Resource-Related Parameters of Industrial and Commercial Structures – Data Base for Assessing Urban Developments

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1 Introduction

The settlement fabric is determined not only by housing land but also by industrial and commercial land, which must be accordingly be taken into account in assessing future urban development. Few informative and reliable approaches, procedures, and data have hitherto been available for describing and assessing industrial and commercial structures with regard to resource-related consumption and impacts. Although some information on industrial and commercial building stock is available, varying quality and reference preclude consistent statements or comprehensive analysis.

2 Data for Describing the Resource Consumption of Industrial and Commercial Structures.

Data capturing the physical properties of industrial and commercial buildings can be obtained by assessing and analysing construction documents (drawings, plans, specifications) of completed buildings (Objekt-Daten 2008). This procedure produces precise results but it is arduous and time-consuming. Such data can also be generated from official statistics (StaBu 2007, StaBu 1999). They are less precise but nevertheless informative. For example, the usable area, cubage, structural volume, building material structure, etc. of non-residential buildings can be calculated. The types of building taken into consideration are office and administrative buildings, agricultural buildings, factory and workshop buildings, commercial buildings and warehouses, as well as hotels and restaurants. Energy consumption, water consumption, waste water discharge, etc, can also be ascertained by sector. Manufacturing sectors are examined, including the metalworking industry, mechanical engineering, and clothing. The data show that the building type influences construction and building methods and thus the building's physical properties (physical fabric, incorporated materials and energies). In contrast, the type of economic activity carried out more strongly determines the operating costs arising from use (use-related materials and energy consumption).

2.1 Data for Describing the Physical Properties of Buildings

Net Usable Area and Building Volume

Among buildings used for industrial and commercial purposes, office and administrative buildings have the highest average **usable area** (1,675 m²). The net usable area is the floor space in the building that serves the intended purpose and use of the building. The next largest net usable area, an average 1,200 m² per building, is to be found in factory and workshop buildings and warehouses. Agricultural buildings have the smallest usable area per building (468 m²) (figure 1).

