Physical Supply and Use Tables: the Most Comprehensive Way for Reporting Waste Flows

Jan Kovanda[1] | *Charles University Environment Centre, Prague, Czech Republic*

Abstract

Material flow analysis is a useful tool to measure resource use and mitigate the related problems. In order to increase its analytical potential, it is advisable to construct physical input-output tables. (PIOT). PIOT, defined by SEEA (UN et al., 2014), are based on two basic building stones: physical supply tables and physical use tables (PSUT). Besides other information, PSUT include data on waste and secondary materials. We collected waste and secondary material data for the Czech Republic, 2014, and incorporated them into various PSUT Tables. We argue that PSUT are a useful tool for organizing and depicting these data in a clear and comprehensive way. We constructed a Sankey diagram based on PSUT which provides some important insights into waste and secondary material flows in the Czech Republic. These insights can be used in reports assessing waste flows in the Czech Republic and for further shaping and updating of waste policies. We therefore think that our argument on usefulness of PSUT for organizing data on waste and secondary materials proved valid.

Keywords

System of environmental-economic accounting (SEEA), physical supply and use tables (PSUT), solid waste, secondary materials, Czech Republic

JEL code

Q56

INTRODUCTION

Sustainable consumption and production aims at "doing more and better with less," increasing net welfare gains from economic activities by reducing resource use, degradation and pollution along the whole lifecycle, while increasing quality of life (UN, 2017). In order to measure resource use and to mitigate the related problems, material flow analysis has been conceived (Eurostat, 2001; OECD, 2008). To increase analytical potential of this tool, it is advisable to construct physical input-output tables (PIOT). Data from PIOT can be used to analyse physical flows, considering the economic activities and structural changes that lie behind these flows, to analyse technological change, material substitution and to assess the effectiveness of policies targeting at sustainable consumption and production.

[1] Charles University Environment Centre, J. Martiho 2/407, 162 00 Prague 6, Czech Republic. E- mail: jan.kovanda@czp.cuni.cz, phone: (+420)220199476.

The implementation of PIOT is a labour-intensive task involving many data entries. This is the reason why it has only been compiled for a few countries so far including Denmark (Mulalic, 2007), Finland (Mäenpää, 2004), Germany (Stahmer et al., 1997), Italy (Nebbia, 2000), New Zealand (McDonald and Patterson, 2006), Spain (Gasco et al., 2005), the Netherlands (Hoekstra and van den Bergh, 2006) and the EU (Giljum and Hubacek, 2004). Moreover, as no standardized approach for PIOT compilation was available until 2014, the above studies use different approaches and the resulting PIOTs thus have different formats and are not fully comparable.

The procedures for compilation of PIOT have been currently standardised in the System of Environmental-Economic Accounting (SEEA) (UN et al., 2014). PIOT are based on two basic building stones: physical supply tables and physical use tables (PSUT). While physical supply tables set out the flows relating to the production, generation, and supply of natural inputs, products and residuals by different economic units or the environment, the physical use tables set out the flows relating to the consumption and use of natural inputs, products and residuals by different economic units or the environment. The structure of PSUT is shown in Figure 1.

Figure 1 Structure of physical supply and use tables (PSUT)

Supply table

	Production; Generation of residuals		Accumulation	Flows from the rest of the world	Flows from the environment	Total
	Production; Generation of residuals by industries	Generation of residuals by households	Industries			
Natural inputs					A. Flows from the environment	Total supply of natural inputs
Products	C. Output			D. Imports of products		Total supply of products
Residuals	I1. Residuals generated by industry I2. Residuals generated following treatment	J. Residuals generated by households	K1. Residuals from scrapping and demolition of produced assets K2. Emissions from controlled landfill sites	L. Residuals received from the rest of the world	M. Residuals recovered from the environment	Total supply of residuals
Total supply						

Use table

	Intermediate consumption of products; Use of natural inputs; Collection of residuals	Final consumption	Accumulation	Flows to the rest of the world	Flows to the environment	Total
	Industries	Households	Industries			
Natural inputs	B1. Extraction of natural inputs used in production B2. Extraction of natural resource residuals					Total use of natural inputs

Figure 1 (continuation)

Products	E. Intermediate consumption	F. Household final consumption	G. Gross capital formation (including fixed assets and inventories)	H. Exports of products		Total use of products
Residuals	N. Collection and treatment of residuals		O. Accumulation of waste in controlled landfill sites	P. Residuals sent to the rest of the world	Q1. Direct residual flows from industry and households Q2. Residual flows following treatment	Total use of residuals
Total use						

Source: UN et al. (2014)

The compilation of PSUT can be understood as an extension of and addition to the compilation of supply and use tables and input-output tables in monetary units. These are commonly compiled at statistical offices, including the Czech Statistical Office. The PSUT tables in monetary units for the Czech Republic are regularly published at: <*http://apl.czso.cz/pll/rocenka/rocenka.indexnu*> (Czech Statistical Office, 2017a).

