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Household recycling rates for plastic and wet organic waste in Norwegian municipalities – possible influence by sociodemographic, geographic and waste management properties.

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Abstract

With population growth and a huge increase in consumption over the last decades, waste has transitioned from being considered a problem to being considered a resource. To exploit this resource in the most efficient way possible, household recycling of plastic and wet organic waste plays an important role. There is still potential to increase recycling rates for both these waste fractions.

The main hypothesis of the study is as follows: Norwegian households' recycling rates of plastic and wet organic waste are expected to vary with differences in sociodemographic, geographic and waste management variables between the municipalities.

The study uses data collected from Statistics Norway's KOSTRA database. Stepwise multiple regression analyses were performed to analyze if there is a correlation between the different variables and the recycling rates for both waste fractions. The results indicate that some properties, such as the share of the population sent to recycling facilities, unemployment rate and the share of the population living in detached houses, correlate with the recycling rates. However, the goodness of fit of the models were quite low, and the properties only partly explain the variance in the recycling rates between municipalities.

Through the use of chi-square tests and t-tests it was found that some of the variables characterize the municipalities with the highest and lowest recycling rates, geographical region and annual number of collection days for wet organic waste. Chi-square tests were also applied for the annual waste management fee, and the most important result is that the relationship between a high fee and a high recycling rate is not an instinctive relation.

The results of the study can be used by local and national waste authorities, waste management companies and environmental organisations working with waste, to better adjust the recycling systems to the households' performance and requests. Understanding how the factors influences the rate, can help to find ways of increasing it.

Sammendrag

Over de siste tiårene, med befolkningsvekst og en stor økning i forbruket, har vi endret hvordan vi håndterer og betrakter avfall. Vi har gått fra å anse avfall som et problem til å anse det som en nyttig ressurs. For å kunne utnytte disse ressursene på den mest mulig effektiv måte, spiller kildesortering av plast og våtorganisk avfall i husholdninger en viktig rolle. Det er ennå store forskjeller i husholdningers kildesorteringsgrad mellom norske kommuner, og det er usikkerhet knyttet til hvorfor disse forskjellene eksisterer.

Hypotesen for studiet er som følger: Norske husholdningers kildesorteringsgrad for plast og våtorganisk avfall er forventet å variere med forskjeller i sosiodemografiske, geografiske og avfallstilknyttede variabler mellom norske kommuner.

Studiet tar i bruk data innsamlet fra Statistisk Sentralbyrås KOSTRA-database. Stegvise multiregresjonsanalyser ble gjennomført for å analysere om det var en sammenheng mellom de forskjellige variablene og resirkuleringsgraden for begge avfallsfraksjoner. Resultatene indikerer at noen av variablene, blant annet andel avfall sendt til materialgjenvinning, arbeidsledighet og andel av befolkningen som bor i eneboliger, korrelerer med kildesorteringsgradene. Modellen har imidlertid lav forklaringsstyrke og variablene forklarer derfor lite av variansen i grad av kildesortering mellom ulike kommuner.

Ved bruk av kji-kvadrattester og t-tester ble det også funnet at noen variabler, deriblant geografisk område og antall hentedager for våtorganisk avfall, kjennetegner de kommunene med høyeste og laveste kildesorteringsgrader. Kji-kvadrattester ble også utført for det årlige renovasjonsgebyret, og det viktigste funnet fra disse analysene var at sammenhengen mellom høyt gebyr og høy kildesorteringsgrad ikke er en selvfølgelig sammenheng.

Resultatene av studien kan brukes av nasjonale og lokale myndigheter, renovasjonsselskaper og miljøorganisasjoner som jobber med avfall, for å bedre tilpasse kildesorteringssystemene til husholdningenes behov og kildesorteringsinnsats.