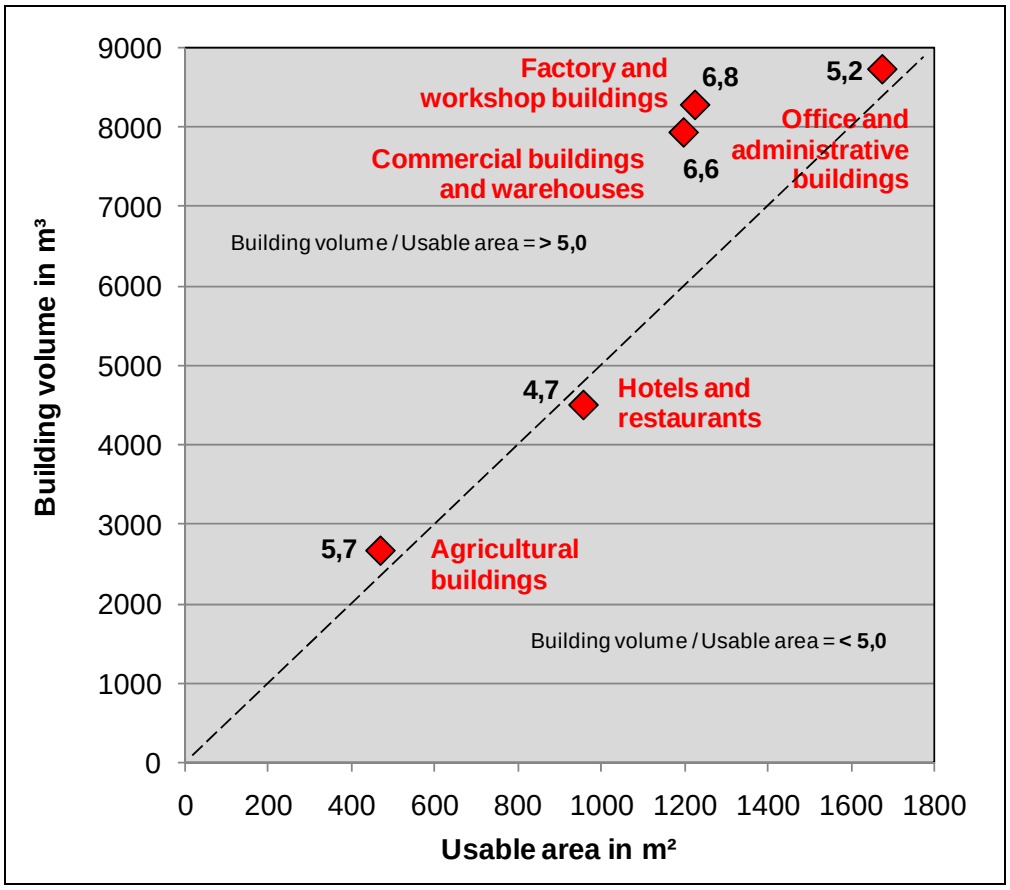

Fig. 1: Usable area and volume per building – comparison between building types

Building volume presents a different picture. Building volume refers to the gross space enclosed by the external limits of the building. The category of edifice with the greatest usable area, office and administrative buildings, also has the greatest building volume (8,733 m³). The large usable area is distributed over several storeys. This gives a high building volume. But factory and workshop buildings and warehouses have similarly large volumes (8,000 to 8,300 m³). The reason lies in the uses and functions performed in these types of building. One-storey, ground-level usable areas and considerable ceiling height are needed for production, manufacturing, and storage (assembly shops with overhead cranes, high-bay storage, etc.). Hotels and restaurants, as well as agricultural buildings have lower building volumes. The latter category generally has the smallest volume per building (4,498 m³).

The ratio of building volume to usable area reveals the commonalities and differences between building types. The building volume of most types of building is larger than the net usable area by a factor of five. The exceptions are factory and workshop buildings, as well as commercial buildings and warehouses. Owing to the frequent hall-like construction, their volume is often six to seven times greater than the usable area (figure 1).

If the physical properties of industrial and commercial building stock are to be assessed, e.g., in the context of GIS analyses, and no further information on the built-up area is available – for instance on storey structure or building height – typical building volumes can be assigned to the designated buildings where the building type is known. On a small scale (e.g., single industrial estate), this way of determining building volume is by no means precise but on a larger scale (e.g., throughout a state) it enables rough estimates.

Structural Volume and Building Material Structure

Structural volume refers to the cubic metres of building materials contained in the foundations, walls, floors, roofs, etc. of a building. Official statistics ignore structural volume. It can be calculated on the basis of empirical investigation of areas and volumes.

Analysis of the building documents (drawings, plans, technical specifications) of completed industrial and commercial buildings show that the ratio of structural area to total area differs from one building type to the next. Agricultural buildings in general have the lowest average ratio of structural area to total area (4%). The categories factory and workshop buildings and commercial buildings and warehouses both have an average 8 % structural area per building. An average level of 13 % was calculated for office and administrative buildings. Also typical for this category of building is that the 16 % of total floor space devoted to circulation, i.e., corridors, hallways, staircases, etc., is almost twice as high as in factory and workshop buildings and commercial buildings and warehouses. No empirical data are available on structural areas in hotels and restaurants. A figure of 14 % in analogy to office and administrative buildings is postulated (figure 2).

