EXPLORING CIRCULAR SOLUTIONS IN THE WASTE SYSTEM

Executive summary of waste analysis

METABOLIC

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FONDEN TEKNOLOGI RÅDET

EXECUTIVE SUMMARY

Denmark is among the top resource consumers and waste producers in Europe. Despite ambitious green efforts, transitioning to a circular waste system is currently inhibited by lack of information as well as technological, logistical and economic lock-ins. This reinforces the current linear waste system that leads to high volumes of waste and to an unnecessarily high rate of incineration instead of reuse and recycling.

Metabolic has worked with Teknologirådet and DAKOFA to give the Capital Region of Denmark an actionable overview of waste streams and intervention hotspots. This creates the basis for further collaboration among stakeholders to drive a shift to a circular economy - across the value chain.

ABOUT THE REGION

The Capital Region of Denmark is the largest contributor to national GDP. Despite its relatively small size, it is internationally famous for its thriving entrepreneurial scene, high quality of life, and ambitious targets on energy and climate. The Region's growth strategy for the coming decade hinges on leveraging this position as a green knowledge economy.

The Region's commitment to become a sustainable and circular economy does, however, face a number of challenges. Currently, Danes are responsible for some of the highest levels of resource consumption and waste production in Europe. With a public waste management system structured around waste incineration with energy recovery, a paradigm shift to a 'waste free' economy is necessary but financially, politically, and logistically challenging.

This analysis is one of the first outcomes from the Region's three-year collaborative project, "Across Waste and Resources" (Affald og ressourcer på tværs). The goal is to identify new opportunities for collaboration and innovation, as well as creating a strong cross-sectoral stakeholder network - all of which will be translated into a roadmap for transitioning the waste system towards a circular economy.

WASTE FLOWS AND TREATMENT

Figure 1 illustrates the results from the material flow analysis for the Capital Region. It displays the inflow of material and products to three key sectors: construction & demolition; industry; and agriculture.

ONE-THIRD OF HOUSEHOLD MIXED WASTE IS FOOD

Household waste is the primary focus of this report and accounts for the biggest share of the regional waste streams (41%). One-third of this household waste is not sorted and ends up in mixed waste, which is incinerated. In turn, one-third of that mixed-waste (150,000 tons) is food, which is 'wet waste' and burns poorly. Half of it is avoidable food waste, which should be prevented earlier in the value chain.

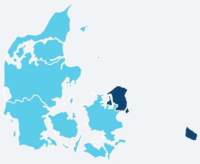
TWO-THIRDS IS RECYCLED - ONE-THIRD IS INCINERATED

The total amount of annually registered waste is 3 million tonnes[1], which can be allocated to four main waste treatment options. Only a very small fraction is landfilled. Instead, about two-thirds is recycled and one-third is incinerated with energy recovery. While it is good that so few materials are lost to landfills, it is still necessary to divert waste from incineration towards more recycling, to minimise direct and embodied emissions and keep materials at their highest possible value. But even among the waste streams that are being recycled, many are being downcycled, effectively losing quality and hence economic value.

1 All statistics are excluding soil and stones which is excluded from this analysis.

KEY FACTS
Captial Region of Denmark

Size



6%
of Denmark's total land surface.

30%
of the Danish population inhabitants (1.8 million).

Economy and knowledge

ACCOUNTS FOR
40%
of national GDP.

2007 → 2017
+ 8.2%
increase in employment rate from 2007-2017.

2006 → 2016
+ 37%
GDP growth rate from 2006 to 2016.

5%
of the Region's GDP is invested in research and development.

> 50%
of the Region's workforce has a higher education degree.

Green targets

80%
Waste recycling rate by 2035.

Fossil free transport sector by 2050.

Fossil free electricity and heat by 2035.

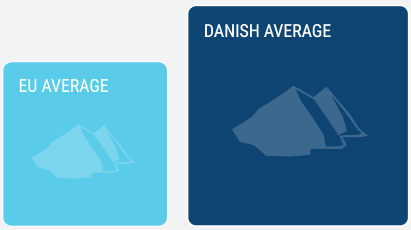
8%
Growth in green business and cleantech by 2025.