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Definitions

Recycling rate	The recycling rate of a waste fraction is the percentage of the total amount of materials of the respective fraction that is recycled in the households in a year.
Virgin materials	Materials and raw materials that are exploited from nature to be used in technical systems.
Household plastic waste	Packaging waste consisting of different types of plastic collected from the households.
Household wet organic waste	Food waste and other organic waste generated collected from the households, excluded gardening waste.
Sociodemographic properties	Properties connected to demographic and social characteristics of a municipality's population. Examples are age, education and income.
Geographic properties	Properties connected to distribution and types of houses in a municipality, such as share of people in densely populated areas, population size and share of people living in row houses.
Waste management properties	Characteristics of the waste management system or collected household waste in a municipality.
KOSTRA database	KOmmune-Stat-RApportering. Statistics Norway's data base for Norwegian municipalities' and counties' annual operations.

Table of content

1 Introduction

Historically, waste has been seen mostly as a local problem of pollution and littering. Waste piling up in landfills, urban areas and nature is affecting land use, health and hygiene, as well as the natural environment. Waste disposed in landfills is also a source of methane – a greenhouse gas contributing to global warming. As the population and our consumption grew drastically from the middle of the 20th century, the problems of waste increased. It became evident that waste that was burnt or disposed in landfills was also a loss of valuable resources (European Environment Agency 2014). The need for a more resource effective solution for handling waste became urgent, and over the last couple of decades our take on the matter has shifted. Through obtaining more knowledge on the topic and developing technology to deal with the waste in new ways, our focus has changed into considering waste as a *resource*; something valuable to countries, organisations and people (Cambridge Dictionary 2017).

Reusing, recycling and remanufacturing these resources are fundamental actions of the circular economy. This is a new way of thinking and a new economic model in which the goal is to "*retain the highest utility and value of products, components and materials at all times.*" (European Parliament 2016). As opposed to linear economy, the circular economy focuses on getting a product or material from cradle to cradle, rather than just from cradle to grave (European Commission 2015). The cradle being the first extraction, processing or manufacturing of a raw material or product, and the grave being the landfill.

Among the main targets of the circular economy is the minimisation of waste sent to end-of-life treatment, for which we are seeing a transition in Europe where less waste is being sent to landfills (European Environment Agency 2014). Thus, we are saving both natural resources and energy associated with the extraction and manufacturing of new materials and products. Reuse of natural resources reduce physical impacts on the natural environment, and using less energy leads to a reduction of greenhouse gas (GHG) emissions, which is the main cause of climate change today. Preventing that more waste is generated by consuming less has the least negative impact on the environment is (Arnøy & Modahl 2014). However, when the waste is already generated, the least polluting alternative is to recycle as much as possible, thereby replacing and reducing the use of virgin materials (Raadal et al. 2016).

Figure 1. The concepts and movements of the circular economy (European Parliament 2015)

To specify an action plan for circular economy, the European Union has developed a program for circular economy that was presented in 2015, which is in the early stage of its implementation. Even though the countries in the union have reduced the amount of waste that goes to landfill, 2.5 billion tonnes of waste are still generated, 8 % of this being from household waste (European Parliament 2016). Therefore, waste management is an important part of the program. Particularly reduction of plastic waste is highly prioritised in the EU, due to the amount of plastic being disposed of. One of the goals in the circular economy package is to recycle 65 % of the household waste by 2030 (Klima- og miljødepartementet 2017).

Through the European Economic Area agreement, Norway is committed to the previously mentioned circular economy program and to the targets attached to it, being legally obliged to follow the union's framework directive for waste. In Norway, more than 80 % of all waste was material recycled or used for energy recovery in 2014 (Klima- og miljødepartementet 2017) and the overall household source sorting rate is relatively high (Raadal et al. 2016). However, there is still big potential for improvements. To reach the goal of 65% of household waste being recycled, several measures must be implemented.

In order to increase the recycling rates, a recycling system should be implemented for wet organic and/or plastic waste in the municipalities without access to one today. In addition, it is important to introduce new and improve existing instruments and measures to increase the household recycling rate in municipalities using such a system already. A systematic analysis of the different factors impacting recycling rates in Norwegian household can improve our understanding of the efficiency of different instruments in increasing the recycling rates.