Reporting of residuals, including solid waste and also secondary materials produced from waste, is an important part of PSUT. We argue that PSUT are a useful tool for organizing and depicting these data in a clear and comprehensive way. Waste and secondary material data are covered by many tables. Table I shows production of waste by particular industries and production of waste which is intended for final disposal after treatment while Table J shows production of waste by households. Table K1 quantifies wastes from scraping and demolition of physical capital.

Tables L and P shows imports and exports of waste and Table M shows amount of waste recovered from the environment. Table N shows collection of waste and Table Q quantifies the flow of waste to the environment after treatment. Table C shows the production of recycled secondary materials for use in the economy. Finally, Tables E, F and G show the consumption of secondary materials by industries, households and for gross fixed capital formation while Tables D and H show imports and exports of secondary materials. As waste is approached from both the supply and use perspective and the direct and after treatment flows perspective, PSUT can be considered as the most comprehensive way for reporting waste flows.

The PSUT has been compiled for the Czech Republic for 2014 (Kovanda, 2018). This article shows how various data on solid waste have been integrated into PSUT. It also tries to show in a clear and comprehensive way the production of waste and use of secondary materials in the Czech Republic from the viewpoints of sectoral contribution and all other perspectives the PSUT can offer.

1 INTEGRATION OF WASTE DATA INTO PARTICULAR PSUT TABLES

1.1 Tables I and J

Table I shows production of waste by particular industries and production of waste which is intended for final disposal after treatment while Table J shows production of waste by households. Both tables do not include waste identified as unused domestic extraction[2] which is not considered a waste flow according

[2] Unused domestic extraction refers to materials extracted or otherwise moved on a nation's territory on purpose and by means of technology which are not fit or intended for use. Examples are soil excavated during construction or overburden from mining (Eurostat, 2001).

to the material flow analysis and PSUT methodologies (Eurostat, 2001; UN et al., 2014). Table I does not further comprise production of waste from demolition of buildings, transport infrastructures and other physical capital which is included in table K1. The amounts of waste in Tables I and J were based on data published by the Czech Statistical Office (Czech Statistical Office, 2015a). Some data needed for the calculations such as unused domestic extraction and demolition waste were provided by Eurostat (2017) and at request by the Czech Statistical Office employees (Czech Statistical Office, 2015b).

Table I and J Production of waste by particular industries and households and production of waste which is intended for final disposal after treatment (thousand tonnes), Czech Republic, 2014

NACE	01–03	05–09	10–36	37–39	41–43	45–47	49–53	55–99	Households
Production of waste	63	97	4 418	1 744	200	702	22	242	3 261
Production of waste which is intended for final disposal after treatment				5 697					

Source: Czech Statistical Office (2015ab), Eurostat (2017)

1.2 Table K1

Table K1 quantifies wastes from scraping and demolition of physical capital. This data was available from the Czech and Eurostat waste statistics (Czech Statistical Office, 2015b; Eurostat, 2017). Total volume of wastes from scraping and demolition of physical capital amounted to 4 597 thousand tonnes of which 4 518 thousand tonnes originated from demolished buildings and transport infrastructures and 79 thousand tonnes originated from other physical capital such as machinery.

1.3 Tables L, P and M

Tables L and P shows imports and exports of waste and Table M shows amount of waste recovered from the environment. Data on imports and exports of waste was provided by the Czech Statistical Office (Czech Statistical Office, 2015a). Table M was set equal to zero, as no waste is recovered from the environment in the Czech Republic. Total amount of waste imported to the Czech Republic equaled to 1 584 thousand tonnes while total export equaled to 2 945 thousand tonnes in 2014.

1.4 Table N

Table N shows collection of waste. The data are based on waste generated by enterprises and waste from municipalities under assumption that this waste is collected and further treated by NACE 38. Once again the amounts were reduced by waste identified as unused domestic extraction. Data for Table N was provided by the Czech Statistical Office (Czech Statistical Office, 2015ab).

