Measuring reading's resource consumption – an application of urban metabolism

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10 Measuring Reading's resource consumption – an application of urban metabolism

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Introduction

Resource efficiency in our urban areas will be central to humanity's long-term mission to a sustainable relationship to our planetary support systems. Our parallel goal for economic growth can be made more sustainable through this lens using material flow management (Niza, Rosado and Ferrdo, 2009). Looking at the urban level, a greater understanding of the urban resource flows, or urban metabolism, enables a quantitative approach for gauging resource efficiency, understanding where anomalies in resource demands exist, and lessons that can be learned from these.

With over 50% of the world's population now living in urban areas and these urban areas representing 70% of global GDP, cities are focal points of resource consumption (Barles, 2009; Niza et al., 2009; Mckinsey Global Institute, 2011); they must be targeted to achieve greater resource efficiency in our economies. Understanding the material flows of cities enables new insight on resource intensity and how this can be reduced (Voskamp et al., 2017). However, the rise of globalisation has led to resource flows becoming increasingly global. The majority of consumption within cities is now comprised of imported finished and intermediary products instead of raw materials (Barles, 2009; Niza, Rosado and Ferrdo, 2009). These new commodity chains highlight that resource consumption within cities and waste produced can have environmental impacts beyond the administrative boundary (Kennedy et al., 2014).

Whilst urban metabolism studies of cities are rare due to inadequate data availability (Niza et al., 2009), the development of material flow analysis (MFA) in the 1990s has provided a framework to understand the sustainable development of cities (Kennedy, Pincetl and Bunje, 2011). Since then, urban metabolism studies have been completed for several major European cities including Paris and the surrounding region (Barles, 2009), Amsterdam (Voskamp et al., 2017) and Lisbon (Niza, Rosado and Ferrdo, 2009). These studies provide context to explain how cities' characteristics can affect its resource requirements.

For instance, Voskamp et al., (2017) discuss the influence of the Port of Amsterdam on the city's material balance. Given the large volumes of material flows, mainly fossil fuels, entering and leaving the city through the port, calculating which of these flows are a throughput (trade-related flows that simply pass through the city without being consumed or processed) gives great insight into the city's imports, exports and stocks (Voskamp et al., 2017). Without this differentiation, the material consumption within Amsterdam could be distorted and considerably higher than the true value. An accurate reflection can be used to establish how much of Amsterdam's resource consumption could be met through local sourcing.

Kennedy, Pincetl and Bunje (2011) discusses the potential applications of urban metabolism including; greenhouse gas accounting, mathematical modelling for policy analysis, urban design and as an indicator for sustainability. Their section on mathematical modelling is particularly relevant to this report and discloses how these models can be used to quantify the stocks and flows in metabolism.

A particular gap that exists in the research is the role of medium-sized cities in realising improvements in resource efficiency (Bahers, Barles and Durand 2018); many existing major MFA studies (such as those discussed above) have focused on large cities, particularly mega cities (Kennedy et al., 2015). However, residents of these megacities do not represent the majority of the population. For example, 61% of the population lives in urban areas between 100,000 and 500,000 residents (ONS, 2014). This increases to 67% if you also include urban areas between 500,000 to 999,999. Only 20% of the population lives in urban areas greater a million residents. If the UK is to be successful in realising a more sustainable economy, these medium-sized cities will require dramatic changes in their resource consumption.

This chapter discusses the results of an MFA of one such medium-sized European urban area: Reading, UK. The motivation of this is to determine in which ways urban areas such as Reading's differ from their larger counter parts. We explore the trends in resource demands over the 5-year study period (2010 - 2015), with further insight on where Reading's sustainability challenges lie. Finally, we explore spatial variations in resource consumption to gain insight into the local drivers of resource consumption.

Background

Within this study the MFA method will be applied to the municipality of Reading. Reading is a large town made up of 16 wards and 2 constituencies, situated along the Thames River in the South-East county of Berkshire (Figure 10.1). An important technology and commercial centre within the Thames Valley region, Reading is ranked as the UK's top economic area for economic success and wellbeing (PriceWaterhouseCoopers, 2018), and home to the University of Reading and major national sports teams.