This study compares Norwegian municipalities' recycling performance for wet organic and plastic waste in households, using a mean of actual data from 2014 to 2016. Sociodemographic and geographic properties as well as properties connected to the waste management are applied, in order to examine what variables creates differences in recycling rates. Knowledge about how sociodemographic factors can affect the achievements of a recycling program, will make it easier to make informed choices, set more realistic goals and customize programs to adapt and better respond to the population's efforts and requirements (Callan & Thomas 1997). The findings of this study can contribute to the knowledge base used by local and national waste management authorities when making decisions and implementing new waste management programs and instruments, or when improving existing ones.

This research has been a continuation and a unifying factor of the knowledge acquired during five and a half years of studies with a wide range of courses within economics and renewable energy. The background and main inspiration for the thesis was a report presented by Østfoldforskning, which looked into different instruments for improving different recycling rates in Norway (Raadal et al. 2016). The report found that increased collection and recycling rates, meaning the equipment and transportation logistics are used by a larger population, can increase the efficiency of the waste system.

In chapter 2 of this report the goals and research questions of the study will be presented. Chapter 3 goes on to give an overview of the previous research on the topic. Chapter 4 is a presentation of the data and the methodology used in the study, while chapter 5 shows the results of the analyses. A discussion of the results is found in chapter 6, and the conclusion and recommendations for further work is expressed in chapter 7.

2 Goal of the study and research questions

The main objective of the study is to analyse if sociodemographic and/or geographical properties of Norwegian municipalities can explain differences in recycling rates of plastic and wet organic waste in households. Similarly, to analyse if the recycling rates significantly correlate with the waste management properties of the municipality, such as the cost of recycling (the waste management fee) and number of collections of wet organic waste per year.

The hypothesis is stated as follows: Norwegian households' recycling rates of plastic and wet organic waste are expected to vary with differences in sociodemographic, geographic and waste management variables between the municipalities.

Based on the main objective and hypothesis, the following research questions were derived and aimed to be answered.

- **RQ1:** Which sociodemographic, geographic and waste management properties are explanatory for the municipalities in which the households have the 25 % highest and 25 % lowest recycling rate for plastic and wet organic waste, respectively?

- **RQ2:** Is the correlation between the level of the waste management fee and the performance level of recycling in the households significant, or is this fee more affected by properties characterizing the municipalities and their waste management system, e.g. the density of the municipalities, the mean income of the population, and the number of collection days for wet organic waste?

- **RQ3**: Which of the three independent categories of variables in the study, sociodemographic, geographic and waste management, have the strongest correlation with the households' recycling rate of plastic and wet organic waste?

3 State of the art

3.1 Significance of sociodemographic and/or geographic factors on the recycling rate

The results of previous research on the topic vary with regards to whether sociodemographic and/or geographic factors affect the recycling performance, or not. In this chapter, the studies are divided into whether these factors are statistically significant or not.

Folz and Hazlett (1991) were the first to study demographic and sociodemographic factors' importance in explaining variation in recycling performance and a waste program's success. They studied whether waste policies that stimulated high recycling rates in some places would lead to the same effects in places with other sociodemographic and geographic characteristics. The authors found that some sociodemographic factors were related to successful recycling programs, but did not account for the success in recycling rates. Consequently, they concluded that sociodemographic factors could be important in predicting which specific recycling program is preferable for a specific community, but not in determining the citizens' level of recycling performance with a recycling program.

Sidique et al. (2010) did a similar study for counties in Minnesota, USA, and like the previous study it did not find a significant relationship between the recycling rate and the sociodemographic factors. Among the factors studied were the inhabitants' income, population density, education and the cumulative effect of the cost connected to recycling and the variable pricing for waste disposal. The study found that variable pricing on waste disposal increases the recycling rate significantly. A mandatory recycling order and curbside recycling in combination with drop-off centers and education on recycling also had a positive effect on the recycling rate. They found no significant relationship between the population density and the recycling rate.

