Data Article

Data on the domestic processed output, balancing items, and solid waste potential for five major world economies

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ABSTRACT

This data article reports the domestic processed output (DPO), balancing items, and solid waste potential for five major world economies (Australia, China, Germany, Japan, and the United States of America) for the years 1990–2015. The main DPO database assembles data from a number of national and international sources. Linking this with data on domestic material consumption and the calculation of balancing items, we have been able to provide fully balanced inputs and outputs for these five economies. To integrate poor statistics on solid waste, we modelled an additional solid waste potential account based on a stock and flow driven model that estimates solid waste output for the year 2015. These data underlies the research published in “On the importance of linking inputs and outputs in material flow accounts. The Weight of Nations report revisited” (Schandl and Miatto, 2018).

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## Specifications table

| Subject area          | Environmental sciences |
|----------------------|------------------------|
| More specific subject area | Ecology               |
| Type of data         | Tables and figures     |
| How data were acquired | Collection of statistical data (for DPO account), own calculations (for balancing items), and modelled (for solid waste potential) |
| Data format          | Raw and analysed       |
| Experimental factors | Data are sourced from major international and, when unavailable, national agencies for five countries: Australia, China, Germany, Japan, and the United States of America |
| Experimental features | The DPO account is comprised of untreated data from several sources; the balancing items are calculated in accordance with the economy-wide material flow account manual issued by Eurostat; the solid waste potential is estimated through a depreciation model fed by material extraction and trade statistics issued by the International Resource Panel. |
| Data source location | International sources (FAO, IEA, UNFCCC), national statistical accounts. |
| Data accessibility   | Data are included in this article |
| Related research article | Schandl, Heinz, and Alessio Miatto. “On the Importance of Linking Inputs and Outputs in Material Flow Accounts. The Weight of Nations Report Revisited.” Journal of Cleaner Production [1]. |

## Value of the data

- This data article provides a complete dataset on the material outflows of five major world economies. For the first time we can compare the emissions and waste of developed old world countries (Germany and Japan), developed new world countries (Australia and the United States), and developing Asian countries (China) on a per-capita level.
- This dataset can be integrated and expanded with other countries in future and offers a valid benchmarking point for monitoring emissions and waste production on a per-capita level, linking to the sustainability efforts outlined by the sustainable development goals (SDGs).
- The calculation of the balancing items makes explicit the quantification of the net additions to stock (NAS), which can be compared to empirical calculations to assess the soundness of stock accumulation models.
- Disaggregated data on material types reported in the solid waste potential permits the evaluation of the quality of reported solid waste production, offering a clear indication of which sectors are the main contributors to these categories, and links to ongoing discourse on the circularity of the economy.

## 1. Data

The composition of the DPO data was made by collecting the comprising elements from a number of national and international sources [2–7]. These data did not undergo any further processing, since our intention was to assess the availability of data and countries’ capabilities to compile DPO data without any modelling or interpolation.

