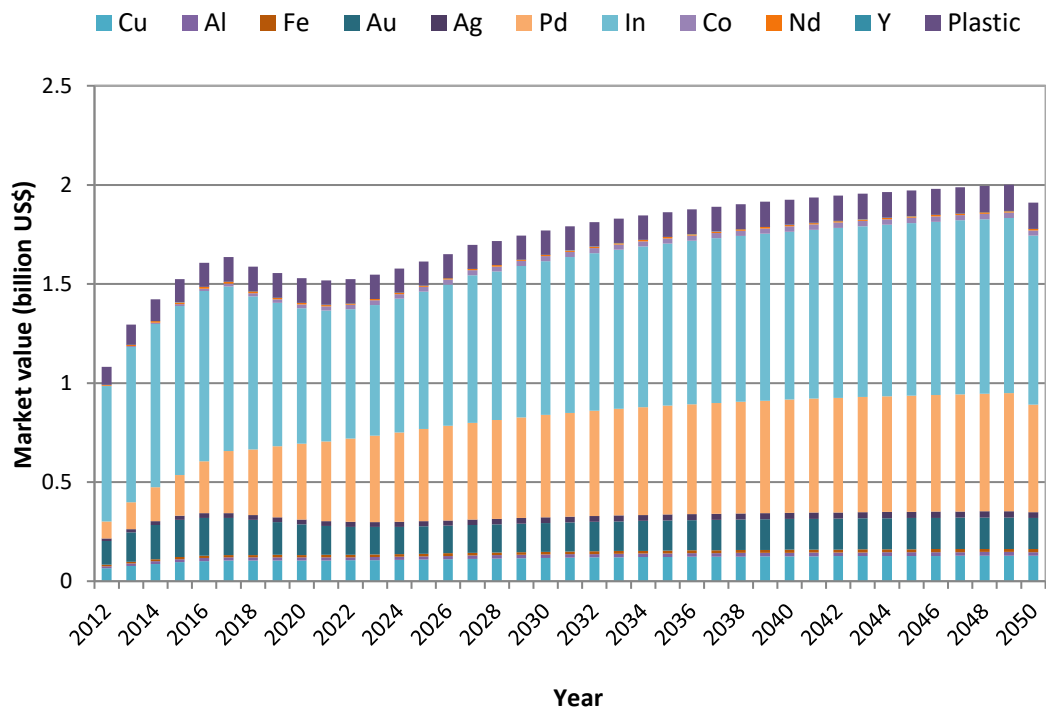


Figure S10 Economic potential of annually generated e-waste



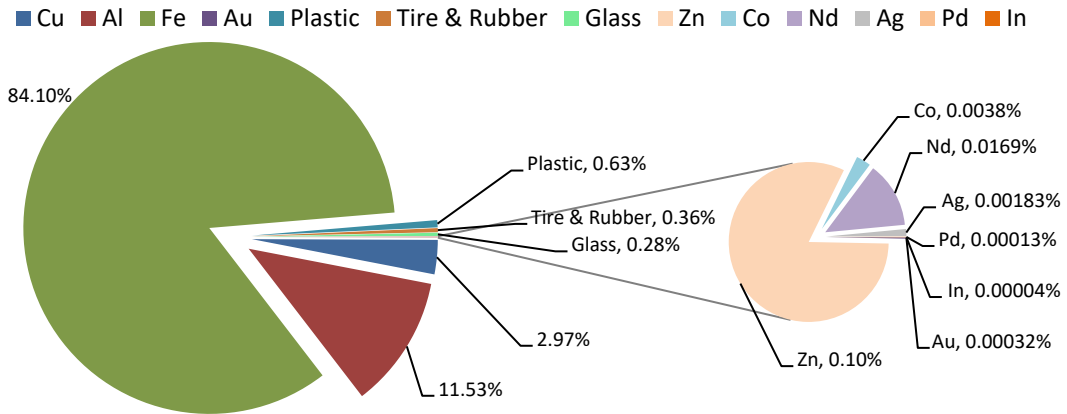


Figure S11 The weight distribution of various resources in ELV