Callan and Thomas (1997) included sociodemographic variables like income, educational attainment and population density to isolate the role of policies. This way they could find the factors that were not in the hands of local officials, making them serve as central control variables in the model developed in the study. The results suggested that not only were income, education and urbanization statistically significant for the people's recycling effort, but also housing age, population size and community classification seemed to have an impact on households' performance in recycling.

In a study of Swedish municipalities the collection rate of plastic packaging was positively correlated with the unemployment rate, share of private houses, and the presence of immigrants in the municipality (Hage & Söderholm 2008). However, in the case of Norway, a high share of people owns their houses, and therefore the current study will not consider this variable. Also, municipal data on immigrants was not possible to find for the years of study in Norway, which is why this variable also was not included in the current study.

Another study where this category of factors proved relevant was by Starr and Nicolson (2015). They examined both context and program factors in relation to recycling rate in municipalities in Massachusetts. The three most relevant ones varied somewhat between the different time periods studied. In most time periods, however, age, education and whether the municipality had a Pay as You Throw (unit-based pricing) program were the most relevant properties. In only one of the time periods did the cost of the program have a significant impact on the recycling rate. Finally, they also found that on average, the policy variables explain a little more of the recycling rate than the contextual variables.

3.2 Importance of non-demographic factors

Folz (1999) examined the effects of program changes over time on recycling participation (within each specific type of recycling program) in the 1990s as a whole. For voluntary programs, as most are in Norway, cities with a near term recycling goal, free bins provided and assigned block leaders to encourage the inhabitants to recycle were the factors with the most successful results. Providing a metal and glass-waste fraction in the program, allowing the use of compost and a high participation rate were key factors for high recycling rates.

Folz and Hazlett (1991), found that factors such as education on recycling, specific recycling policies adopted to the area and how these were adopted significantly affected the recycling rates.

3.3 Qualitative studies

Some studies are based on more qualitative approaches, using interviews and surveys to determine the factors that could cause a program to be successful or not. One example is Xu et al. (2016), who used a mixed methods approach, with in-depth interviews of stakeholders in a successful food waste recycling project in Vietnam. Inhabitants with good relationships with the local government were perceived to perform better capture rates than others.

Another study examined how recycling in households in ten OECD countries is associated with intrinsic motivation and economic incentives using a behavioural regression model (Halvorsen 2010). One of the main findings of this study was that sociodemographic properties like income and people that have lived in their current home for a longer amount of time, people living in detached houses, and people living as couples were positively correlated with the level of recycling, while the number of people living in cities had a negative correlation with recycling effort.

3.4 The waste management fee

In a report on green household habits done for the OECD countries based on surveys, it was found that putting a unit price on the amount of delivered waste for the inhabitants would increase the amounts of sorted waste (OECD 2011). Similarly, a study by Callan and Thomas (1997) found that the recycling rate in their study objects increased when unit pricing was implemented. They also concluded that opportunity cost is an important determinant of the decisions made by people generating waste when choosing where to place their waste. Therefore, a policy that lowers opportunity cost and improves the convenience of recycling, should increase the recycling rates. The same should result of an increase in the relative cost of disposal, meaning the relative cost of recycling decreases.

As seen above, several studies have examined the waste management fee and how it affects the recycling performance of households. In Norway, there is typically a set annual fee paid by the households to the municipality. Raadal et al. (2016) also suggests that differentiating the prices can increase the recycling rate, to make it more economically lucrative to recycle. However, a differentiated price, also known as a unit-based pricing, can lead to more people dumping their residual waste in nature, burning it, or more contaminated waste fractions (Bel & Gradus 2016).

According to Raadal et al. (2016), the waste management operational cost and fee for the inhabitants are influenced more by the size and the location of the municipalities than the recycling rate of the municipalities. This is confirmed by Tchobanoglous et al. (1993), who found that the distance between the households and the recycling facility location can influence the cost of recycling participation, and thereby the recycling behaviour itself.

4 Data and methodology

4.1 About the KOSTRA data base

Data for this study were extracted from the Statistics Norway's (SSB) databank, of which the data on waste management properties were collected from the KOSTRA (KOmmune-STat-RApportering) data base. These data were combined with demographic and sociodemographic variables characterizing the municipalities, to study if and how these are related to and affect the recycling rate.