Data on balancing items, both on the input and output sides have been calculated using the economy-wide material flow analysis manual issued by the European Statistical Office Eurostat [8,9]. The data on material inflows, trade, domestic material consumption (DMC), domestic processed output (DPO), balancing items, and net additions to stock (NAS) are reported in Table 1–5. Note that these are all yearly flows, and do not refer to a cumulative total.
| Year | Domestic extraction (DE) | Imports | Exports | Domestic material consumption (DMC) | Domestic processed output (DPO) | Balancing items: input side | Balancing items: output side | Net additions to stock (NAS) |
|------|-------------------------|---------|---------|-------------------------------------|---------------------------------|-----------------------------|-----------------------------|-----------------------------|
| 1990 | 908,514                 | 24,965  | 265,288 | 668,191                             | 401,243                         | 502,314                     | 369,569                     | 399,694                     |
| 1991 | 919,444                 | 25,770  | 302,911 | 642,303                             | 401,373                         | 482,646                     | 361,016                     | 362,560                     |
| 1992 | 943,094                 | 26,572  | 299,479 | 670,187                             | 403,206                         | 453,009                     | 363,107                     | 356,884                     |
| 1993 | 985,525                 | 30,955  | 319,345 | 697,135                             | 407,209                         | 445,587                     | 363,196                     | 372,317                     |
| 1994 | 985,355                 | 33,807  | 333,434 | 685,728                             | 415,240                         | 450,084                     | 365,735                     | 354,837                     |
| 1995 | 1,042,701               | 35,128  | 347,906 | 729,924                             | 426,217                         | 450,097                     | 377,575                     | 376,228                     |
| 1996 | 1,118,937               | 36,331  | 363,548 | 791,720                             | 436,643                         | 462,090                     | 385,196                     | 431,971                     |
| 1997 | 1,161,494               | 40,650  | 409,250 | 792,893                             | 448,616                         | 470,350                     | 383,690                     | 430,937                     |
| 1998 | 1,218,310               | 39,477  | 408,017 | 849,770                             | 465,243                         | 479,436                     | 393,611                     | 470,352                     |
| 1999 | 1,227,227               | 43,059  | 417,319 | 852,967                             | 477,390                         | 495,646                     | 390,967                     | 480,256                     |
| 2000 | 1,284,431               | 43,301  | 459,293 | 868,439                             | 487,038                         | 506,722                     | 400,384                     | 487,739                     |
| 2001 | 1,313,474               | 44,098  | 469,505 | 888,067                             | 495,290                         | 524,277                     | 403,470                     | 513,583                     |
| 2002 | 1,291,501               | 46,817  | 491,035 | 847,282                             | 500,590                         | 524,419                     | 395,020                     | 476,091                     |
| 2003 | 1,375,504               | 47,777  | 512,591 | 910,690                             | 508,074                         | 520,245                     | 402,245                     | 520,615                     |
| 2004 | 1,394,463               | 49,091  | 558,561 | 884,994                             | 519,520                         | 526,654                     | 397,364                     | 494,763                     |
| 2005 | 1,461,576               | 53,505  | 600,701 | 914,379                             | 525,837                         | 544,543                     | 409,665                     | 523,420                     |
| 2006 | 1,426,286               | 55,408  | 614,774 | 866,921                             | 533,065                         | 562,488                     | 406,442                     | 489,902                     |
| 2007 | 1,502,948               | 59,210  | 641,246 | 920,912                             | 543,129                         | 565,601                     | 417,443                     | 525,940                     |
| 2008 | 1,526,834               | 65,757  | 691,402 | 901,190                             | 545,714                         | 554,465                     | 413,700                     | 496,241                     |
| 2009 | 1,624,230               | 59,885  | 763,038 | 921,078                             | 551,413                         | 554,846                     | 415,003                     | 509,508                     |
| 2010 | 1,673,832               | 67,425  | 841,706 | 899,551                             | 548,500                         | 535,374                     | 404,711                     | 481,714                     |
| 2011 | 1,728,499               | 70,915  | 881,751 | 917,663                             | 548,991                         | 532,156                     | 417,271                     | 483,557                     |
| 2012 | 1,804,101               | 72,159  | 965,826 | 910,434                             | 552,880                         | 520,362                     | 417,612                     | 460,304                     |
| 2013 | 1,936,692               | 75,016  | 1,091,410 | 920,298 | 546,273 | 515,196 | 421,657 | 467,564 |
| 2014 | 2,108,788               | 75,456  | 1,275,297 | 908,947 | 543,522 | 514,879 | 420,167 | 460,136 |
| 2015 | 2,172,404               | 76,979  | 1,333,299 | 916,083 | 551,911 | 512,174 | 410,731 | 465,615 |
### Table 2
China’s material balance from 1990 to 2015. Units in thousand tonnes.

| Year | Domestic extraction (DE) | Imports | Exports | Domestic material consumption (DMC) | Domestic processed output (DPO) | Balancing items: input side | Balancing items: output side | Net additions to stock (NAS) |
|------|--------------------------|---------|---------|-------------------------------------|-------------------------------|-----------------------------|-----------------------------|------------------------------|
| 1990 | 6,524,453                | 52,832  | 91,928  | 6,485,356                           | 3,908,493                     | 3,527,557                   | 2,882,293                   | 3,222,127                   |
| 1991 | 6,912,487                | 61,474  | 109,070 | 6,864,891                           | 4,078,970                     | 3,651,385                   | 2,948,701                   | 3,488,605                   |
| 1992 | 7,910,739                | 95,516  | 114,929 | 7,891,326                           | 4,263,069                     | 3,769,797                   | 3,010,803                   | 4,387,251                   |
| 1993 | 8,737,623                | 139,976 | 121,367 | 8,756,232                           | 4,677,613                     | 4,079,004                   | 3,120,036                   | 5,037,587                   |
| 1994 | 9,481,551                | 164,389 | 118,093 | 9,527,847                           | 4,902,050                     | 4,226,413                   | 3,213,164                   | 5,639,047                   |
| 1995 | 10,347,813               | 151,788 | 131,828 | 10,367,772                          | 5,333,238                     | 4,537,552                   | 3,426,016                   | 6,146,070                   |
| 1996 | 10,669,359               | 163,270 | 140,420 | 10,692,209                          | 5,428,848                     | 4,651,750                   | 3,593,729                   | 6,326,907                   |
| 1997 | 10,856,731               | 195,873 | 161,480 | 10,891,123                          | 5,477,431                     | 3,401,858                   | 6,637,848                   | 6,717,001                   |
| 1998 | 11,173,518               | 186,806 | 143,299 | 11,217,026                          | 5,666,734                     | 4,672,957                   | 3,506,249                   | 6,987,538                   |
| 1999 | 11,430,100               | 208,469 | 136,169 | 11,502,400                          | 5,594,807                     | 4,649,585                   | 3,569,640                   | 7,136,666                   |
| 2000 | 11,716,680               | 280,433 | 191,314 | 11,805,799                          | 5,871,066                     | 4,887,334                   | 3,685,401                   | 7,304,874                   |
| 2001 | 12,316,931               | 320,789 | 228,598 | 12,409,122                          | 6,146,764                     | 4,997,365                   | 3,704,874                   | 7,586,939                   |
| 2002 | 13,008,985               | 370,636 | 257,522 | 13,122,100                          | 6,484,786                     | 5,248,923                   | 3,761,182                   | 8,125,054                   |
| 2003 | 14,248,104               | 474,637 | 265,679 | 14,457,063                          | 7,289,882                     | 5,831,972                   | 3,872,770                   | 9,126,382                   |
| 2004 | 15,611,568               | 602,660 | 259,883 | 15,954,345                          | 8,251,396                     | 6,536,407                   | 4,103,249                   | 10,136,106                  |
| 2005 | 16,641,788               | 682,334 | 293,720 | 17,030,402                          | 9,162,435                     | 7,165,116                   | 4,225,812                   | 10,807,271                  |
| 2006 | 18,176,847               | 773,943 | 342,086 | 18,608,704                          | 9,993,790                     | 7,743,290                   | 4,359,617                   | 11,998,588                  |
| 2007 | 19,550,432               | 895,369 | 350,890 | 20,094,911                          | 10,818,062                    | 8,239,974                   | 4,467,896                   | 13,048,927                  |
| 2008 | 20,275,300               | 968,194 | 314,666 | 20,928,827                          | 11,149,039                    | 8,451,769                   | 4,637,932                   | 13,593,626                  |
| 2009 | 22,379,811               | 1,329,048| 222,131 | 23,486,728                          | 11,721,226                    | 8,880,051                   | 4,817,626                   | 15,827,926                  |
| 2010 | 25,009,193               | 1,439,157| 265,405 | 26,182,945                          | 12,628,582                    | 9,431,881                   | 5,081,277                   | 17,904,967                  |
| 2011 | 27,016,123               | 1,631,510| 281,534 | 28,366,100                          | 14,326,870                    | 10,189,513                  | 5,285,505                   | 18,943,238                  |
| 2012 | 28,003,974               | 1,806,196| 272,038 | 29,538,132                          | 14,640,386                    | 10,446,270                  | 5,421,840                   | 19,922,176                  |
| 2013 | 29,151,179               | 1,999,941| 301,968 | 30,849,152                          | 15,267,004                    | 10,984,911                  | 5,536,623                   | 21,030,437                  |
| 2014 | 29,922,955               | 2,056,170| 380,270 | 31,598,885                          | 15,804,465                    | 11,375,784                  | 5,539,526                   | 21,630,648                  |
| 2015 | 30,844,488               | 2,076,598| 381,564 | 32,539,522                          | 16,377,547                    | 11,768,025                  | 5,558,737                   | 22,371,263                  |
Table 3
Germany's material balance from 1990 to 2015. Units in thousand tonnes.