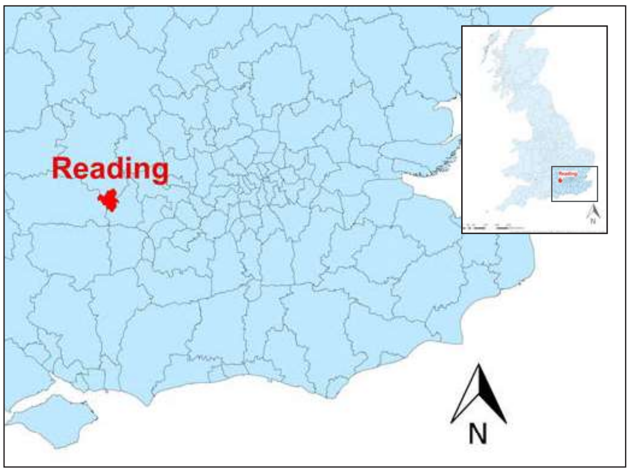

Figure 10.1 Location of Reading in the UK, the South-East region and the municipality boundaries

The following table provides key social and economic statistics for Reading in both of the base years studied (see Table 10.1). There has been a 4% increase in population from 2010 to 2015, and therefore an increase in the population density by 186 per km^2 (Office for National Statistics, 2017). In terms of Gross Value Added (GVA), Reading's economy grew by £1,042M in the five years between the base years (Office for National Statistics, 2017). Also, the table shows there is a difference in the climate of the two years studied. In 2015, the daily average temperature was 1.44°C hotter than 2010, and the year saw 30.2mm more precipitation than 2010 (University of Reading, 2017).

Table 10.1 Reading: Key statistics, 2010 and 2015

Indicator	Unit	2010	2015
Population	Number	154,296	160,825
Land area	m^2	40,398,188	40,398,188
Population density	Per km^2	3,857	4,043
Gross Value Added (GVA)1	£ million	5637	6679
Average daily temperature	°C	9.75	11.19
Annual precipitation	mm	544.6	574.8

[1]GVA is Gross Domestic Product (GDP) excluding taxes and subsidies on products.

As shown in Table 10.2, the largest land use in Reading is suburban, covering 55.87% of total land area, followed by urban areas covering 20.19%, given a combined total of 76.06% of land used for urban processes. The land uses that can be considered more natural (neutral grassland, improved grassland, broadleaf woodland, and arable and horticulture) together only amount to 24% of land use. This presents Reading as a predominantly urban environment, with most space characterised as developed areas serving to host urban resource consumption activities (Figure 10.2).

Table 10.2 The area and percentage of each land use type in Reading (Ordnance Survey, 2017)

Land use	Area (m2)	Percentage (%)
Arable and Horticulture	540,772	1.34
Broadleaf Woodland	1,304,317	3.23
Freshwater	621,688	1.54
Improved grassland	7,148,004	17.69
Neutral Grassland	54,367	0.13
Urban	8,158,319	20.19
Suburban	22,570,721	55.87
Total Area	40,398,188	100

Areas defined by the Biodiversity Broad Habitat Classification (Jackson, 2000).

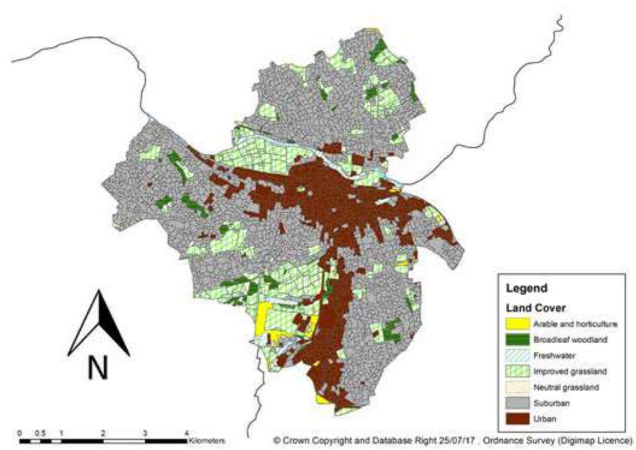

Figure 10.2 Land use map of Reading (Ordnance Survey, 2017)