The KOSTRA data base includes information on municipalities' and counties' operation. It also gives information about the resource input, priorities and goal achievement in urban districts, municipalities and counties (SSB 2017c). This information provides a basis for analysis, planning and governing for local and national officials and other users, and serves as a basis to assess whether national goals are met.

KOSTRA is based on both the municipalities' own reporting to SSB, and information from other sources inside and outside of the statistical agency. The data are published on a yearly basis; first as an unedited version March 15th, followed by a possibility for the municipalities to correct errors in and shortage of reported data, before the revised numbers are published June 15th the same year.

4.2 The waste fractions

4.2.1 Introduction

The main study objects of the thesis were the recycling rate for plastic waste and wet organic waste from Norwegian households. They are analysed in separate analyses. A short description of the two waste fractions are presented in sections 4.2.2 and 4.2.3.

4.2.2 Wet organic waste

The term wet organic waste includes household food waste and waste from the food industry, such as the aquaculture and dairy industries (Miljødirektoratet 2015). The amount of wet organic waste has increased in Norway in the last decades. Looking at wet organic waste from Norwegian households, the total amount increased from 181 to 189 thousand metric tonnes from 2015 to 2016 (SSB 2017a). According to Hanssen et al. (2013) the average wet organic waste generated in Norwegian households was 78,8 kilograms per person in 2011, which is the average value used in this study.

The recycling rate for wet organic waste varies greatly between Norwegian municipalities, from 13 to 116% (numbers above 100 % caused by source of error, i.e. garden waste being included etc.) (Raadal et al. 2016). In 2014, 69 % of Norway's population lived in an area with access to a recycling system including a wet organic waste fraction. Out of these households, an average of 69 % of the total wet organic waste is recycled. Thus, there is potential for increasing the recycling rate, not only by implementing new recycling systems for wet organic waste, but also by improving the existing ones. The challenges met when calculating the recycling rate are explained in section 4.4.2.

4.2.3 Plastic waste

The plastic fraction in Norwegian households is packaging materials which includes bottles, bags, films, trays and cups, among others. According to Raadal et al. (2016), around 90 % of Norway's households live in municipalities which have the possibility of recycling plastic. This is done through one of three different systems; curbside (large plastic bags or bins), drop-off points where consumers bring their plastic waste, or in blue-colored bags that are sorted from bags with other colors in the facility (optibag system) (Grønt Punkt Norge 2017). The total amount of plastic packaging waste generated from Norwegian households was 97 856 tonnes in 2016, which corresponds to 18,7 kilos per inhabitant (SSB 2017b). This per capita number is used to calculate the recycling rate for each municipality in this study. Of the total, 25 % went to material recycling, while 73,7 % were used for energy recovery (Grønt Punkt Norge 2017).

Sorted plastic is collected from households by the municipality or an intermunicipal waste company and the company must yearly report to the Norwegian Environment Agency on their collection data (Grønt Punkt Norge 2017). The results from packaging optimization is reported through Næringslivets Emballasjeoptimeringskomité.

Both waste fractions studied in this thesis constitute an environmental problem if not treated properly. This problem can be reduced by treating as much as possible in material recycling facilities. When wet organic waste is sent to landfill it leads to air and soil contamination, as well as smells and attraction of rats and birds (Miljødirektoratet 2015). This potential contamination can lead to health problems in humans and a degradation of biodiversity in the local environment. Plastic waste is one of the present day's largest environmental problems, with much of it being disposable (in the sense that it is only used once), yet takes the nature hundreds of years to degrade. Raadal et al. (2016) point out that there is a bigger potential for improvement in the recycling rate for plastic than there is for wet organic waste in Norwegian households.

4.3 Accessing and preparing data

4.3.1 IBM SPSS Statistics

The data processing program chosen for the analysis is IBM SPSS Statistics, which is user-friendly and has a wide area of application in statistical analysis.