| Year | Domestic extraction (DE) | Imports | Exports | Domestic material consumption (DMC) | Domestic processed output (DPO) | Balancing items: input side | Balancing items: output side | Net additions to stock (NAS) |
|------|--------------------------|---------|---------|-------------------------------------|----------------------------------|-----------------------------|-------------------------------|-----------------------------|
| 1990 | 1,143,971                | 242,122 | 47,011  | 1,339,082                           | 1,466,596                        | 1,178,076                   | 675,284                       | 375,278                     |
| 1991 | 1,028,241                | 371,202 | 127,550 | 1,271,893                           | 1,439,805                        | 1,136,918                   | 646,951                       | 322,055                     |
| 1992 | 1,019,622                | 393,957 | 133,581 | 1,279,998                           | 1,400,454                        | 1,088,718                   | 619,155                       | 349,107                     |
| 1993 | 984,153                  | 371,655 | 120,720 | 1,235,088                           | 1,381,505                        | 1,074,317                   | 607,962                       | 319,938                     |
| 1994 | 1,023,239                | 390,206 | 138,149 | 1,284,296                           | 1,379,202                        | 1,057,034                   | 600,089                       | 362,039                     |
| 1995 | 954,031                  | 399,604 | 134,873 | 1,218,762                           | 1,379,933                        | 1,056,757                   | 602,451                       | 293,134                     |
| 1996 | 911,283                  | 402,296 | 139,221 | 1,174,537                           | 1,400,215                        | 1,086,156                   | 620,226                       | 240,073                     |
| 1997 | 935,199                  | 410,832 | 147,310 | 1,198,721                           | 1,382,060                        | 1,059,152                   | 614,305                       | 261,507                     |
| 1998 | 1,027,037                | 430,088 | 159,855 | 1,297,270                           | 1,375,765                        | 1,048,281                   | 606,244                       | 363,542                     |
| 1999 | 1,079,484                | 415,066 | 165,343 | 1,329,206                           | 1,358,337                        | 1,015,999                   | 593,000                       | 393,867                     |
| 2000 | 1,045,966                | 438,118 | 177,418 | 1,306,666                           | 1,367,027                        | 1,014,324                   | 588,999                       | 364,963                     |
| 2001 | 990,187                  | 436,633 | 180,085 | 1,246,734                           | 1,384,343                        | 1,034,976                   | 600,044                       | 297,323                     |
| 2002 | 954,943                  | 430,307 | 188,733 | 1,196,518                           | 1,363,542                        | 1,042,450                   | 591,496                       | 283,929                     |
| 2003 | 931,073                  | 423,322 | 185,859 | 1,168,536                           | 1,355,519                        | 1,041,166                   | 585,292                       | 268,892                     |
| 2004 | 951,441                  | 448,215 | 204,207 | 1,195,449                           | 1,338,828                        | 1,029,144                   | 594,692                       | 291,074                     |
| 2005 | 906,920                  | 457,087 | 227,019 | 1,136,987                           | 1,323,209                        | 1,007,679                   | 583,532                       | 237,926                     |
| 2006 | 932,377                  | 476,080 | 234,124 | 1,174,333                           | 1,344,764                        | 1,019,738                   | 584,149                       | 265,158                     |
| 2007 | 1,017,324                | 478,134 | 248,760 | 1,246,698                           | 1,324,454                        | 981,313                     | 566,913                       | 336,644                     |
| 2008 | 1,000,703                | 480,319 | 244,656 | 1,236,366                           | 1,330,534                        | 987,105                     | 578,950                       | 313,987                     |
| 2009 | 975,248                  | 414,392 | 211,530 | 1,178,500                           | 1,250,408                        | 925,950                     | 563,781                       | 289,872                     |
| 2010 | 948,269                  | 459,650 | 227,706 | 1,180,212                           | 1,298,042                        | 958,481                     | 556,801                       | 283,850                     |
| 2011 | 996,155                  | 467,756 | 233,060 | 1,230,851                           | 1,297,288                        | 938,670                     | 554,537                       | 317,696                     |
| 2012 | 966,890                  | 459,045 | 223,184 | 1,202,752                           | 1,286,701                        | 943,783                     | 556,733                       | 303,100                     |
| 2013 | 945,872                  | 474,331 | 225,055 | 1,195,148                           | 1,311,023                        | 963,656                     | 562,092                       | 285,689                     |
| 2014 | 961,901                  | 474,452 | 229,494 | 1,206,859                           | 1,282,621                        | 914,521                     | 547,093                       | 291,666                     |
| 2015 | 960,308                  | 489,052 | 237,773 | 1,211,588                           | 1,281,274                        | 919,783                     | 555,290                       | 294,807                     |
### Table 4
Japan's material balance from 1990 to 2015. Units in thousand tonnes.