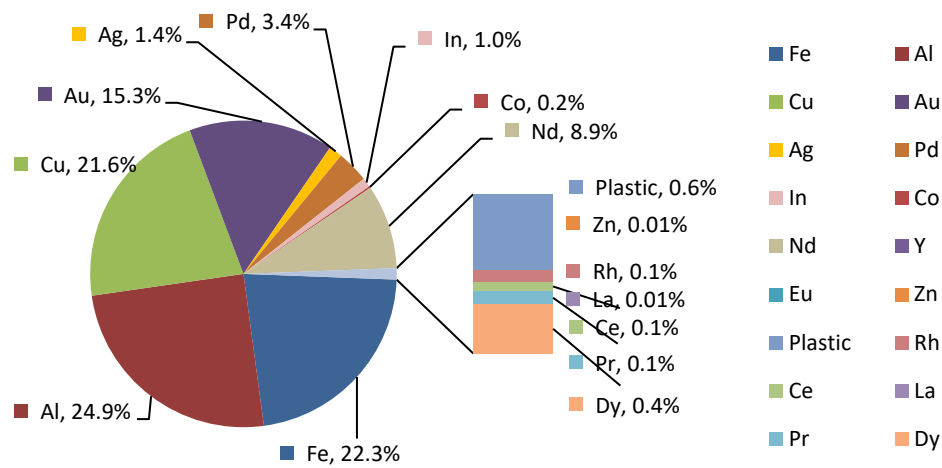
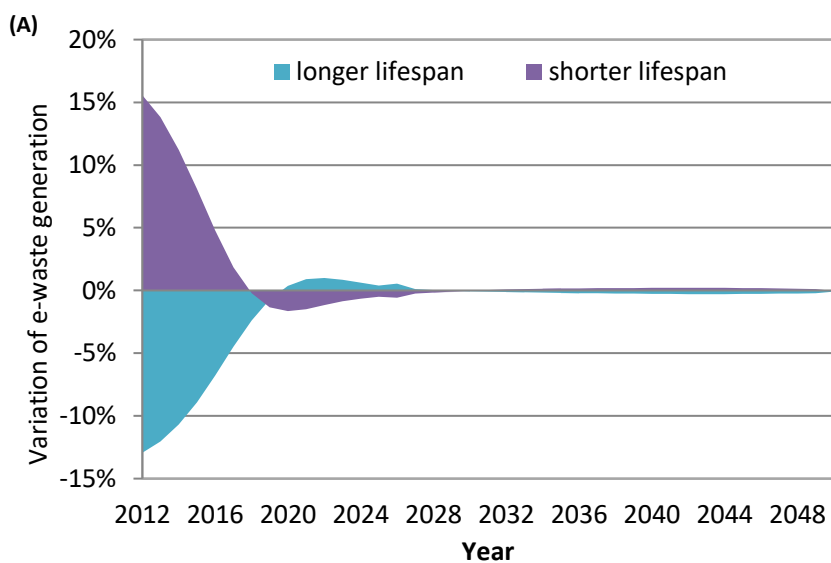


Figure S12 Market value share of various resources in ELV



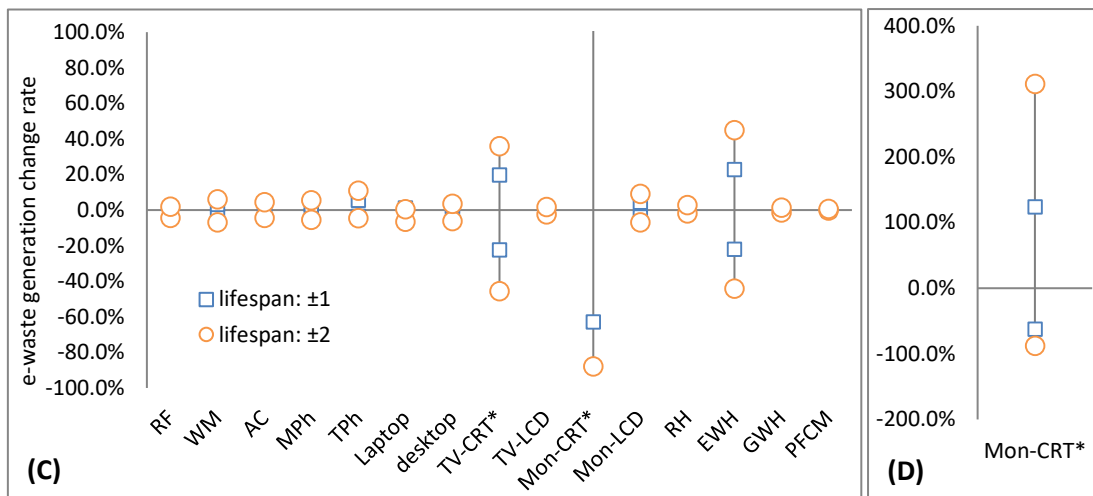
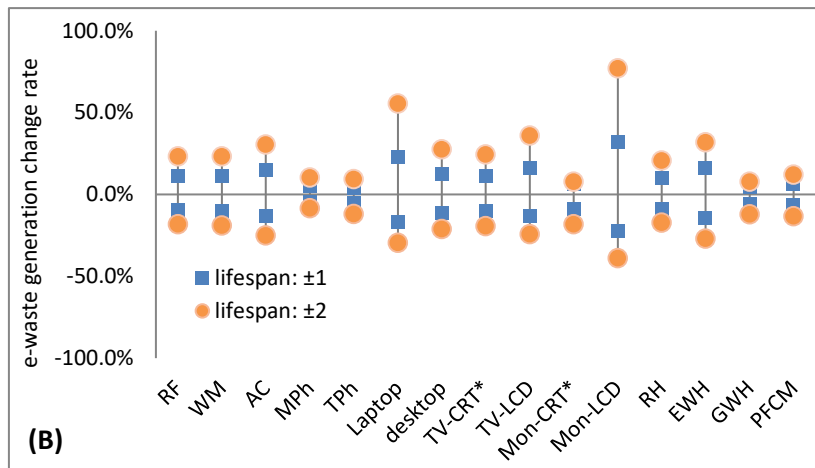