Research method

Reading resource flow data were examined for the years 2010 and 2015. These years were chosen as 2015 was the most recent substantial data source available at the time of the study (2017–18), given that data are often released after two years and 2010 provides a five year difference – long enough to be able to see any potential comparative change. Three recent major UM studies for European cities all refer to the Eurostat (2001) method for MFA

(Barles, 2009; Niza et al., 2009; Voskamp et al., 2017), though they highlight that it was originally designed for use at the national level and subsequently adapted at the regional and urban level as in these studies by Hammer et al. (2003).

Using the original MFA would leave out flows that are significant within Reading, such as water and renewable energy. At the national level, the magnitude of water flows is deemed too large so is left out as it could alter other results (Eurostat, 2001). However, at a local level, all flows become vital to be able to understand a city's overall material balance (Voskamp et al., 2017). Renewable energy is also quantified since increasing the proportion of locally generated renewables in Reading is a key target for the town moving forward. Consequently, similar to Voskamp's et al. (2017), the Eurostat method used in this research has been modified to include these important flows within Reading that would not be included under the original Eurostat MFA. Figure 10.3 illustrates the flows that are examined in this modified MFA, with a list of data sources provided in Table 10.3.

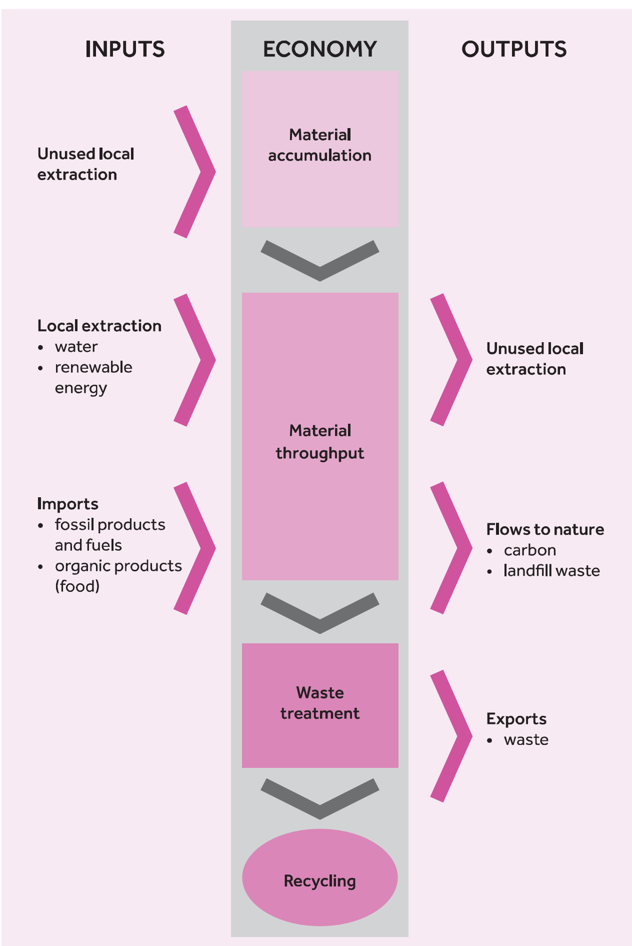

Figure 10.3 MFA flow diagram

Table 10.3 Table of data sources

Flow	Data sources and remarks
Local Abstraction	
Renewables	Average daily solar radiation and totalled quarterly data. University of Reading – Meteorology Observatory climate data extractor; WasteDataFlow – Waste management: Reading Final reprocessor report 2010 and 2015.
Water	Annual abstraction data. Environmental Agency Water Balance components report for Thames Water 2016 (EA, 2017a)
Imports	
Fossil fuels	Total annual consumption. Department for Business, Energy & Industrial Strategy: Regional and local authority electricity consumption statistics: 2005 to 2015; Regional and local authority gas consumption statistics: 2005 to 2015; Road transport energy consumption at regional and local authority level 2005 – 2015.
Organic products	Totalled weekly data. Department for Environment, Food & Rural Affairs – Family food datasets
Flows to nature	
Waste to landfill	Totally quarterly data. WasteDataFlow – Waste management: Reading Q100 PI Summary (UA) 2015 and 2010 (Wastedataflow, 2016).
Carbon	Derived from Fossil fuel data (see entry above). Department of Energy and Climate Change (DECC) Greenhouse gas reporting – Conversion factors 2015 (DECC, 2015).
Water	Annual data on leakage of different types. Thames Water – Final water Resources Management Plan 2015 – 2040 – Main Report (Thames Water, 2014a).