**Unit: thousand tonnes**

| Year | Domestic extraction (DE) | Imports | Exports | Domestic material consumption (DMC) | Domestic processed output (DPO) | Balancing items: input side | Balancing items: output side | Net additions to stock (NAS) |
|------|--------------------------|---------|---------|------------------------------------|-------------------------------|-----------------------------|-----------------------------|----------------------------|
| 1990 | 995,283                  | 661,421 | 38,541  | 1,618,164                          | 1,659,749                     | 1,224,391                   | 609,824                     | 572,981                    |
| 1991 | 1,000,778                | 670,969 | 44,055  | 1,627,692                          | 1,671,447                     | 1,222,587                   | 607,214                     | 571,619                    |
| 1992 | 966,312                  | 660,334 | 51,575  | 1,575,071                          | 1,686,353                     | 1,241,571                   | 624,147                     | 506,142                    |
| 1993 | 939,752                  | 663,618 | 59,317  | 1,544,054                          | 1,671,954                     | 1,231,296                   | 618,177                     | 485,219                    |
| 1994 | 950,235                  | 696,444 | 61,746  | 1,584,933                          | 1,743,731                     | 1,301,825                   | 650,507                     | 492,520                    |
| 1995 | 935,558                  | 713,707 | 61,139  | 1,588,126                          | 1,745,460                     | 1,310,392                   | 648,242                     | 504,816                    |
| 1996 | 970,064                  | 716,398 | 56,661  | 1,629,800                          | 1,769,003                     | 1,324,354                   | 656,294                     | 528,857                    |
| 1997 | 943,679                  | 731,607 | 61,976  | 1,613,310                          | 1,776,713                     | 1,320,127                   | 656,003                     | 500,721                    |
| 1998 | 894,996                  | 692,631 | 61,735  | 1,525,892                          | 1,733,917                     | 1,281,980                   | 640,327                     | 433,628                    |
| 1999 | 882,036                  | 709,772 | 61,356  | 1,530,452                          | 1,759,533                     | 1,316,654                   | 652,691                     | 434,882                    |
| 2000 | 888,037                  | 755,793 | 68,425  | 1,575,394                          | 1,790,179                     | 1,344,010                   | 668,020                     | 461,205                    |
| 2001 | 852,529                  | 724,700 | 73,450  | 1,503,780                          | 1,763,054                     | 1,314,843                   | 648,213                     | 407,355                    |
| 2002 | 811,967                  | 736,679 | 76,874  | 1,469,972                          | 1,792,832                     | 1,348,719                   | 658,028                     | 367,830                    |
| 2003 | 786,735                  | 752,947 | 78,230  | 1,461,453                          | 1,815,962                     | 1,355,512                   | 669,134                     | 331,868                    |
| 2004 | 780,965                  | 771,830 | 84,785  | 1,468,010                          | 1,821,686                     | 1,357,077                   | 670,143                     | 333,258                    |
| 2005 | 775,700                  | 770,056 | 90,888  | 1,454,868                          | 1,832,355                     | 1,366,113                   | 670,036                     | 318,589                    |
| 2006 | 794,162                  | 765,053 | 94,657  | 1,464,558                          | 1,808,479                     | 1,352,259                   | 665,598                     | 342,740                    |
| 2007 | 774,526                  | 778,955 | 98,599  | 1,454,882                          | 1,841,995                     | 1,387,343                   | 675,449                     | 324,781                    |
| 2008 | 723,663                  | 764,253 | 100,896 | 1,387,020                          | 1,736,090                     | 1,316,796                   | 656,297                     | 311,429                    |
| 2009 | 664,464                  | 667,282 | 96,335  | 1,235,211                          | 1,647,485                     | 1,237,297                   | 619,487                     | 205,518                    |
| 2010 | 632,834                  | 741,528 | 107,166 | 1,267,195                          | 1,694,271                     | 1,292,776                   | 643,055                     | 222,644                    |
| 2011 | 625,003                  | 737,899 | 101,051 | 1,261,851                          | 1,734,574                     | 1,349,813                   | 666,101                     | 210,990                    |
| 2012 | 606,466                  | 750,986 | 95,896  | 1,267,557                          | 1,764,355                     | 1,386,853                   | 682,602                     | 207,452                    |
| 2013 | 587,835                  | 769,296 | 106,938 | 1,250,193                          | 1,786,413                     | 1,398,892                   | 679,839                     | 182,833                    |
| 2014 | 568,086                  | 751,432 | 104,184 | 1,215,333                          | 1,746,087                     | 1,353,343                   | 664,090                     | 158,500                    |
| 2015 | 547,738                  | 748,320 | 108,566 | 1,187,492                          | 1,699,544                     | 1,314,899                   | 650,829                     | 152,018                    |
Table 5
United States' material balance from 1990 to 2015. Units in thousand tonnes.