Current Danish waste management and resource consumption

69%
Recycling rate for all waste.

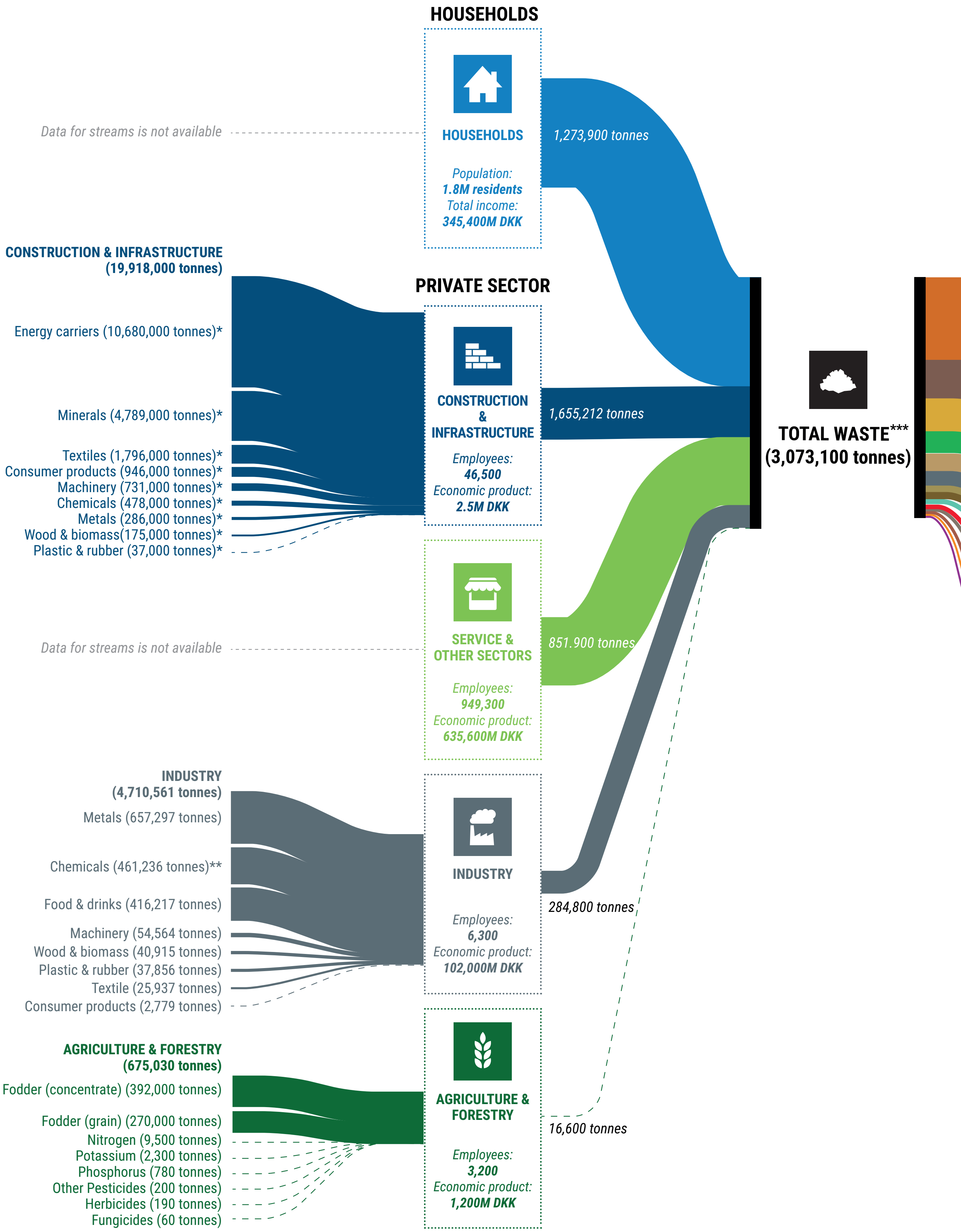
3%
Landfilling rate.