Table N Collection of waste (thousand tonnes), Czech Republic, 2014

N1	Waste from enterprises	12 083
N1.1	Waste resulting from exploration, mining, quarrying, physical and chemical treatment of minerals	95
N1.2	Waste from agricultural, horticultural, aquaculture, forestry, hunting and fishing, food preparation and processing	206
N1.3	Waste from wood processing and production of panels and furniture, pulp, paper and cardboard	189

Table N (continuation)

N1.4	Waste from the leather, fur and textile industries	78
N1.5	Waste from petroleum refining, natural gas purification and pyrolytic treatment of coal	14
N1.6	Waste from inorganic chemical processes	14
N1.7	Waste from organic chemical processes	106
N1.8	Waste from the manufacture, formulation, supply and use of coating (paints, varnishes and vitreous enamels), adhesive, sealants and printing inks	39
N1.9	Waste from the photographic industry	1
N1.10	Waste from thermal processes	1 769
N1.11	Waste from chemical surface treatment and coating of metals and other materials; non-ferrous hydrometallurgy	76
N1.12	Waste from shaping and physical and mechanical surface treatment of metals and plastics	608
N1.13	Oil waste and waste of liquid fuels (except edible oils, 05 and 12)	121
N1.14	Waste organic solvents, refrigerants and propellants (except 07 and 08)	3
N1.15	Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified	690
N1.16	Waste not otherwise specified in the list	431
N1.17	Construction and demolition waste	4 517
N1.18	Waste from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)	32
N1.19	Waste from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use	2 212
N1.20	Municipal waste from enterprises	881
N2	Waste from municipalities	3 553

Source: Czech Statistical Office (2015ab)

1.5 Table Q

Table Q quantifies the flow of waste to the environment after treatment, i.e. incineration and recycling, which can be identified with disposed waste (mostly landfilling). Total amount of disposed waste, without unused domestic extraction, equalled to 5 697 thousand tonnes in the Czech Republic in 2014 (Czech Statistical Office, 2015b).

1.6 Table C

Table C shows the production of secondary materials for use in the economy broken down by particular industries. The table was compiled with the use of two data sources: production of particular types of secondary materials such as secondary materials from metals, textiles or construction materials in tonnes (Czech Statistical Office, 2015a) and production of particular types of secondary materials in monetary units (Czech Statistical Office, 2015c). The data in tonnes was taken as a basis for Table C and was attributed to particular industries using monetary production of secondary materials under the assumption of homogenous prices of secondary materials. Table C shows the result of this attribution for industries which generated any secondary materials.

Table C Production of secondary materials by industries (thousand tonnes), Czech Republic, 2014

	Production of secondary materials (SM)										
NACE	13	16	17	22	24	25	28	31	32	35	38
SM from precious metals	0	0	0	0	0	0	0	0	0	0	47
SM from ferrous metals	0	0	0	0	10	1	0	0.4	0.1	0	3 172
SM from copper	0	0	0	0	0	0	0	0	0	0	30
SM from nickel	0	0	0	0	0	0	0	0	0	0	0
SM from aluminum	0	0	0	0	0	0	0	0	0	0	112
SM from other metals, glass and rubber	0	0	0	0	0	0	0	0	0	0	492
SM from paper	0	0	0.3	0	0	0	0	0	0	0	709
SM from plastic	0	0	0	0	0	0	0	0	0	0	354
SM from tires	0	0	0	2	0	0	0	0	0	0	13
SM from textile	1	0	0	0	0	0	0	0	0	0	1
SM from wood	0	11	0	0	0	0	0	0	0	0	167
SM from construction materials	0	0	0	0	0	0	127	0	0	0	3 471
SM from thermal processes	0	0	0	0	0	0	0	0	0	9 934	0
Other SM	0	0	0	0	0	0	1	0	0	0	97
Total SM	1	11	0.3	2	10	1	128	0.4	0.1	9 934	8 665

Source: Czech Statistical Office (2015ab)

1.7 Tables E, F and G

Tables E, F and G show the consumption of secondary materials by industries, households and for gross fixed capital formation. Data on consumption, household final consumption and gross capital formation were not available in physical units at all. The attribution of produced and imported secondary materials (sum of Tables C and D) to industries, households and accumulation was therefore based on relationships in the monetary use tables (Czech Statistical Office, 2017a) under the assumption of homogenous prices of secondary materials.