United States of America’s material balance

| Year | Domestic extraction (DE) | Imports | Exports | Domestic material consumption (DMC) | Domestic processed output (DPO) | Balancing items: input side | Balancing items: output side | Net additions to stock (NAS) |
|------|--------------------------|---------|---------|------------------------------------|-------------------------------|-----------------------------|----------------------------|------------------------------|
| 1990 | 6,669,981                | 586,041 | 360,758 | 6,895,265                          | 6,016,539                     | 5,324,402                   | 3,019,788                  | 3,183,340                    |
| 1991 | 6,381,938                | 578,327 | 374,520 | 6,585,746                          | 5,961,979                     | 5,250,490                   | 2,986,425                  | 2,887,832                    |
| 1992 | 6,593,860                | 610,639 | 357,135 | 6,847,364                          | 6,082,995                     | 5,376,686                   | 3,057,863                  | 3,083,192                    |
| 1993 | 6,561,635                | 670,345 | 325,941 | 6,906,039                          | 6,208,654                     | 5,507,707                   | 3,075,207                  | 3,129,885                    |
| 1994 | 7,053,823                | 726,983 | 313,906 | 7,466,900                          | 6,324,129                     | 5,626,292                   | 3,220,948                  | 3,548,115                    |
| 1995 | 7,008,314                | 722,627 | 376,898 | 7,354,043                          | 6,391,388                     | 5,684,097                   | 3,170,756                  | 3,475,997                    |
| 1996 | 7,181,130                | 777,710 | 368,312 | 7,590,528                          | 6,599,768                     | 5,853,642                   | 3,256,498                  | 3,587,904                    |
| 1997 | 7,476,281                | 836,166 | 353,586 | 7,958,861                          | 6,688,037                     | 5,965,911                   | 3,314,260                  | 3,922,476                    |
| 1998 | 7,739,691                | 894,779 | 348,462 | 8,286,009                          | 6,740,476                     | 6,036,333                   | 3,351,921                  | 4,229,944                    |
| 1999 | 7,726,687                | 915,277 | 337,238 | 8,304,725                          | 6,844,872                     | 6,094,716                   | 3,345,613                  | 4,208,956                    |
| 2000 | 7,755,532                | 975,268 | 368,792 | 8,362,008                          | 7,038,313                     | 6,252,743                   | 3,390,036                  | 4,186,402                    |
| 2001 | 7,610,081                | 995,689 | 352,503 | 8,253,268                          | 6,934,645                     | 6,258,527                   | 3,450,583                  | 4,126,567                    |
| 2002 | 7,399,839                | 984,659 | 346,655 | 8,039,843                          | 6,978,861                     | 6,234,015                   | 3,378,332                  | 3,916,665                    |
| 2003 | 7,391,047                | 1,031,376| 357,523 | 8,064,901                          | 7,038,613                     | 6,286,176                   | 3,419,930                  | 3,892,534                    |
| 2004 | 7,778,052                | 1,120,078| 379,543 | 8,518,588                          | 7,171,775                     | 6,406,989                   | 3,473,422                  | 4,277,381                    |
| 2005 | 8,003,532                | 1,159,465| 392,538 | 8,770,459                          | 7,216,860                     | 6,400,437                   | 3,473,417                  | 4,480,619                    |
| 2006 | 7,860,070                | 1,178,618| 416,881 | 8,621,807                          | 7,143,762                     | 6,344,062                   | 3,489,785                  | 4,332,321                    |
| 2007 | 7,499,056                | 1,123,062| 451,273 | 8,170,845                          | 7,241,283                     | 6,440,498                   | 3,518,183                  | 3,851,877                    |
| 2008 | 7,100,313                | 1,060,229| 514,461 | 7,646,082                          | 7,040,747                     | 6,256,749                   | 3,459,657                  | 3,402,427                    |
| 2009 | 6,381,275                | 897,903 | 472,520 | 6,806,658                          | 6,547,674                     | 5,853,325                   | 3,375,648                  | 2,736,661                    |
| 2010 | 6,520,897                | 939,472 | 545,959 | 6,914,410                          | 6,749,370                     | 6,001,712                   | 3,383,101                  | 2,783,651                    |
| 2011 | 6,543,501                | 921,939 | 615,773 | 6,849,667                          | 6,618,925                     | 5,873,489                   | 3,369,085                  | 2,735,145                    |
| 2012 | 6,444,891                | 855,903 | 623,762 | 6,677,031                          | 6,412,777                     | 5,688,631                   | 3,326,775                  | 2,626,109                    |
| 2013 | 6,615,207                | 822,074 | 622,511 | 6,814,769                          | 6,557,752                     | 5,785,556                   | 3,337,792                  | 2,704,782                    |
| 2014 | 6,765,225                | 755,059 | 613,142 | 6,907,143                          | 6,619,337                     | 5,908,434                   | 3,441,391                  | 2,754,849                    |
| 2015 | 6,667,735                | 758,952 | 623,033 | 6,803,654                          | 6,459,897                     | 5,842,912                   | 3,495,164                  | 2,691,506                    |
The results shown above can be visually represented as flows that either enter, exit, or are stocked in each economy. The following figures display a graphical representation of the per-capita material balance for years 1990 and 2015 for the five countries in our case study (Figs. 1–5). Note that all the figures are in scale with each other, to better give the reader a sense of the total amount of materials used by the average resident of each country.