Exports	
Waste	Totalled quarterly data. WasteDataFlow – Waste management: Reading Q100 PI Summary (UA) 2015 and 2010 (Wastedataflow, 2016).

Results and discussion

The complete MFA table of the data collected in this study is presented below in Table 10.4. Some observations include improvements in renewable energy capacity, declines in municipal solid waste, domestic and transportation energy demand/GHGs, as well as food consumption (though this figure may be due to changes in quantification methods used by the source). Trends in water consumption are not observable as 2010 data were not available. Leakage quantities do suggest improvements in non-revenue water at the level of the supply infrastructure (excluding buildings), which is a further positive development.

Table 10.4 MFA results

Resource classification	Unit	2010	2015
INPUTS			
Local extraction			
Renewables	**ktoe**	**0.71**	**0.77**
Solar PV	ktoe	0.42	0.44
Waste-to-energy	ktoe	0.29	0.33
Water	**kt**	**–**	**16731.81**
Groundwater abstraction	kt	–	11712.27
Surface water abstraction	kt	–	5019.54
Imports			
Fossil Fuels	**ktoe**	**131.71**	**124.10**
Total domestic consumption	ktoe	92.90	86.41
Electricity	ktoe	23.59	22.70
Gas	ktoe	69.31	63.71
Total mobile energy	ktoe	38.81	37.69
Diesel	ktoe	19.81	21.83
Petrol	ktoe	19.00	15.86
Organic products			
Total food	kt	118.46	71.63
DMI	**kt**		**17161.72**
OUTPUTS			
Flows to nature			
Waste tolandfill	kt	20.27	18.15
Household	kt	17.66	15.94
Non-household	kt	2.61	2.21
Carbon	**kt CO_2**	**391.77**	**363.12**
Total domestic emissions	kt CO_2	281.19	257,44
Electricity	kt CO_2	132.29	121.04
Gas	kt CO_2	148.90	136.40
Total mobile energy emissions	kt CO_2	110.58	105.68
Diesel	kt CO_2	57.62	61.52
Petrol	kt CO_2	52.96	44.16
Water	**kt**	**4881.25**	**4671.39**
Total building leakage	kt	3336.27	3651.78
Non-household leakage	kt	54.22	45.61
Measured non-household uspl	kt	51.10	40.89
Unmeasured non-household uspl	kt	3.12	4.72
Household leakage	kt	891.75	953.05
Measured household uspl	kt	388.19	265.78
Unmeasured household uspl	kt	503.56	687.26
Void properties uspl	kt	10.91	28.31
Total mains and trunk mains leakage (Distribution losses)	kt	2469.47	2624.81
Total supply leakage	kt	1544.98	1019.61
Distribution system operational use	kt	–	64.98
Raw water losses and operational use	kt	–	94.36
Treatment works losses and operational use	kt	1544.98	860.26
Exports			
Waste			
Total municipal waste collected	kt	70.81	73.87
Total Household waste collected	kt	63.01	65.27
Household waste sent for dry recycling	kt	15.21	13.02
Household waste sent for composting	kt	6.17	7.04
Household waste used for energy recovery	kt	23.31	28.32
Household reusable waste	kt	0.65	0.90
DMC		**360.69**	**16973.30**

Table 10.4 notes

ktoe = thousand tonnes of oil equivalent; uspl = underground supply pipe leakage

Direct Material Input (DMI) is the sum of all local extraction and imports. 2015 is substantially bigger than 2010 given the inclusion of water extraction data for 2015 that was not available for 2010.