Figure S13 The effect of lifespan variation on e-waste generation.

(A) total e-waste with 1-year variation; (B) Maximum variation before 2025; (C)

Maximum variation after 2025. (D) Maximum variation of Mon-CRT\* after 2025.

\*The sensitivity of CRT products to lifespan could be significant due to their small consumption in the future.

## Text S1 Verification of Data Adaptability

EEE lifespan may vary country by country. Here the adaptability of EEE lifespan data from Netherlands is verified, by means of comparing an array of factors between two economies. The evaluated factors include GDP per capita, imports, exports, consumer price index, Gini coefficient, dependency ratio and uncertainty avoidance, as shown in Figure S14. GDP per capita is one of the most critical factors in EEE lifespan. Consumers can afford new electronic products due to higher income, which results in the shorter lifetime of electronic devices. Furthermore, GDP is relative to other economic activities, such as imports and exports.

Two other economic factors that can affect EEE lifespan are prices and Gini coefficient. The former is simply straightforward; higher price of equipment may inhibit the desire of buying new products. Gini coefficient is a measure of income inequity of a society, ranging from 0 to 1. The higher the Gini coefficient, the wider the gap between the poor and the rich is. In highly unequal society, people will tend to lengthen the lifespan of EEE owing to their diminished affordability.

In perspective of society and culture, dependency ratio and uncertainty avoidance are assessed. Age distribution and acceptability to changes can affect EEE lifespan. Dependency ratio is a population size ratio of those out of the labor force (aged 0-14 and 65+) to those in the labor force (15-64). Since younger people are usually more often to replace their equipment in a shorter period than older people are, a low dependency ratio of society can imply a relatively low EEE lifespan. Uncertainty avoidance refers to the degree, to which the society refuses changes and taking risks. Therefore, high uncertainty avoidance index (UAI) can infer that people have low tendency to new technologies, which leads to longer EEE lifetime.

Assessment of factor significance to EEE lifespan can be performed by the approach suggested by Petridis et al.<sup>22</sup> Overall variance of the EEE lifespan, which is dependent on every individual factor with different significances, can be given by following equation:

$$OV = \frac{\sum_{i=1}^n X_i Y_i}{\sum_{i=1}^n Y_i}$$
$$X_i = e^{-\beta_i \cdot \Delta x_i}$$

Here  $OV$  is overall variance;  $X_i$  is the impact of factor  $i$ ;  $Y_i$  is the independence factor

(weight) of factor  $i$ ;  $\beta_i$  is the beta parameter that determines the individual impact of factor  $i$ ;

$\Delta x_i$  is the average difference of factor  $i$  between Netherlands and Hong Kong over a period  $t$ ,

$$\text{which can be given by } \Delta x_i = \left( \sum_t \frac{x_{i(HK)} - x_{i(NLD)}}{x_{i(NLD)}} \right) / t.$$

Based on the data for the factors in two regions (Figure S14), the result is presented in Table S9. The overall variance of -8.7% suggests that the EEE lifespan in Hong Kong will be 8.7% shorter than Netherlands. Because the maximum lifespan of the studied EEEs is 16.5 years, the maximum variance will be less than 1.5 years, which can be considered insignificant. The data can be approximately adopted in this study, and the possible error will be covered in sensitivity analysis.