Fig. 1. Material balance for Australia. Fig. 1A refers to year 1990, while Fig. 1B refers to year 2015.

Fig. 2. Material balance for China. This figure refers to year 1990, while the figure for year 2015 can be found in Schandl and Miatto [1].

Fig. 3. Material balance for Germany. Fig. 3A refers to year 1990, while Fig. 3B refers to year 2015.

Fig. 4. Material balance for Japan. Fig. 4A refers to year 1990, while Fig. 4B refers to year 2015.

Fig. 5. Material balance for the United States of America. This figure refers to year 1990, while the figure for year 2015 can be found in Schandl and Miatto [1].
Domestic processed output is comprised of five categories: emissions to air, emissions to land, emissions to water, dissipative use of products, and dissipative losses. Emissions to air are gases emitted into the atmosphere such as carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), etc. Note that all these gases are reported in mass terms, and not according to their global warming potential in carbon dioxide equivalent (CO₂-eq). Emissions to land account for the solid waste reported in official statistics on solid waste production. Emissions to water comprise all substances that are released in water. Note that this value considers only substances that are not properly treated in waste water management plants. Dissipative use of products are those materials that are voluntarily used and dispersed in the environment, such as fertilizers, seeds, pesticides, and so on. Dissipative losses refer to products that are unintentionally dispersed into the environment, such as rubber from vehicle tires. The values of the components of the domestic processed output for the countries we analysed are reported in Tables 6–10.

2. Experimental design, materials, and methods

To complement and evaluate official statistics on solid waste we developed a model based on domestic material consumption data available in the global material flow database [6]. These data are paired with assumptions on product lifespan, which ends up in a stock and flow model that estimates outflows [10,11]. The global material flow database covers data from 1970 to 2015, and firstly we attempted to estimate solid waste flows with this data span. While sufficient for most materials,
Table 7
Components of China's domestic processed output from 1990 to 2015. All units are in thousand tonnes.

| Year | Emissions to air | Emissions to land | Emissions to water | Dissipative use of products | Dissipative losses |
|------|------------------|-------------------|--------------------|-----------------------------|-------------------|
| 1990 | 3,278,112        | 372,877           | n/a                | 257,505                     | n/a               |
| 1991 | 3,405,957        | 407,554           | n/a                | 265,459                     | n/a               |
| 1992 | 3,528,987        | 465,427           | n/a                | 268,655                     | n/a               |
| 1993 | 3,878,148        | 530,121           | n/a                | 269,344                     | n/a               |
| 1994 | 4,020,684        | 599,037           | n/a                | 282,328                     | n/a               |
| 1995 | 4,326,939        | 708,726           | n/a                | 297,573                     | n/a               |
| 1996 | 4,395,242        | 721,441           | n/a                | 306,640                     | n/a               |
| 1997 | 4,381,032        | 736,102           | n/a                | 311,714                     | n/a               |
| 1998 | 4,477,828        | 884,015           | n/a                | 304,891                     | n/a               |
| 1999 | 4,407,072        | 874,101           | n/a                | 313,634                     | n/a               |
| 2000 | 4,640,248        | 910,671           | n/a                | 320,147                     | n/a               |
| 2001 | 4,781,581        | 991,373           | 14,048             | 327,672                     | n/a               |
| 2002 | 5,075,945        | 1,057,047         | 13,670             | 338,124                     | n/a               |
| 2003 | 5,378,392        | 1,194,823         | 13,330             | 343,338                     | n/a               |
| 2004 | 6,512,060        | 1,365,343         | 13,392             | 360,662                     | n/a               |
| 2005 | 7,264,012        | 1,511,874         | 14,142             | 372,408                     | n/a               |
| 2006 | 7,922,034        | 1,674,663         | 14,282             | 382,811                     | n/a               |
| 2007 | 8,496,739        | 1,919,251         | 13,818             | 388,253                     | n/a               |
| 2008 | 8,675,415        | 2,069,217         | 13,207             | 391,200                     | n/a               |
| 2009 | 9,096,639        | 2,211,069         | 12,775             | 400,743                     | n/a               |
| 2010 | 9,621,514        | 2,583,358         | 12,381             | 411,329                     | n/a               |
| 2011 | 10,473,441       | 3,425,988         | 30,023             | 397,418                     | n/a               |
| 2012 | 10,713,293       | 3,495,904         | 29,240             | 401,950                     | n/a               |
| 2013 | 11,351,828       | 3,480,974         | 28,496             | 405,706                     | n/a               |
| 2014 | 11,897,083       | 3,471,137         | 28,042             | 408,202                     | n/a               |
| 2015 | 12,442,339       | 3,501,970         | 27,395             | 405,843                     | n/a               |