Domestic Material Consumption (DMC) is DMI minus exports. This is a partial DMC as processed waste flows are the only exports included in this MFA.

Energy

The MFA shows that energy imports have decreased over the 5-year period by 5,8%. Domestic energy consumption has consistently been the greater flow compared to mobile energy consumption, with it being 70.53% and 69.63% of total consumption in 2010 and 2015, respectively. Commercial and industrial energy consumption data were not available. Domestic energy consumption is presented in Figure 10.4, comparing areas where electricity and gas consumption are highest on an average “per meter” basis. There are areas where information has not been disclosed but some areas of little or no gas consumption can be explained through much higher electricity consumption compared to the rest of Reading.

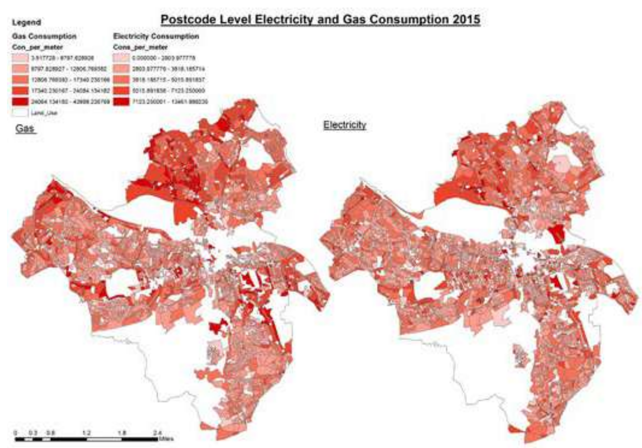

Figure 10.4 Postcode level electricity and gas consumption, Reading, 2015 (BEIS, 2017)

Furthermore, the MFA demonstrates that only a very small proportion of Reading’s energy consumption is generated from local renewable sources. In 2015, renewables generated only 3.4% of domestic electricity consumption in Reading (of course this excludes the consumption of other non-residential urban functions). This underscores the challenge of Reading achieving its target to generate 8% of its energy consumption by 2020 (RCCP, 2013). However, wind and biogas generation data were not available and would increase this figure so that it is closer to the stated target.

Water

The results from the MFA show that 2015 local water utility abstraction in Reading totalled 16731.81kt, with 70% of this derived from groundwater, and 30% from surface water. Water flows make up nearly 99% of inputs and therefore dominate the composition of the total resource input (DMI). Despite not obtaining the abstraction figures for 2010, it can be assumed that the share of water abstraction would be of a similar magnitude to 2015. With regards to water flow outputs between 2010 and 2015, total building leakage increased by 9.46% despite Thames Water efforts to reduce water inefficiencies (Thames Water, 2016), while total supply leakage decreased by 34%, although 2010 figures do not include data for raw water losses, distribution system losses and operational use. The different leakage components accumulative proportion of the total domestic material consumption equates to 91.12% in 2010 and 90.99% in 2015, representing a very slight decrease in the MFA. This would support the idea that there is progress in the attempt to achieve the objective of reducing leakage (RCCP, 2013). Figure 10.5 visualises the relative sizes of inputs and outputs of water flows in Reading.