4.3.2 Missing data

Some of the variables in the data sets contain samples of missing data. In the SPSS program, these were set to -99, to ensure that the missing numbers did not interrupt the remaining data. When calculating the mean for the waste management fee per inhabitant, the cells with missing data were taken out of the equation, as to get realistic results for the municipalities that had -99 in only one or two of the years.

4.3.3 Delimitation of time

For most of the demographic and geographic variables, except the population, the values from the median year 2015 were applied to all the years, as these are factors that typically do not change significantly from one year to another. For the waste managment factors directly connected to the waste management, the mean values were calculated from the exact data from all the three years, to get the most accurate numbers when performing the analyses.

In the three years chosen for the study, 2014 through 2016, the numbers of municipalities and the borders between them have remained unchanged, which made the study simpler regarding homogeneity of the samples, calculating a mean for all the same municipalities.

4.4 The variables

4.4.1 Presenting all variables

The variables are presented in table of data below, with a brief presentation of the each of them. Then follows a more detailed description of the variables that needed more explaining.

Table 1. The variables included in the analyses

VARIABLE NAME	DEFINITION	SOURCE, YEAR	MEAN	STANDARD DEVIATION
Recycling rate	The recycling rate of a waste fraction is the percentage of the total amount of the respective fraction that is recycled.	SSB, t. 05458 and KOSTRA 10133. Calculated mean of all three years.	Plastic 36,46 %	Plastic: 21,91
			Wet organic: 47,62 %	Wet organic: 36,15
Population	Number of inhabitants, including the use of cabins in the municipality.	SSB, t. 05458. Calculated mean of all three years.	13626,66	40592,06
Age 25-40	Share of population aged 25 to 40 years.	SSB, t. 07459. Median year.	17,89 %	2,74
Age 59+	Share of population aged 60 years and above.	SSB, t. 07459. Median year.	25,77 %	4,60
Mean income	Mean income after taxes, in NOK.	SSB, t. 06944. Median year.	490286,49	50246,05
Share densely populated	Share of the inhabitants living in densely populated areas.	SSB, t. 05212. Median year.	54,08 %	27,15
Inhabitants per household	Average number of people per household in the municipality.	SSB, t. 09747. Median year.	2,25	0,14
Living alone	Share of inhabitants that live alone.	SSB, t. 06079. Median year.	16,06 %	2,93
Detached house	Share of inhabitants that live in a detached house.	SSB, t. 11509. Median year.	77,46 %	13,16
Duplex	Share of inhabitants that live in a duplex house.	SSB, t. 11509. Median year.	6,95 %	3,71
Row house	Share of inhabitants that live in a row house.	SSB, t. 11509. Median year.	5,95 %	4,98
Apartment building	Share of inhabitants that live in an apartment building.	SSB, t. 11509. Median year.	4,02 %	6,22
Basic education	Share of inhabitants that have basic education (13 years of schooling or less).	SSB, t. 09429. Median year.	75,15 %	5,99

Higher education	Share of inhabitants that have higher education (more than 13 years of schooling).	SSB, t. 09429. Median year.	23,88 %	5,97
Unemployment rate	The municipalities' rate of unemployment, for inhabitants aged 15-74.	SSB, t. 10540. Median year, month 11.	2,49 %	0,98
Waste management fee	Annual cost of the waste management paid from inhabitants to the municipality or the waste management company (NOK/inhabitant/year).	KOSTRA 05456. Calculated mean of all three years.	1224,23	494,09
Opportunities to change fee	The number of changes the inhabitants can make to their subscription that can change the level of their waste management fee.	KOSTRA 05456. Calculated mean of all three years.	3,65	16,00
Share of expenses to hire external services	Share of the total operational expenses that is used to buy external goods and services for waste management.	KOSTRA 10131. Calculated mean of all three years.	54,82 %	43,08
Household waste per inhabitant	Total amount of residual waste per person collected from household (tonnes).	KOSTRA 10133. Calculated mean of all three years.	0,44	0,08
Household waste to recycling	Share of the total waste collected from households that is sent to recycling.	KOSTRA 10133. Calculated mean of all three years.	82,13 %	4,27
Amount of plastic recycled	Amount of plastic waste that was sent to material recycling (tonnes).	KOSTRA 10133 Calculated mean of all three years.	79,80	217,18
Plastic collected per inhabitant*	Amount of plastic waste collected from households in the municipality (tonnes/inhabitant).	KOSTRA 10133. Every year, calculated mean.	0,007	0,007
Annual no. of collection days for wet organic waste	The number of days per year the container with wet organic waste is collected from the households.	KOSTRA 05456. Calculated mean of all three years.	34,73	13,88
Wet organic collected per inhabitant*	Amount of wet organic waste collected from households in the municipality (tonnes/inhabitant).	KOSTRA 10133. Every year, calculated mean.	0,037	0,029