Tables E, F and G Consumption of secondary materials by industries, households and for gross fixed capital formation (thousand tonnes), Czech Republic, 2014

NACE	01–03	05–09	10–36	37–39	41–43	45–47	49–53	55–99	Households	Gross fixed capital formation
Secondary materials	65	52	9 900	5 357	338	518	79	1 022	2 364	–942

Source: Czech Statistical Office (2015ac), Czech Statistical Office (2017ab)

1.8 Tables D and H

Tables D and H show imports and exports of secondary materials. Data for these tables were provided by the foreign trade statistics of the Czech Statistical Office (Czech Statistical Office, 2017b). Total amount of secondary materials imported to the Czech Republic equaled to 90 tonnes while total export equaled to 61 tonnes in 2014.

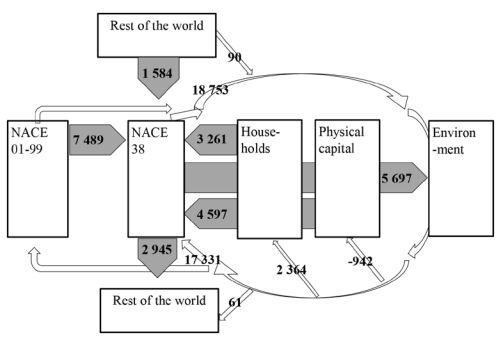
2 OVERALL PICTURE OF WASTE AND SECONDARY MATERIAL PRODUCTION AND USE IN THE CZECH REPUBLIC

Major reason for incorporating waste data into physical supply and use tables is to provide a complete and comprehensive picture of waste and secondary material flows in a country.

In the Czech Republic, 2014, industries produced 7 489 thousand tonnes with largest flow coming from the manufacturing industries (NACE 10-36, 4 418 thousand tonnes). Households contributed by 3 261 thousand tonnes. Another 4 597 thousand tonnes was added from demolishing of buildings, transport infrastructures and decommissioning of other physical capital. Production of waste intended for final disposal after treatment was 5 697 thousand tonnes. The amount of waste imported to the Czech Republic equaled to 1 584 thousand tonnes, the amount of waste exported was 2 945 thousand tonnes and no waste was recovered from the environment. Total amount of waste collected for treatment, i.e. produced waste from industries, households, physical scraping of physical capital plus imported waste, minus exported waste and plus balance of waste taken from stock, was equal to 15 636 thousand tonnes. Total amount of waste heading to the environment which can be identified with disposed waste (and production of waste intended for final disposal after treatment) was 5 697 thousand tonnes.

Total amount of produced secondary materials was 18 753 thousand tonnes with most secondary materials coming from electricity, gas, steam and air conditioning supply (NACE 35, 9 934 thousand tonnes). The reason why total volume of produced secondary materials is higher than the difference between total production of waste (Tables I, J, K1) and production of waste intended for final disposal after treatment is that some secondary materials such as ashes from electricity-related coal burning do not enter the waste system and statistics according to the Czech legislation, but are directly declared as secondary materials when they leave industries. Additionally to the domestic production, 90 tonnes of secondary materials was imported from abroad. Regarding the consumption of secondary materials, 17 331 thousand tonnes was consumed by industries, mostly by manufacturing industries (NACE 10-36, 9 900 thousand tonnes), 2 364 thousand tonnes was consumed by households and –942 thousand tonnes was used for gross fixed capital formation. Moreover, 61 tonnes of secondary materials was exported in 2014.

Figure 2 Scheme of waste and secondary material flows (thousand tonnes, import and export of secondary materials in tonnes), Czech Republic, 2014



Note: Waste flows are depicted by grey arrows, secondary material flows by white arrows.

Source: Czech Statistical Office (2015abc), Eurostat (2017), Czech Statistical Office (2017ab)

The scheme of waste and secondary material flows in the Czech Republic in 2014 is shown in Figure 2.

An important insight obvious from Figure 2 is that production of secondary materials for use in the economy is somewhat larger than the sum of waste produced by NACE 01-37, 39-99, households and from demolition of physical capital (18 754 thousand tonnes vs. 16 934 thousand tonnes). This is favourable news from the viewpoint of transition to circular economy (Commission to the European Parliament et al., 2015). Other insights include that production of waste by households is almost the half of waste production by NACE 01-37, 39-99 or that relatively significant amount of waste is exported and thus cannot be recycled for use in the economy.