46.3%
Recycling rate for household waste (just under EU average.)



24.1 tonnes
of material is consumed by the average Dane annually.

13.3 tonnes
of material is consumed by the average EU inhabitant annually.



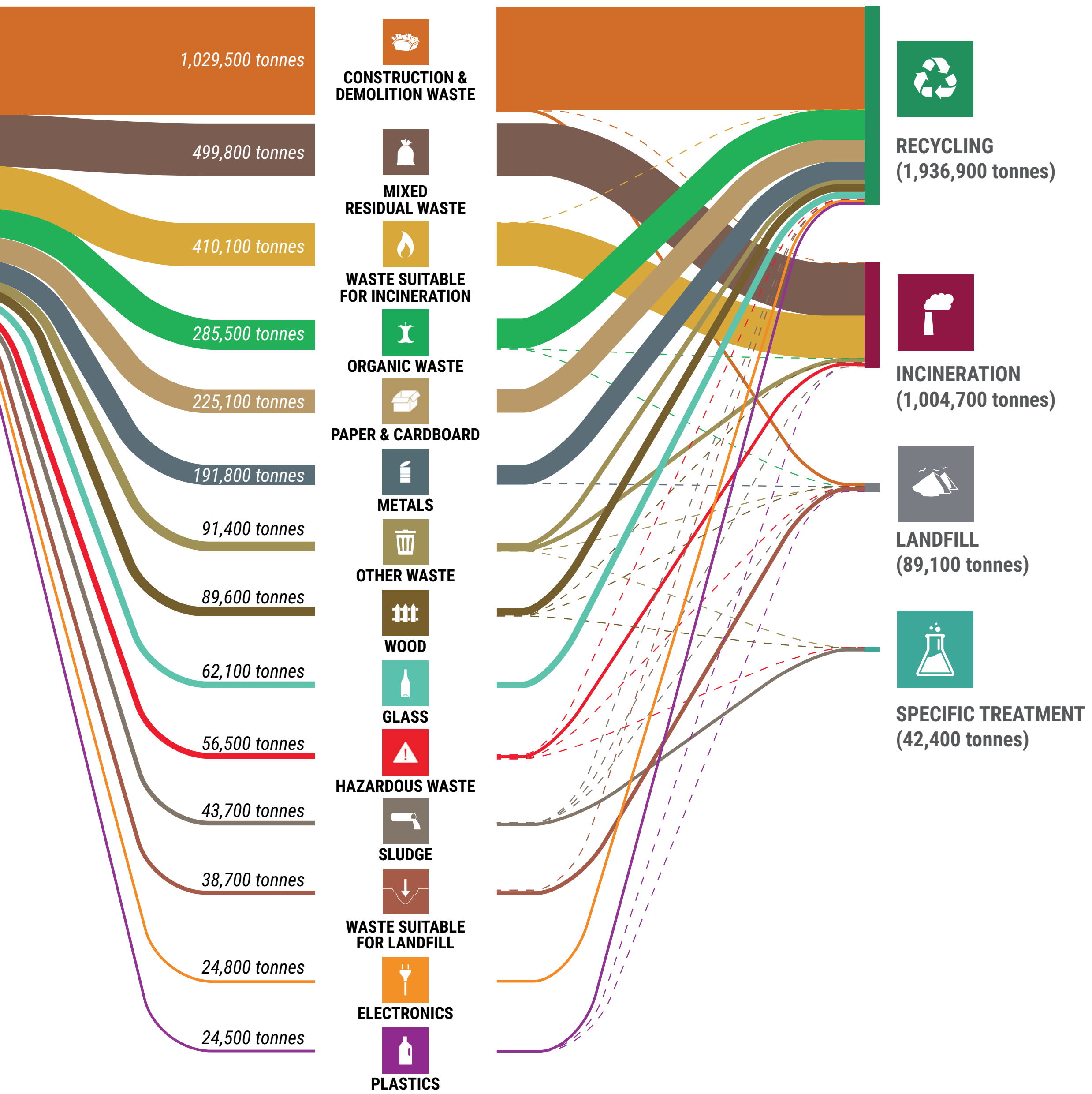
HOUSEHOLDS
Data for streams is not available
HOUSEHOLDS
Population:
1.8M residents
Total income:
345,400M DKK
1,273,900 tonnes
CONSTRUCTION & INFRASTRUCTURE
(19,918,000 tonnes)
Energy carriers (10,680,000 tonnes)*
Minerals (4,789,000 tonnes)*
Textiles (1,796,000 tonnes)*
Consumer products (946,000 tonnes)*
Machinery (731,000 tonnes)*
Chemicals (478,000 tonnes)*
Metals (286,000 tonnes)*
Wood & biomass(175,000 tonnes)*
Plastic & rubber (37,000 tonnes)*
PRIVATE SECTOR
CONSTRUCTION & INFRASTRUCTURE
Employees:
46,500
Economic product:
2.5M DKK
1,655,212 tonnes
TOTAL WASTE***
(3,073,100 tonnes)
Data for streams is not available
SERVICE & OTHER SECTORS
Employees:
949,300
Economic product:
635,600M DKK
851.900 tonnes
INDUSTRY
(4,710,561 tonnes)
Metals (657,297 tonnes)
Chemicals (461,236 tonnes)**
Food & drinks (416,217 tonnes)
Machinery (54,564 tonnes)
Wood & biomass (40,915 tonnes)
Plastic & rubber (37,856 tonnes)
Textile (25,937 tonnes)
Consumer products (2,779 tonnes)
INDUSTRY
Employees:
6,300
Economic product:
102,000M DKK
284,800 tonnes
AGRICULTURE & FORESTRY
(675,030 tonnes)
Fodder (concentrate) (392,000 tonnes)
Fodder (grain) (270,000 tonnes)
Nitrogen (9,500 tonnes)
Potassium (2,300 tonnes)
Phosphorus (780 tonnes)
Other Pesticides (200 tonnes)
Herbicides (190 tonnes)
Fungicides (60 tonnes)
AGRICULTURE & FORESTRY
Employees:
3,200
Economic product:
1,200M DKK
16,600 tonnes