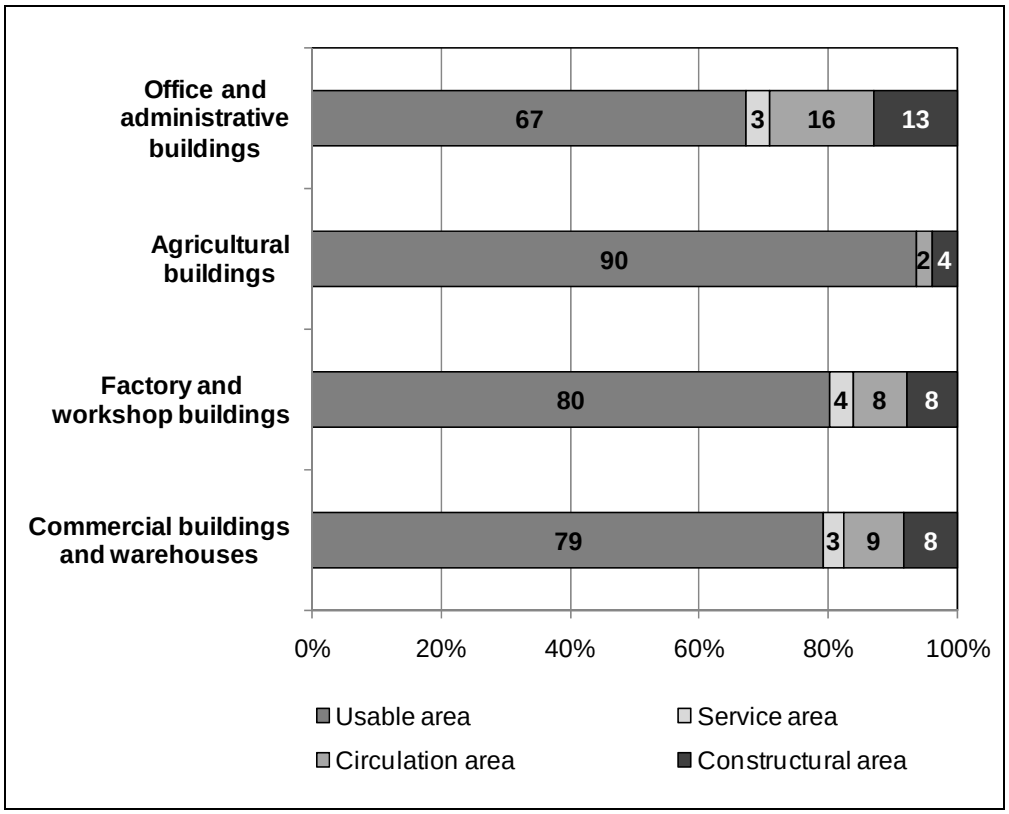

Fig. 2: Area ratios – comparison between building types

The structural area ratio is the basis for calculating the structural volume typical of different categories of building. It is assumed that the ratio of structural area to total area equals the ratio of structural volume to building volume. This means that area ratios are transferred to volumes. Structural volume per building and building type is roughly calculated on the basis of the percentage of structural area per building type and the building volume. If data are available not on building volume but on built-up area, the structural volume per built-up area can be calculated with the aid of empirical data. This is not a very precise procedure, but it does permit rough estimates (table 1).

Tab. 1: Data on structural volume – comparison between building types

Building types	Structural area	
	[%]	[m³/m² built-up area]
Office and administrative buildings	13	2.217
Agricultural buildings	4	0.230
Factory and workshop buildings	8	0.714
Commercial buildings and warehouses	8	0.746
Hotels and restaurants	14	No data

The structural volume ratios in different types of building are also reflected in the data on structural volume in cubic metres per unit of built-up area. Office and administrative buildings have the highest structural volume. Factory and workshop buildings and commercial buildings and warehouses have a similarly high to medium structural volume. Agricultural buildings have the lowest structural volume. No empirical data are available on hotels and restaurants.

Building material structure refers to the proportion of steel, reinforced concrete, wood, brick and other masonry, and other building materials used in erecting the bearing structure. It varies greatly from building type to building type (figure 3).