CONCLUSION

The article describes how physical supply and use tables defined by SEEA can be used for organizing and depicting data on waste and secondary material flows. We argued that PSUT are a useful tool. We showed how waste and secondary material data are incorporated in various PSUT tables and on an example of the Czech Republic we illustrated how these data can be depicted in a clear and comprehensive Sankey diagram. An important feature of this depiction is that it integrates data on waste and secondary materials and indicates their ratios. This provides an information on how far the Czech Republic is on its transition to circular economy. Such insights can be used in reports assessing waste flows in the Czech Republic such as the Report on the Environment of the Czech Republic (CENIA, 2017). It can also be used for shaping and updating of waste policies including Waste Management Plan of the Czech Republic (Government of the Czech Republic, 2014) and broader environmental policies such as State Environmental Policy (Ministry of the Environment, 2016) in order to further strengthen the capacity of the Czech Republic to implement circular economy. We therefore think that our argument on usefulness of PSUT for organizing data on waste and secondary materials proved valid.

ACKNOWLEDGEMENT

This work was supported by the Czech Science Foundation under grant No. 16-00262S "Anthropogenic material flows in the Czech Republic: Analysis of structure and trends and opening a black-box of the physical economy". This support is gratefully appreciated.

References

COMMISSION TO THE EUROPEAN PARLIAMENT et al. *Closing the loop – An EU action plan for the Circular Economy.* Brussels: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 2015.

CZECH STATISTICAL OFFICE. *Annual national accounts database* [online]. Prague: Czech Statistical Office, 2017a. <http://apl.czso.cz/pll/rocenka/rocenka.indexnu>.

CZECH STATISTICAL OFFICE. *Database on foreign trade* [online]. Prague: Czech Statistical Office, 2017b. <http://apl.czso.cz/pll/stazo/STAZO.STAZO>.

CZECH STATISTICAL OFFICE. *Generation, recovery and disposal of waste 2014.* Prague: Czech Statistical Office, 2015a.

CZECH STATISTICAL OFFICE. *Internal waste database.* Prague: Czech Statistical Office, 2015b.

CZECH STATISTICAL OFFICE. *Production of selected industrial products 2014.* Prague: Czech Statistical Office, 2015c.

CENIA. *Report on the Environment of the Czech Republic in 2016.* Prague: CENIA, 2017.

EUROSTAT. *Economy-wide material flow accounts and derived indicators: A methodological guide.* Luxembourg: Eurostat, 2001.

EUROSTAT. *Eurostat statistics database* [online]. Luxembourg: Eurostat, 2017. <http://epp.eurostat.ec.europa.eu/portal/page/portal/ statistics/search_database>.

GASCO, G., HERMESILLA, D., GASCO, A., NAREDO, J. M. Application of a Physical Input-Output Table to evaluate the development and sustainability of continental water resources in Spain. *Environmental Management*, 2005, 36, pp. 59–72.

GILJUM, S. AND HUBACEK, K. Approaches of physical input–output analysis to estimate primary material inputs of production and consumption. *Economic Systems Research*, 2004, 16(3), pp. 301–310.

GOVERNMENT OF THE CZECH REPUBLIC. Waste Management Plan of the Czech Republic. Prague: Government of the Czech Republic, 2014.

HOEKSTRA, R. AND VAN DEN BERGH, J. C. J. M. Constructing physical input-output tables for environmental modeling and accounting: Framework and illustrations. *Ecological Economics*, 2006, 59(3), pp. 375–393.

KOVANDA, J. Compilation of physical supply and use tables as a tool for increasing analytical potential of economy-wide material flow analysis and indicators. *Statistika: Statistics and Economy Journal*, 2018, 98(3), pp. 135–148.

MÄENPÄÄ, I. *Physical flow accounts, Finland 1999.* Oulu: Thule Institute, University of Oulu, 2004.

MCDONALD, G. W. AND PATTERSON, M. G. *Development of a New Zealand Physical Input-Output Table.* Palmerston North: New Zealand Centre for Ecological Economics, 2006.

MINISTRY OF THE ENVIRONMENT. *State Environmental Policy (update 2016).* Prague: Ministry of the Environment, 2016.

MULALIC, I. *Material flows and physical Input-output tables – PIOT for Denmark 2002 based on MFA.* Copenhagen: Statistics Denmark, 2007.

NEBBIA, G. Contabilià monetaria e contabilità ambientale. *Economia Pubblica*, 2000, 30(6), pp. 5–33.
OECD. *Measuring material flows and resource productivity.* Paris: OECD, 2008.
STAHMER, C., KUHN, N., BRAUN, M. *Physical input–output tables for Germany, 1990.* Wiesbaden: DESTATIS, 1997.
UN. *Sustainable development goals. Goal 12: Ensure sustainable consumption and production patterns* [online]. New York: United Nations, 2017. <http://www.un.org/sustainabledevelopment/sustainable-consumption-production>.
UN et al. *System of Environmental-Economic Accounting 2012: Central Framework.* New York: United Nations, 2014.