Figure 1: Sankey diagram showing the current waste system of the Capital Region for both households and the private sector.

The analysis is based on regional waste data from the national waste register (Affaldsdatasystemet, 2016) supported by data sets from Danish waste management facilities (ARC and Vestforbrændingen), the Danish producer responsibility schemes and waste composition analysis by the Danish Environmental Protection Agency. All quantities are displayed in tons and the size of the stream corresponds to the amount, besides the materials flowing into the construction sector, which is scaled down to 13% to fit into the figure.

LEGEND

- - - - Under 20,000 tonnes
** Scaled down to 13%*
*** 3,013,760 tonnes of minerals have been excluded*
**** 3,099,900 tonnes of soil have been excluded*



ENVIRONMENTAL ANALYSIS - INDIRECT IMPACTS

Table 1: Waste generation and treatment

	HOUSEHOLDS	CONSTRUCTION	INDUSTRY	AGRICULTURE	ALL OTHER SECTORS
Share of total waste	41%	21%	9%	1%	28%
Recycling	51%	85%	72%	90%	60%
Incineration	47%	10%	16%	7%	36%
Landfill	2%	5%	1%	2%	3%
Special treatment	-	-	11%	1%	1%

When a product enters the waste stream, it has already undergone a long process. For most products, the greatest environmental impacts occur during the raw material sourcing stages, as well as the production and distribution stage. These are called indirect environmental impacts. Figure 2 summarises the indirect environmental impacts of the products and materials in the region's waste system. The waste streams are divided into the waste fractions seen in figure 1 above, and includes waste from both households and businesses.

Figure 2 shows four different dimensions:

- the horizontal axis shows the total carbon footprint of the materials in the waste fraction;
- the vertical axis shows the total raw material footprint in the production of the materials and products;
- the colour indicates the total energy footprint in MJ, in connection with the production;
- and the actual amount of waste in tonnes is shown by the size of the bubble.