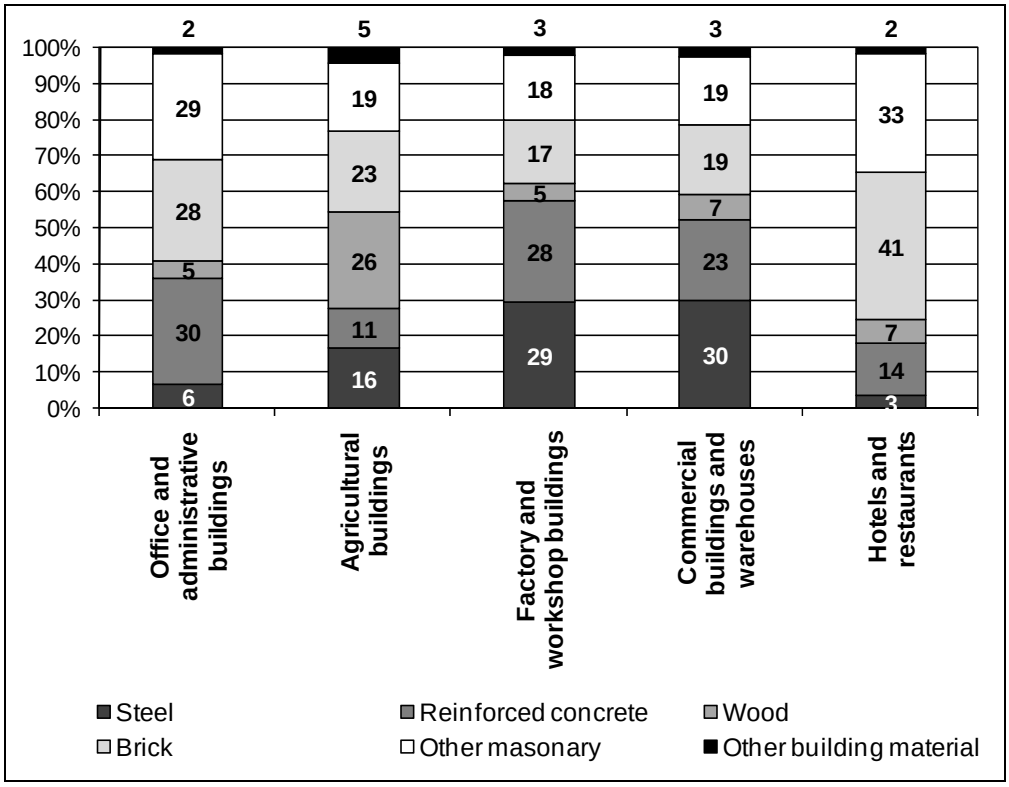

Fig. 3: Building material structure – comparison between building types

Factory and workshop buildings and commercial buildings and warehouses contain a high proportion of steel (some 30 %). This reflects the nature of these buildings. Depending on functional requirements, they are multistorey, hall-type, or low-rise structures. Steel frames or other steel structures are often used. In all other types of building, far less steel is used.

Moreover, factories and workshops, as well as commercial buildings and warehouses have a high proportion of reinforced concrete, since the bearing structure of these edifices is often built of reinforced concrete. The average proportion of reinforced concrete is 25 %. A similar proportion of reinforced concrete is to be found in office and administrative buildings.

Within the category of industrial and commercial buildings, the proportion of brick is highest in office and administrative buildings and in hotels and restaurants: 30 % to 40 %. Brick is a frequent wall material owing to the type of wall construction often used in these categories of building. But brick is also normally used for infill walling in the case of steel framework construction. The proportion of other masonry materials is similar in all these types of building. They are used in about 30 % to 35 % of cases, mostly where brick is not employed for walling.

Characteristic of agricultural buildings is the great use made of wood. Some 25 % of bearing structures are made of wood. With regard to brick and other masonry material, agricultural buildings are similar to factory and workshop buildings and commercial building and warehouses. Each of these building materials is used in about 20 % of cases in the supporting framework.

2.2 Data for Describing Building Use

Energy Consumption and Energy Structure

Official statistics treat **energy consumption** as a separate item covering total consumption of electricity, gas, coal, and fuel oil, including the amounts converted into other types of energy. For some sectors it is recorded in terms of energy sources.

Energy consumption differs relatively strongly from industry to industry, ranging from 15 to 4,000 megawatt hours per employee per annum (MWh/emp.*a). The manufacture of refined petroleum products uses by far the greatest amount of energy. The mean annual per capita consumption in this sector is 4,183 MWh. Energy consumption in this industry is so high because it involves very energy-intensive transformation and processing and because oil is also used as a raw material in production (figure 4).