**Table S10 Average e-waste generation in many countries and regions**

Factor	Effect	beta	Average Difference	Independence Factor (weight)	Weighted Impact
GDP per capita (US\$/cap)	(-)	-0.27	-21.3%	0.79	4.7%
Imports (current US\$/cap)	(-)	-0.29	100%	1.02	-25.6%
Exports (current US\$/cap)	(-)	-0.35	81.7%	0.95	-23.6%
Consumer price index (2010=100)	(+)	0.66	8.1%	0.34	18.1%
Gini coefficient	(+)	0.49	87.1%	0.22	1.2%
Dependency ratio	(+)	0.63	-22.3%	1	-13.1%
Uncertainty avoidance	(+)	0.33	-24.5%	1	-7.8%
Overall variance					-8.7%

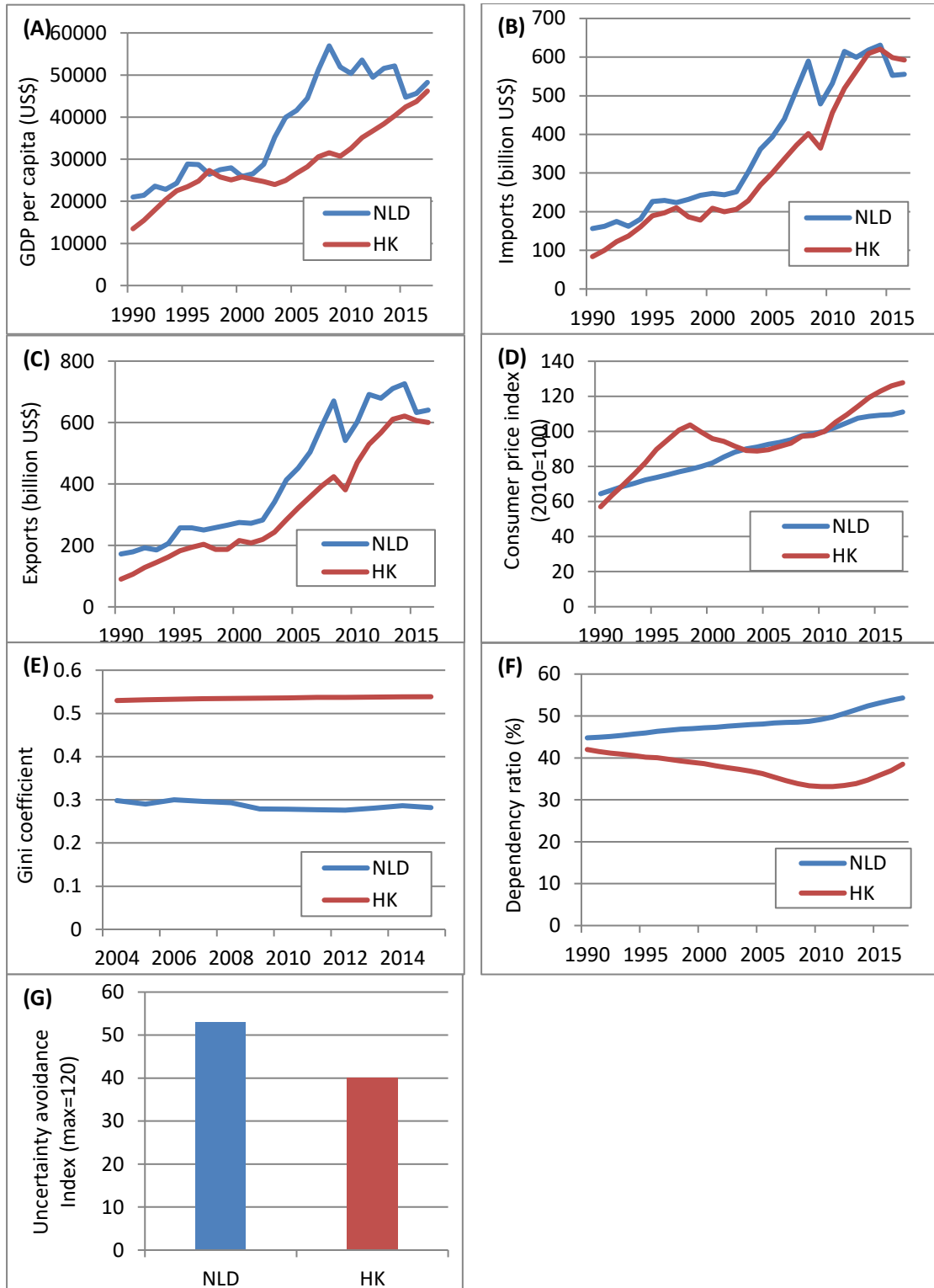


Figure S14 Comparison between Netherlands and Hong Kong

(A) GDP per capita; (B) imports; (C) exports; (D) consumer price index (2010=100); (E) Gini coefficient; (F) dependency ratio; and (G) uncertainty avoidance.

Note: NLD: Netherlands; HK: Hong Kong; Data source of (A)-(F) is the World Bank<sup>23</sup> and of (G) is Clearly Cultural<sup>24</sup>.

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