The environmental footprints of the waste streams show how important it is to reduce the use of new materials and products of a given type through reduced consumption as well as increased reuse and recycling. For example, if more electronic devices are maintained, repaired and refurbished, the demand for new products will fall, as will the overall environmental footprint for electronics in the region.

KEY RESULTS FROM THE ENVIRONMENTAL ANALYSIS

Electronics have the largest material footprint

The analysis shows that although electronic waste is a relatively small waste stream, it has the largest relative environmental footprint. While approx. 2,400 tons electronic waste ends up as household waste, and is then incinerated, the majority is collected separately and sent to recycling. However because of the complexity of these products it is difficult and energy consuming to fully recycle the materials. Thus, the most effective way to reduce the environmental impact of electronics is to extend the life of electronic products through repair, refurbishment and reusing the components.

Metals have the biggest recycling potential

Moreover the analysis looks at which materials produce the greatest environmental savings per kilo recycled, relative to consuming virgin materials. When replacing virgin aluminium with recycled aluminium, CO_2 emissions are reduced by 96%. For steel it is 87%. The recycling rate of metal packaging is currently 70% in Denmark. This is relatively high, but given the high economic value of metals and the great CO_2 saving compared to other materials, it is worth working to further improve the recycling rate of metals.

Construction waste is mostly downcycled

Construction and demolition waste is the largest waste stream, at over 1 million tonnes. Just after electronics it has the biggest CO_2 footprint as well. This makes it one of the key material streams that needs to be addressed. The recycling rate of construction waste is high in Denmark, however the materials are mostly downcycled and replace few virgin materials. Direct reuse of building materials in new buildings with no or little loss of functional value should therefore be of high priority.

Paper is still a large part of the waste stream

Despite the digital revolution, paper still forms a substantial part of the waste. About 225,000 tonnes of paper and cardboard are thrown out annually in the region - a number that has been relatively stable in recent years. Among companies almost all paper and cardboard waste (127,000 tonnes) is separated and recycled, but for households it is only slightly over half (98,000 tonnes). About 80,000 tons of paper and cardboard is also incinerated, which accounts for a carbon footprint of 81,000 tons. There is a 37% saving in CO_2 emissions using recycled paper and cardboard.