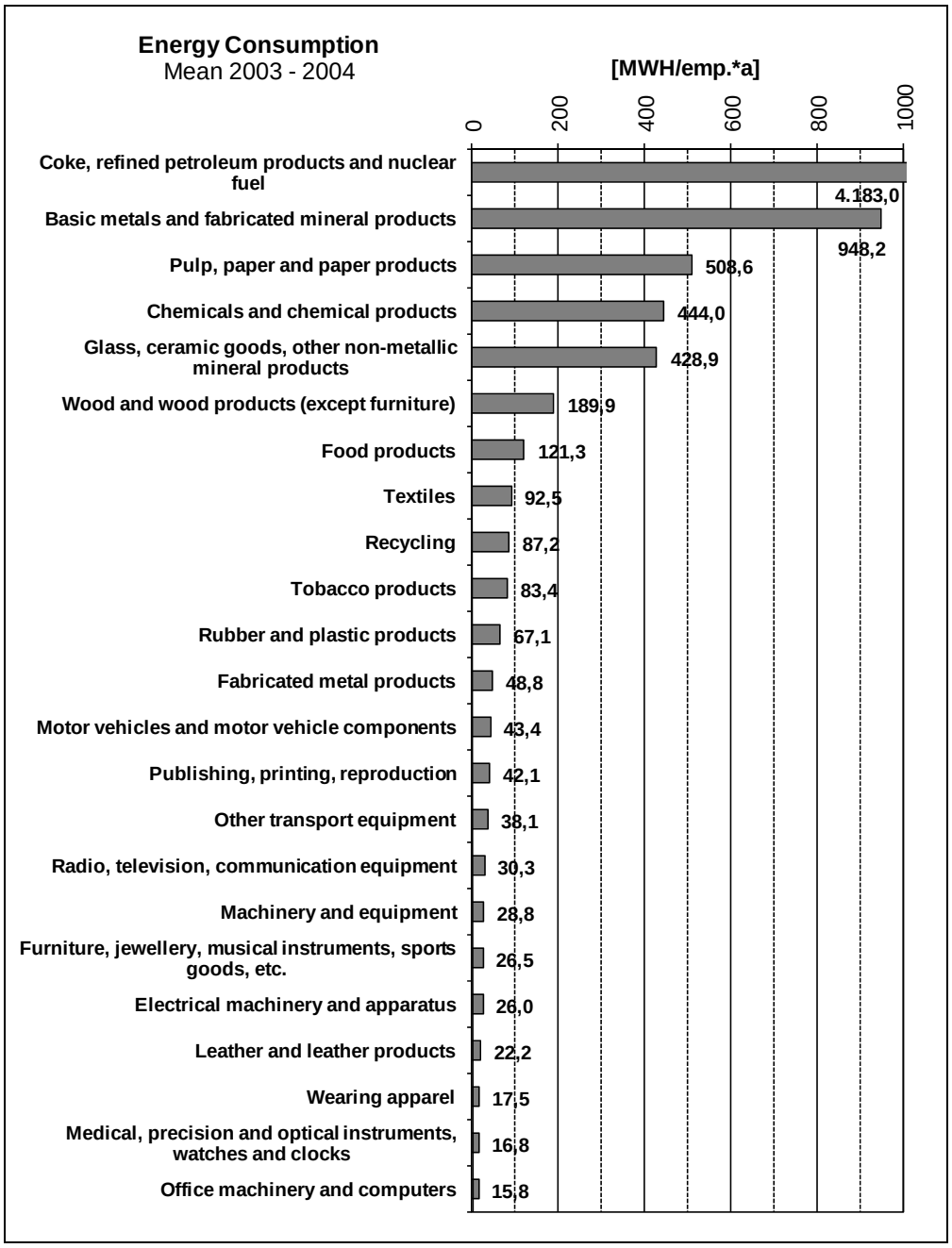

Fig. 4: Energy consumption – comparison between manufacturing sectors

Approximately one quarter of all manufacturing industries – with a good quarter of all jobs (28 %) – consume between 100 and 1,000 MWh. For instance, metalworking and the chemicals sector. Energy consumption in the metalworking industry is relatively high at about 950 MWh per employee per year. In the chemical industry it is well under half that figure. Some 70 % of all sectors providing just under three quarters of all jobs in manufacturing, like mechanical engineering and the clothing industry, consume less than 100 MWh, and half of all manufacturing sectors – with 65 % of all jobs – consume less than 50 MWh per employee per year.

With respect to **energy structure**, electricity and natural gas play a relatively major role. 30 % and more of the sectors consuming less than 50 MWh per capita, in particular, consistently opt for electricity. The manufacture of radio. television and communication equipment and apparatus consumes a particularly high proportion of electricity (67 %), as

does the manufacture of motor vehicles and of office machinery and computers (50 % in each case). Only about 25 % or less of the energy used by sectors with a per capita consumption of over 400 MWh, in contrast, is in the form of electricity. (Figure 5).