Table 8
Components of Germany’s domestic processed output from 1990 to 2015. All units are in thousand tonnes.

| Year | Emissions to air | Emissions to land | Emissions to water | Dissipative use of products | Dissipative losses |
|------|------------------|-------------------|--------------------|-----------------------------|-------------------|
| 1990 | 1,081,463        | 292,604           | 87                 | 92,386                      | 55                |
| 1991 | 1,038,711        | 305,212           | 92                 | 95,733                      | 57                |
| 1992 | 987,763          | 310,328           | 93                 | 102,213                     | 58                |
| 1993 | 976,554          | 308,049           | 93                 | 96,751                      | 59                |
| 1994 | 957,187          | 314,585           | 95                 | 107,276                     | 59                |
| 1995 | 954,934          | 319,378           | 96                 | 105,464                     | 60                |
| 1996 | 974,196          | 323,224           | 97                 | 102,637                     | 61                |
| 1997 | 945,931          | 329,652           | 99                 | 106,317                     | 62                |
| 1998 | 936,932          | 334,201           | 101                | 104,468                     | 63                |
| 1999 | 908,760          | 339,103           | 103                | 110,308                     | 64                |
| 2000 | 911,909          | 348,033           | 106                | 106,915                     | 64                |
| 2001 | 927,739          | 352,304           | 108                | 104,128                     | 65                |
| 2002 | 910,622          | 353,001           | 108                | 99,746                      | 66                |
| 2003 | 911,374          | 347,719           | 107                | 96,253                      | 66                |
### Table 8 (continued)

| Year | Emissions to air | Emissions to land | Emissions to water | Dissipative use of products | Dissipative losses |
|------|------------------|-------------------|--------------------|-----------------------------|-------------------|
| 2004 | 896,670          | 350,019           | 108                | 91,965                      | 67                |
| 2005 | 875,831          | 350,271           | 109                | 96,933                      | 65                |
| 2006 | 887,073          | 361,380           | 113                | 96,132                      | 66                |
| 2007 | 860,089          | 373,110           | 123                | 91,065                      | 67                |
| 2008 | 862,666          | 377,110           | 121                | 90,570                      | 66                |
| 2009 | 796,794          | 358,738           | 108                | 94,703                      | 66                |
| 2010 | 841,175          | 372,168           | 118                | 84,515                      | 67                |
| 2011 | 821,070          | 386,690           | 113                | 89,347                      | 68                |
| 2012 | 825,200          | 380,576           | 109                | 80,748                      | 68                |
| 2013 | 843,438          | 385,729           | 111                | 81,677                      | 68                |
| 2014 | 802,511          | 400,953           | 104                | 78,983                      | 70                |
| 2015 | 799,654          | 402,229           | 106                | 79,215                      | 71                |

### Table 9
Components of Japan’s domestic processed output from 1990 to 2015. All units are in thousand tonnes.

| Year | Emissions to air | Emissions to land | Emissions to water | Dissipative use of products | Dissipative losses |
|------|------------------|-------------------|--------------------|-----------------------------|-------------------|
| 1990 | 1,168,901        | 445,179           | n/a                | 45,669                      | n/a              |
| 1991 | 1,177,255        | 448,716           | n/a                | 45,476                      | n/a              |
| 1992 | 1,187,121        | 453,678           | n/a                | 45,554                      | n/a              |
| 1993 | 1,179,867        | 447,173           | n/a                | 44,914                      | n/a              |
| 1994 | 1,241,446        | 455,991           | n/a                | 46,294                      | n/a              |
| 1995 | 1,254,988        | 446,036           | n/a                | 44,436                      | n/a              |
| 1996 | 1,267,678        | 455,757           | n/a                | 45,568                      | n/a              |
| 1997 | 1,265,478        | 466,054           | n/a                | 45,181                      | n/a              |
| 1998 | 1,229,937        | 460,085           | n/a                | 43,894                      | n/a              |
| 1999 | 1,264,855        | 451,245           | n/a                | 43,433                      | n/a              |
| 2000 | 1,286,127        | 460,871           | n/a                | 43,181                      | n/a              |
| 2001 | 1,268,908        | 452,340           | n/a                | 41,807                      | n/a              |
| 2002 | 1,305,793        | 444,844           | n/a                | 42,195                      | n/a              |
| 2003 | 1,310,579        | 463,230           | n/a                | 42,153                      | n/a              |
| 2004 | 1,309,457        | 470,532           | n/a                | 41,697                      | n/a              |
| 2005 | 1,316,485        | 474,397           | n/a                | 41,473                      | n/a              |
| 2006 | 1,295,683        | 470,521           | n/a                | 42,275                      | n/a              |
| 2007 | 1,330,151        | 470,241           | n/a                | 41,603                      | n/a              |
| 2008 | 1,245,259        | 451,767           | n/a                | 39,064                      | n/a              |
| 2009 | 1,172,328        | 435,998           | n/a                | 39,159                      | n/a              |
| 2010 | 1,223,267        | 431,347           | n/a                | 39,657                      | n/a              |
| 2011 | 1,271,248        | 426,636           | n/a                | 36,690                      | n/a              |
| 2012 | 1,305,534        | 424,371           | n/a                | 34,450                      | n/a              |
| 2013 | 1,320,928        | 429,516           | n/a                | 35,969                      | n/a              |
| 2014 | 1,273,637        | 437,157           | n/a                | 35,293                      | n/a              |
| 2015 | 1,232,028        | 433,886           | n/a                | 33,631                      | n/a              |
### Table 10
Components of the United States of America’s domestic processed output from 1990 to 2015. All units are in thousand tonnes.