Recyclables lost in residual household waste

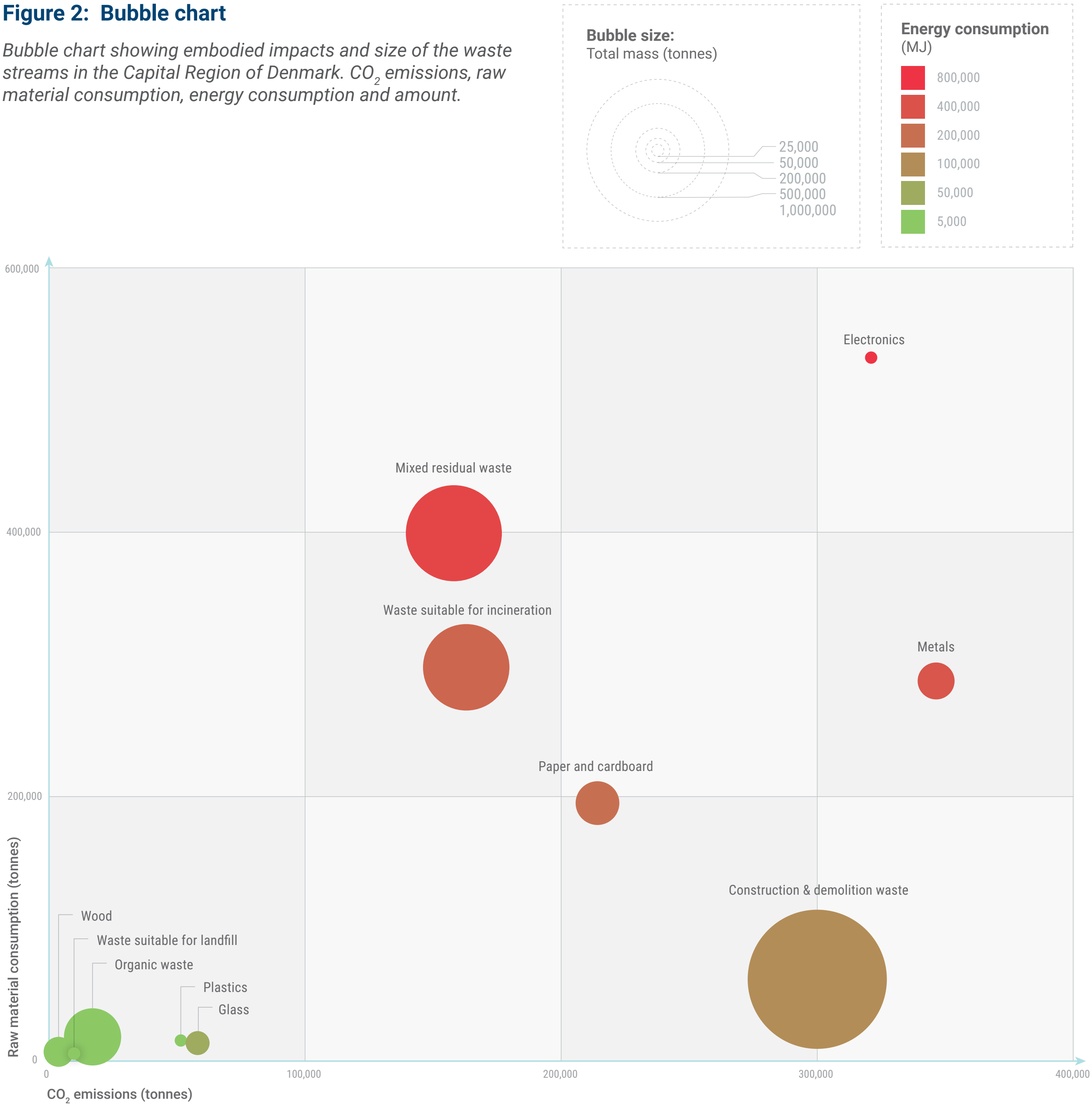
Residual waste is the largest waste stream from households and a source of major environmental impacts. It consists primarily of food, but also contains considerable quantities of recyclable materials such as textiles, plastic, paper and cardboard. All residual waste is incinerated to produce heat and energy, but the materials are lost and brand new materials are therefore needed to meet demand. Improved sorting of household waste has high priority but should be accelerated further.

Reusable products in waste for incineration

Like residual waste, combustible waste is one fairly mixed stream. Its composition varies significantly depending on whether it comes from companies or households. About 135,000 tonnes are bulky waste which mainly consists of furniture and other large objects. Another 130,000 tonnes are household products, mainly covering non-electronic consumables. All these products are incinerated, though many of them may still be functional or have the potential to be repaired or recycled. Having a system in place that ensures that these products are screened and sorted for reuse and recycling should be of high priority.

Figure 2: Bubble chart

Bubble chart showing embodied impacts and size of the waste streams in the Capital Region of Denmark. CO_2 emissions, raw material consumption, energy consumption and amount.



NINE HOTSPOTS

In order to guide the waste management initiatives in the region, we identified nine hotspots. Hotspots are defined as key opportunity areas, where actions will have a relatively high impact. Based on the material flow analysis, the environmental analysis and the knowledge of the project partners, we identified five hotspots in waste streams and four systemic hotspots. The most critical waste streams are concrete and electronics as they have particularly high impact. The systemic hotspots' focus are on structural barriers in the regional waste system.