* Variables that were used in the calculation of other variables.

Most of the variable values are given as a proportion of either a municipality's population or total waste of a fraction. It was found when interpreting the results of the regression analyses carried through with proportion values, that giving the data percentage values leads to the most intuitive way of interpreting the results. Therefore, percentage values are used in the regression analyses.

4.4.2 The recycling rate

The recycling rate of a waste fraction is the percentage of the total amount of materials of the respective fraction that is recycled in the households in a year. In this study, calculation of the recycling rate required using the amount of each waste fraction sorted and collected separately from the households. This is the plastic or wet organic waste sorted from the residual waste in the households, given in tonnes (from KOSTRA table no. 10133, columns named "utsortert plast/våtorganisk fra husholdningsavfall"). This value was divided by the number of inhabitants in the respective municipality, to get an amount per person for each waste fraction. Finally, to get the recycling rate, this per capita value was later divided by the average national number kilos of plastic and wet organic waste per person, respectively.

This way of calculating the recycling rate does give a somewhat misleading value, with some cases exceeding 100 %. This should be kept in mind when reading the results, but because the municipalities are calculated similarly, they are compared based on the same national values, which was the most important for this study.

The recycling rate is a widely used indicator for decision makers when assessing the efficiency of recycling and waste management programs on regional and national levels (Sidique et al. 2010). The recycling rate of a waste fraction is the percentage of the total amount of the respective fraction that is sent to material recycling. As an indicator, the recycling rate is both informative and flexible, as it gives the possibility of observing the changes in amounts of both recycling *and* the general waste generation (Sidique et al. 2010). Critics of the use of recycling rate as an indicator claim that it does not capture the cumulative decrease in total waste generation that some areas experience (Starr & Nicolson 2015). For example, plastic packaging amount might decrease for several reasons, which results in a relative decrease in amount of plastic recycle. However, the recycling rate will not capture that this is caused by a decrease in plastic consumption, and not a decrease in recycling efforts. Nonetheless, because the recycling rate is as informative as it is, it was the most fitting indicator to use for this study.

4.4.3 Population

For the calculation of the number of inhabitants in the municipalities, the term *year's inhabitant* was applied. This value includes the quantity of permanent inhabitants in the municipality as well as the use of cabins to get the most accurate number of people using the waste management systems, using the following formula:

*(Number of inhabitants) + (Number of cabin subscribers * 4people/cabin * 30 days of use/365 days a year)*

4.4.4 Geographical regions

Norway has five main regions, and for the chi-square analyses in sections 5.1 and 0, these five regions are used as categories.

Table 2. Regions of Norway (Wikipedia 2017)

REGION	POPULATION (April 1st 2013)	NUMBER OF COUNTIES	COUNTIES
Northern Norway	475 507	3	Finnmark, Troms, Nordland
Trøndelag	438 241	2	Nord-Trøndelag and Sør-Trøndelag
Western Norway	1 322 218	4	Møre og Romsdal, Sogn og Fjordane, Hordaland and Rogaland
Eastern Norway	2 538 156	8	Østfold, Akershus, Oslo, Oppland, Hedmark, Buskerud, Vestfold, Telemark
Southern Norway	289 587	2	Vest-Agder and Aust-Agder

4.4.5 Share of expenses to hire external services

This variable was divided into three categories, based on its value using the frequency distribution, and assumptions of what the different levels implies follow. The municipalities with a share of expenses of 0 % to 10 % were assumed to not buy any external services. The next level of municipalities, with values ranging from 10 % to 60 %, were assumed to only buy treatment from external actors. Lastly, the cases with a share of more than 60 %, were assumed to buy both waste collection and waste treatment from external actors.