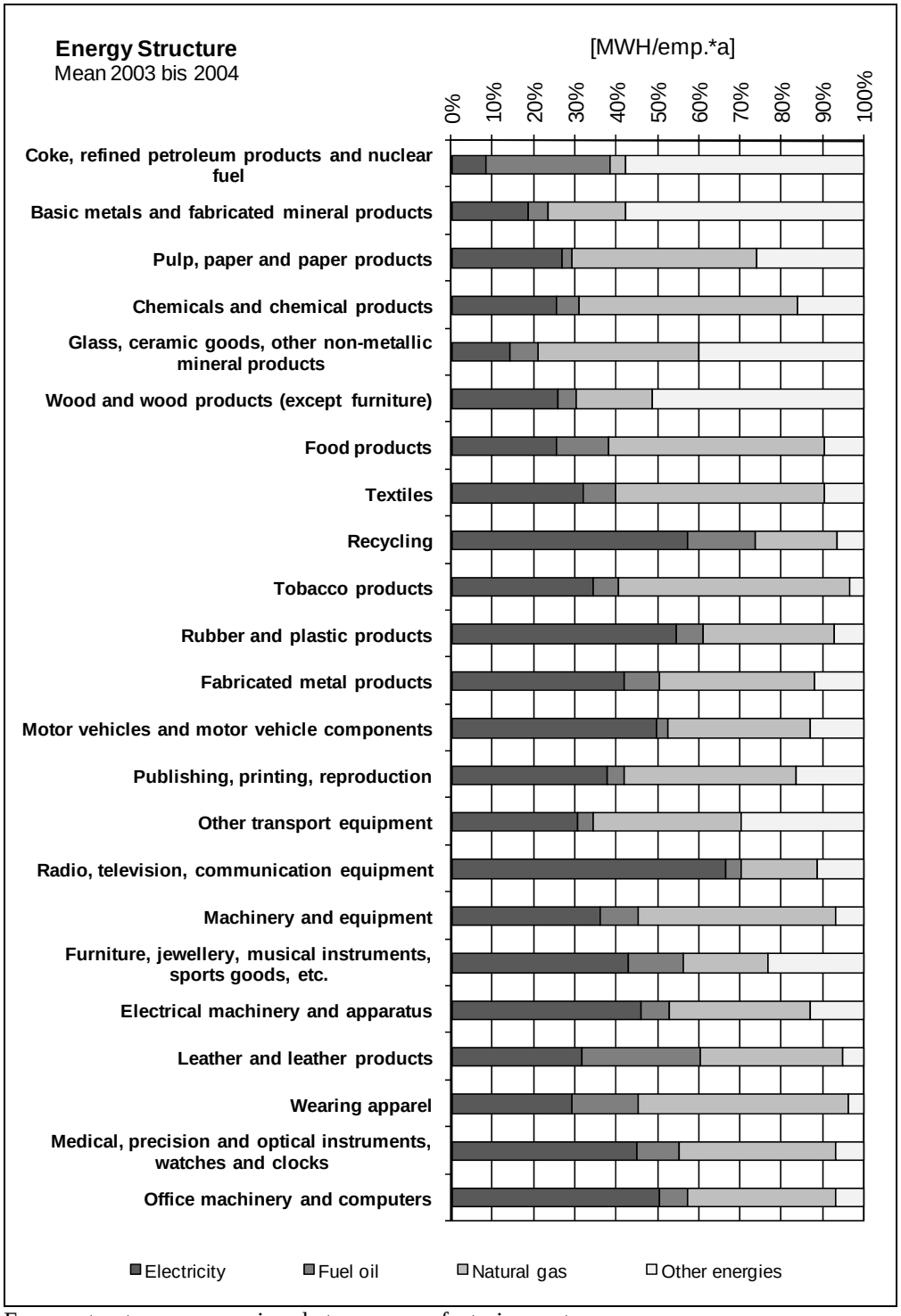

Fig. 5: Energy structure – comparison between manufacturing sectors

The average rate of natural gas use is 36%. A particularly heavy user of natural gas is the manufacture of tobacco products, with a figure of 56 %. The chemical industry (53 %), food manufacturing (52 %), wearing apparel (51 %), and textiles (50 %) use a proportion of about 50 % of natural gas.