WASTE HOTSPOTS

Table 2: Waste hotspots table

WASTE STREAM	STATS	CHALLENGE	RECOMMENDATION
E-waste	Mass: 24,700 tons CO_2-footprint: 326,000 tonnes	Electronic waste has one of the largest CO_2-impacts and contains rare metals. The complexity of electronic products make them difficult to recycle.	Avoid electronics in the waste system all together. The solutions could be a combination of repairs, reuse and better design.
Construction waste	Mass: 1,029,500 tonnes	Construction and demolition has the largest waste stream and one of the largest environmental impacts. Most construction waste is recycled, but unfortunately with a very low functional value.	The majority of construction waste should be reused directly or for secondary (construction) materials, which would reduce the consumption of primary resources and preserve the value of existing construction materials.
Food in residual waste	Mass: 196,600 tons CO_2-footprint: 105,000 tonnes	A large part of food waste ends up in residual waste and is incinerated. More than half is food waste. It is a big loss of value and resources.	Minimize unnecessary food waste and separate the inevitable food waste from residual waste, so it can become a part of the regional bio-economy.
Bulky waste	Mass: 134,600 tons CO_2-footprint: 108,000 tonnes	50-60% percent of bulky waste can be reused or recycled. But due to a lack of capacity for sorting it ends up being incinerated, which leads to substantial loss of value.	Establish better procedures to identify and sort bulky waste with the potential to be reused or recycled.
Plastic and packing	-Mass: 33,000 tons CO_2-footprint: 78,700 tonnes	Most plastic ends up in residual waste and is incinerated. This leads to significant CO_2-emissions at the incineration stage while losing value.	We need a change in the whole supply chain of plastics to solve this challenge.

Note: Reference year is 2016

"CO_2-footprint": Tonnes of $C0_2$ emitted through production and distribution of materials and products in the given waste stream. Can also be from cultivation of land.
"Functional value": A material's ability to function as a constructive input in different products and/or processes.

SYSTEMIC HOTSPOTS

Increase transparency of waste fractions and sources

The material flow mapping also served to identify 'blind spots' in the Region's waste system. An important example is the large group of companies in service, trade, retail and the like. Separately, the companies do not produce much waste, but because companies in these sectors account for 89.4% of all employees, it amounts to considerable quantities. It is commonly assumed that waste from these sectors is similar to household waste, but no further descriptions or analyses of these fractions have been made to verify that. This is approximated to be about 150,000 tonnes of unknown mixed fractions, that today go mostly to incineration. In order to be able to accurately act on the political goal of increasing recycling, it is recommended that this waste stream should be investigated further.

Include quality in recycling data

The analysis shows that 63% of various waste materials are recycled in the Capital Region, but this does not necessarily mean that 63% of the materials will re-enter the economy. Nor does it mean that 63% of the economic value of the materials is recovered. According to the EU Waste Directive of 2018, the recycling rates of the Member States must, as of 2020, contain only the actual quantities of recycled materials. From a circular perspective, it should also be registered whether recycled materials maintain quality, as well as an obligation to provide information on the consumption of virgin raw materials and energy in the recycling process. It is therefore recommended that the recycling processes for waste streams are analysed more thoroughly to establish a "circularity score". This will provide increased clarity on the actual degree of circularity, as well as a better starting point for prioritising waste streams and treatment processes.

Leverage leading position with waste database

Denmark has a national waste data system that registers all national waste streams. One of the main conclusions of the analysis is that this data should be improved and made much more accessible. The waste data system has justifiably been criticised for lack of reliability. Despite its limitations, however, it places Denmark in a unique position ahead of most other countries, as it is rare to have such a complete and centralised waste database.

Denmark has an opportunity to lead the European transition to a circular economy by making waste data more accessible and using smart algorithms to generate tailored insights for companies about waste reduction potential.

Address the systemic lock-in which favours incineration

Denmark has long been a frontrunner for efficiently using the energy generated from waste incineration, but in recent years the pronounced use of waste incineration has been challenged by new political recycling targets. However, the existing waste system has established a strong path dependency, which is related to both the logistics for sorting and the cost of collection, as well as the 25% of district heating that is supplied by waste incineration. These facilities are so effective today that most recycling processes cannot compete on current market conditions. To increase the recycling rate, it is necessary to recognise this path dependency and redesign the existing system - from product design to waste treatment facility.

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