Following on from this, there are water input and output flows not included within the MFA. To have a complete representation in the MFA of Reading, the rainfall flow must be included in the Local Extraction category (Inputs), and the wastewater, infiltration to groundwater and run-off into sewers must be included in the Flows to Nature category (Outputs). The volume of rainfall in Reading has been calculated using annual precipitation (University of Reading, 2015) across the total area of Reading and then converted into kilo tonnes. In 2010, this flow was 21784kt and 22992kt in 2015, indicating 2015 was a significantly wetter year. The rainfall flow would therefore be larger than all other flows combined in both years. This highlights the importance of rainfall as part of the material balance due to its significant magnitude. Through improved communication with local water utilities such as Thames water, more research will lead to more available and abundant data for water flows within urban systems. This in turn will provided a better detailed and disaggregated understanding of how water flows are created and their impacts. The size of the rainfall flow means it cannot be included in the MFA as data on wastewater outputs (from both stormwater and drinking water) were not available, so its inclusion without the outputs would cause the MFA to be imbalanced.

From 2010 to 2015, water consumption decreased in Reading (Thames Water, 2014a). This reduction in water consumption may be due to the wetter climate of 2015 in comparison to 2010, with less water needing to be consumed for outdoor activities such as gardening (Sim et al., 2005).

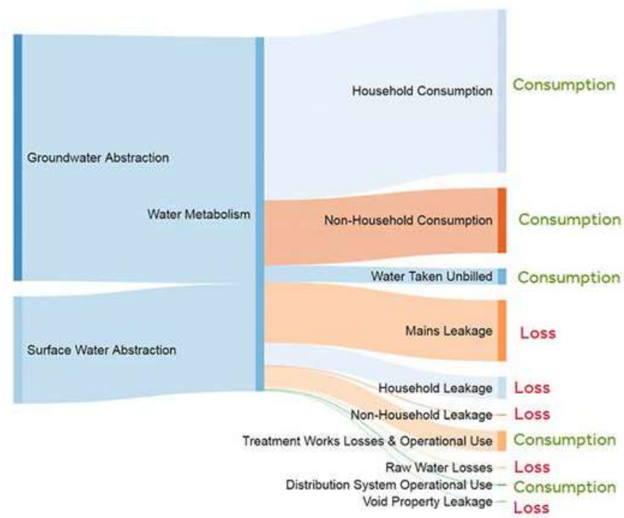

Figure 10.5 Estimated relative size of domestic water flows in Reading's metabolism (scaled using data from Thames Water 2014a)

Figure 10.6a) portrays the spatial variation in annual water consumption for different housing typology. This gives a good indication as to which typology use the most water, with detached and terraced housing having two and four lower super output areas (LSOAs) with the highest water consumption (between 50 and 60 ML) respectively. Furthermore, Figure 10.6a) indicates where there is greater concentrations of different housing types; areas of lowest water consumption would indicate a relatively low concentration of that housing type in that area. The total annual water consumption per LSOA for all four housing typologies is shown in Figure 10.6b), with the lowest areas of water consumption appearing to be in the East of Reading.

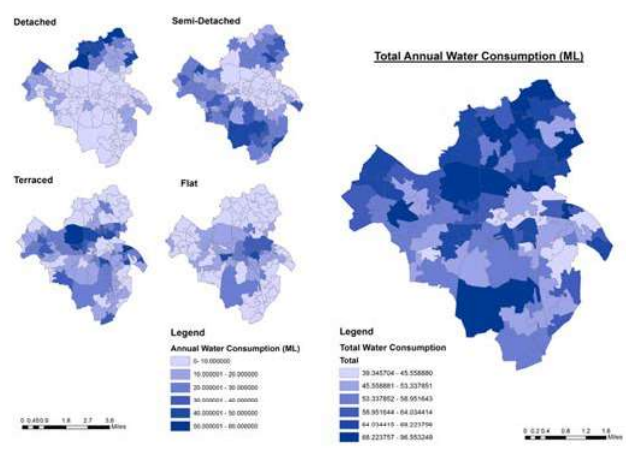

Figure 10.6 a) Water consumption per housing type (left), and b) Total annual water consumption (right) by LSOA (ML)