In these sectors fuel oil reaches an average consumption of only 10 %. In about one third of sectors the proportion is even 5 % or less. Exceptions are the manufacture of refined petroleum products and the leather industry. 30 % of the energy used for petroleum processing is fuel oil. It is used both as a source of energy and as a primary product in product manufacture.

In calculating current expenditure, the data on energy consumption and its differentiation by source can be used for a rough assessment of resources in the use phase of a building. If the sector to which the industrial building is to be put is known, the total energy consumption per year (differentiated into electricity, fuel oil, gas, and other energies) can be estimated on the basis of the employment level.

Water Consumption and Waste Water Discharge

Statistics on public water supply and sewage disposal cover the purchase and discharge of water and waste water. Water consumption refers to the amount of water taken from the public water supply. Waste water discharge refers to the amount of waste water discharged into the public sewage disposal system.

The analysis of **water consumption** reveals marked differences between industries. In general, consumption ranges from about 200 to 18,000 cubic metres per employer per year (m^3/emp.*a). Petroleum processing, chemicals, the paper industry, and printing and publishing are the biggest users of water, between 12,000 and 18,000 m^3. 22 % of all manufacturing jobs are in these sectors. The manufacture of basic metals and fabricated metal products uses about 6,000 m^3/emp.*a. 10 % of all manufacturing jobs are in this sector (figure 6).