**United States of America’s Domestic Processed Output**

| Year | Emissions to air | Emissions to land | Emissions to water | Dissipative use of products | Dissipative losses |
|------|------------------|-------------------|-------------------|----------------------------|-------------------|
| 1990 | 5,352,042        | 439,806           | n/a               | 224,691                    | n/a               |
| 1991 | 5,297,921        | 439,486           | n/a               | 224,572                    | n/a               |
| 1992 | 5,396,554        | 455,111           | n/a               | 231,330                    | n/a               |
| 1993 | 5,504,104        | 467,604           | n/a               | 236,946                    | n/a               |
| 1994 | 5,597,307        | 486,479           | n/a               | 240,344                    | n/a               |
| 1995 | 5,649,286        | 500,248           | n/a               | 241,854                    | n/a               |
| 1996 | 5,830,175        | 519,237           | n/a               | 250,356                    | n/a               |
| 1997 | 5,900,322        | 542,535           | n/a               | 245,179                    | n/a               |
| 1998 | 5,938,844        | 566,677           | n/a               | 234,955                    | n/a               |
| 1999 | 6,013,867        | 593,227           | n/a               | 237,777                    | n/a               |
| 2000 | 6,180,205        | 617,503           | n/a               | 240,604                    | n/a               |
| 2001 | 6,072,388        | 623,530           | n/a               | 238,727                    | n/a               |
| 2002 | 6,108,496        | 634,667           | n/a               | 235,698                    | n/a               |
| 2003 | 6,145,439        | 652,481           | n/a               | 240,693                    | n/a               |
| 2004 | 6,259,374        | 677,182           | n/a               | 235,219                    | n/a               |
| 2005 | 6,279,701        | 699,835           | n/a               | 237,324                    | n/a               |
| 2006 | 6,192,124        | 718,497           | n/a               | 233,141                    | n/a               |
| 2007 | 6,267,817        | 729,941           | n/a               | 243,525                    | n/a               |
| 2008 | 6,058,235        | 739,092           | n/a               | 243,420                    | n/a               |
| 2009 | 5,610,961        | 704,448           | n/a               | 232,266                    | n/a               |
| 2010 | 5,809,952        | 705,542           | n/a               | 233,876                    | n/a               |
| 2011 | 5,680,362        | 703,043           | n/a               | 235,520                    | n/a               |
| 2012 | 5,473,447        | 711,973           | n/a               | 227,356                    | n/a               |
| 2013 | 5,618,648        | 705,506           | n/a               | 233,598                    | n/a               |
| 2014 | 5,666,083        | 717,737           | n/a               | 235,517                    | n/a               |
| 2015 | 5,507,858        | 718,406           | n/a               | 233,633                    | n/a               |

### Table 11
Short run waste potential for year 2015 for five countries and seven material categories. All units in thousand tonnes.

**Waste potential in 2015, short run**

| Unit: thousand tonnes | Australia | China | Germany | Japan | United States |
|-----------------------|-----------|-------|---------|-------|---------------|
| Crop residues         | 2283      | 43,000| 1537    | 621   | 17,786        |
| Timber                | 2568      | 71,876| 11,202  | 24,986| 45,932        |
| Glass and chemicals   | 16,777    | 150,989| 19,634 | 14,895| 89,018        |
| Plastics              | 3,821     | 81,174| 17,968  | 36,948| 117,480       |
| Mining waste          | 318,571   | 2,097,779| 25,737 | 65,251| 591,472       |
| Metals                | 13,794    | 224,690| 11,969 | 40,219| 47,601        |
| C&D non-metallic minerals | 5770 | 1,154,517| 49,732 | 660,955| 119,068       |
47 years of data are a short period of time in comparison to building lifespan (especially in western countries). For this reason, we developed a secondary domestic material consumption dataset that starts in 1900, compiled using existing data or projecting flows based on historical GDP data [12–14]. We then reran the model with this longer dataset and obtained new results that we compared to the first attempt. We named these two sets of results "short run" (47 years of data) and "long run" (115 years of data). The results are shown in Tables 11 and 12, respectively.

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Transparency document. Supporting information

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