Waste

Flows of processed waste are included in the Exports category of MFA since there are no waste treatment plants located within Reading's administrative boundary and hence all waste is exported in other municipalities for treatment. These flows are the only export data obtained for the MFA; neither data on wastewater exported and treated outside Reading nor were estimates on exports of other (organic or inorganic) materials available. The municipality of Reading collected 3.06kt more waste in 2015 than in 2010. This can be assumed to be in response to population growth (ONS, 2017a) and the increased material consumption that comes with it. From 2010 to 2015, household waste sent for composting increased by 14% (from 9.8% to 10.8% of total household waste), household waste sent for energy recovery increased by 22% (from 37% to 43% of total household waste) and reusable waste increased (from 1.0% to 1.4% of total household waste). Despite these improvements in more sustainable waste flows, dry recycling decreased by 14% (by 24% to 20% of total household waste), casting doubt on the realisation of the recycling rates target of 42% by 2020 (RCCP, 2013).

Waste flows to landfill (households and non-households) are included in the Flows to Nature category since, differently from exports, no economic value is attached non-recycled waste following the MFA method (regardless if the landfill is located within or outside the town's boundary). The total amount of these flows also decreased by 2.12kt in this time, indicating a reduction on negative impacts to the environment resulting from hazardous landfill. On identification of the locations the waste is sent to and the distanced needed to transport waste to each of these locations (re3, 2016), it was calculated that emissions totalling 139.86tCO_2 was produced taking waste away from Reading. This creates a negative feedback effect that is extremely minimal in terms of the scale of the waste transported. Also, as the waste is transported outside the municipality, the majority of these emissions will be produced outside of Reading, reducing their visibility as a part of the metabolism of Reading.

Carbon

The carbon emission output flows accounted in ktCO_2in the Flows to Nature category (again, no economic value attached in MFA) are those produced from the fossil fuel flows described in the import category of the MFA. In terms of emissions from electricity, gas, diesel and petrol, these totalled 391.77 in 2010 and 363.12 in 2015 representing a reduction of 28.65 ktCO_2. In this time diesel was the only fossil fuel to increase its carbon emissions. Reading's target of reducing carbon emissions by 34% of 2005 levels by 2020 would mean emissions would equal 643.4 kt CO_2 (RCCP, 2013). According to the Department for Business, Energy & Industrial Strategy (GOV, 2015) the total emissions produced by all sectors of Reading's economy total 595.7 ktCO_2, indicating the Borough's carbon target has already been met. There is slight variation between total transport emissions in this publication and that of diesel and petrol in 2015 resulted from the MFA calculations, with the Department for Business, Energy & Industrial Strategy stating emissions of 114.8 ktCO_2 against 105.68 ktCO_2 in the MFA. This may be due to the inclusion in the MFA of emissions produced from other fuel types for transport such as biofuels.

Conclusion

In conclusion, despite the restriction of not being able to map certain flows, such as wastewater, the modified MFA still indicates the main flows within Reading. Even though water imports appear to dominate Reading's metabolism, it should be noted that the magnitude of water flows is systematically much higher than all other flows when the same mass metric (kton) is used, reason for which Eurostat (2001) recommends accounting for these flows separately. As for the Borough's sustainability targets, it is important to emphasise that locally generated renewable sources were only a small component of the MFA. However, there is scope for Reading Borough Council to increase local extraction in terms of renewables, especially biomass and solar. This could be a good policy when combined with efforts to improve energy efficiency, in a sustainable energy transition perspective. In addition, carbon emissions from domestic gas consumption have reduced, but this can be linked to a decrease in the heating demand (and related gas and electricity consumption) due to higher average daily winter temperatures in 2015. As waste was the only export recognised in this MFA is gives a partial indication of the exports within Reading. Besides Exports, lack of data on Imports of minerals and materials other than food (e.g. construction materials) as well as on other key flows such as wastewater (both from stormwater and drinking water) significantly limit the scope for calculating resource-use aggregate indicators such as DMI and DMC, which are one of the main added values of working with MFA. This points to the need for more complete datasets in order to yield meaningful results from an urban metabolism scan and unravels the data-availability challenges that characterise medium-sized cities compared to big cities (the latter representing the traditional focus of urban metabolism studies).

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