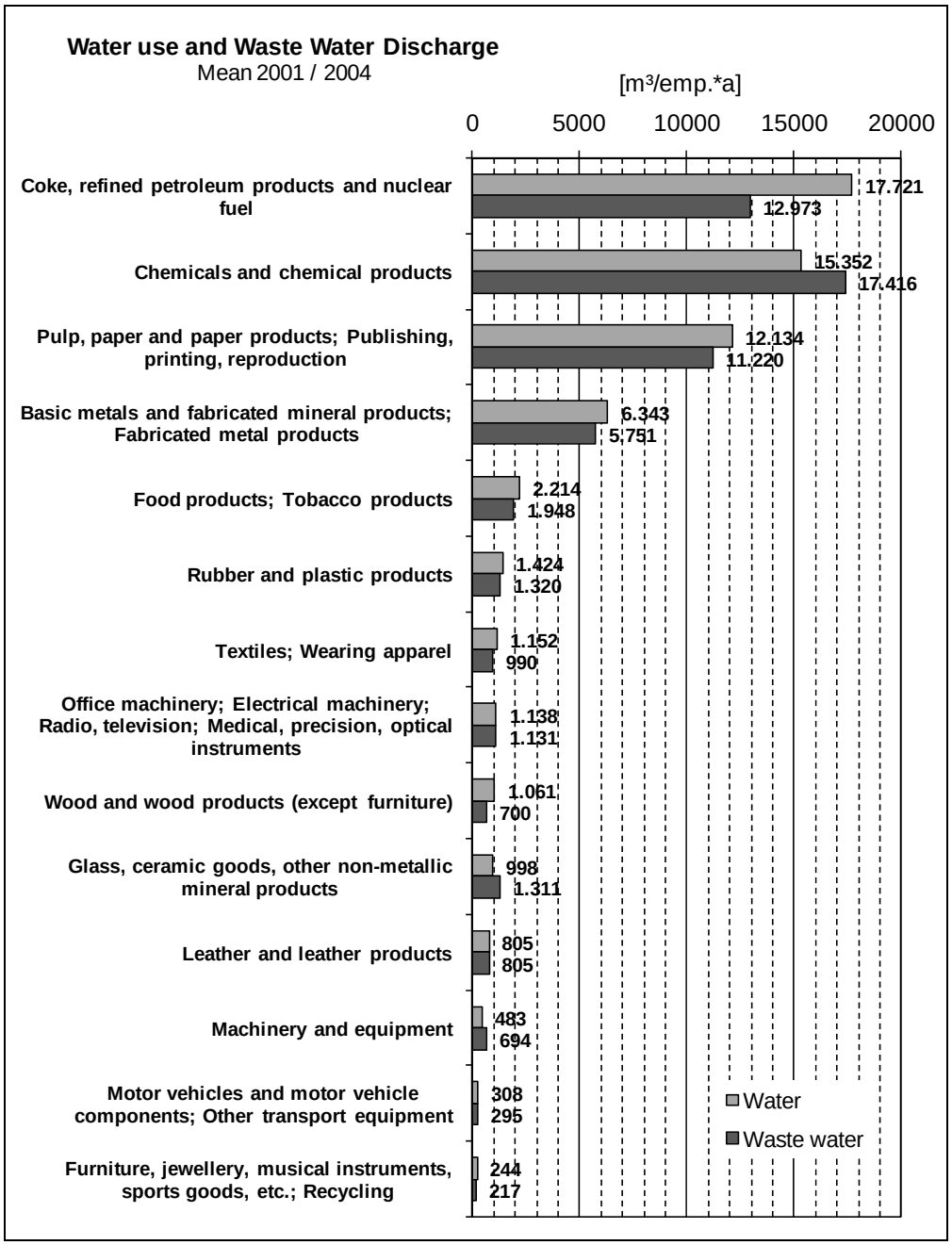

Fig. 6: Water use and waste water discharge – comparison between manufacturing sectors

The other sectors in manufacturing, with 68 % of all jobs, have a water consumption of between 200 and 2,300 m³ per employee per year. The food industry ranges high (2,214 m³). Motor vehicle manufacturing, in contrast, uses little water (308 m³).

Similar ratios are recorded for **waste-water discharge**. The sectors petroleum, chemicals, paper, and printing discharge between 11,000 and 17,500 m³ per employee per year (m³/emp.*a). In the manufacture of basic metals and fabricated metal products, the figure is just under 6,000 m³/emp.*a. The other manufacturing sectors, with 68 % of all jobs, range between 200 and 2,000 m³.

In interpreting these figures it should be remembered that water consumption and waste water discharge levels refer only to the amounts that come from or are discharged into public networks. The amounts consumed and discharged can accordingly prove to be greater or

smaller, e.g., if water is obtained from non-public wells or waste water is discharged into private sewage treatment plants.

Like the data on energy consumption, those on water use and sewage discharge can be employed to calculate resource consumption during the use phase of buildings. If information is available on the number of employees and the activities carried out in the buildings, water consumption and sewage volume can be roughly estimated.

3 Summary

Net usable area, building volume, structural volume, as well as building material structure are important elements in describing the **physical properties** of industrial and commercial buildings.

In comparison between types of building, office and administrative buildings have the greatest usable area, whereas agricultural buildings have the smallest usable area per building. The building volume of most types of building is larger than usable area by a factor of five. The exceptions are factory and workshop buildings, as well as commercial buildings and warehouses. Their volume is between six and seven times greater than their usable area.

The characteristic share of structural volume in building volume is lowest in agricultural buildings (4 %). Factory and workshop buildings and commercial buildings and warehouses have twice the structural volume (8 %). In office and administrative buildings and in hotels and restaurants, structural volume amount to 13 % and 14 % respectively. The most frequently used materials used to construct these buildings are brick and other types of masonry (ca 30 to 40 %). Factory and workshop buildings and commercial buildings and warehouses typically contain a high proportion of steel (some 30 %) and reinforced concrete (ca 25 %). Characteristic of agricultural buildings is the great use made of wood (ca 25 %).

Energy consumption, water use, and waste water discharge are important factors in describing the **use phase** of industrial and commercial buildings.

Although energy consumption per employee per year in manufacturing industries ranges from 15 MWh. to a considerable 4,000 MWh., few sectors record very high consumption. Half of all industries and hence some 65 % of all jobs consume under 50 MWh/emp.*a. A relatively high proportion of electricity and gas is used. 30 % and more of the sectors consuming less than 50 MWh per capita opt for electricity.

Similar figures are recorded for water consumption and sewage discharge. In general, consumption and discharge rates ranges from about 200 to 18,000 cubic metres per employer per year (m^3/emp.*a). The majority of industries, and hence some 70 % of all jobs in manufacturing consume and discharge between 200 and 2,300 m^3/emp.*a.

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