4.5 Analytical methodology

4.5.1 Introduction

Multiple regression analysis, Pearson's chi-square test and independent t-test were all used to reject or confirm the hypothesis and answer the research questions. The analyses were all performed in SPSS, following the steps explained by Field (2009). Each of the steps of the analyses were performed identically for plastic and wet organic waste fractions, unless otherwise specified.

4.5.2 Multiple Regression Analysis

To test the hypothesis of the study, a multiple regression analysis of the recycling rate as dependent variable was conducted, with the sociodemographic, geographic and waste management variables as independent sets of variables. A multiple regression analysis is a linear model with which one can predict an outcome (dependent) variable from a combination of two or more predictor (independent) variables (Field 2009). As this study does several different analyses, a simpler version of multiple regression analysis was used, a linear one.

In general, a regression model can be expressed as:

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon_i$$

in which Y is the dependent variable, the x's represent the value of the independent variables, β_0 is the constant and β_i's are the regression coefficients and indicates how much the Y_i

changes when the value of x_i increases by one unit. The ε_i is the residual term, and represents the difference between the score predicted by the line for participant (municipality) and the score that the same participant actually scored (Field 2009).

A stepwise multiple regression model was chosen. This is a method where the statistical program enters the predictor variables into the model in an order based on a mathematical criterion. Every time a new variable is entered, the program does a performance test of the predictor variable that is least explanatory for the variance in the dependent variable. The results are then ranked in the order that they were entered into the model, identifying the most explanatory variables.

The p-value was used as the predictor value of whether the results are significant or not, and a significance level of 0,05 was applied. The goodness of fit of the regression model is indicated by the criteria R^2 (R squared) and R^2_a (adjusted R squared) to see how much of the outcome is in fact explained in the model (Field 2009). In other words, R^2_a indicates how well the model generalizes. The R^2 indicates how much the regression model contributes to the variance of the Y-value determined in the model of the specific sample, while the R^2_a gives an indication of how much of the variance in Y is accounted for by the model for another sample in the same model. Both criteria take a value between 0 and 1 and the higher the value, the better the fit of the model.

One of the assumptions of regression analysis is normal distribution for the included variables. As the data sets were quite large, this is a reasonable assumption, but it was checked for in SPSS using the *Frequencies* function. Some of the variables were not normally distributed. However, when checked for in a p-p plot, it is evident that many of the factors do have a clear tendency towards a normal distribution, meaning that they follow the normal distribution line quite accurately.

For the variables that had the most diverging distribution, a square-root transformation was performed, which seemed to help to some extent. The proportional variables with non-normal distributions requires other types of handling, and an arcsine transformation was done, a common method of transforming proportion data (University of Colorado Boulder 2006).

Another reason for transforming some of the predictor variables to make them more applicable in the regression analysis, was that three of them had a relatively high standard deviation value; population, share of population living in apartments, and the number of opportunities of changing the waste management fee. This was fixed through a square-root transformation for the population and opportunity variables while the apartment value was fixed through an arcsine-transformation. This has been performed in similar research as well. In Callan and Thomas (1997), squared terms for population and the education were used to capture nonlinearities in the effects of these variables on the recycling effort. When the transformed variables were entered in the regression models, however, the goodness of fit (R^2 and R^2_a) did only increase a little, or not at all. Therefore, the regressions with transformed variables are not included in the report, to simplify the results and interpretation of them.

The variables were also checked for correlation and the significance of this, with a significance level of 0,05. It turned out, as could be expected, that the correlation of some variables was relatively high, leading to a problem of multicollinearity in the regression analysis. However, it was concluded that in the stepwise regression analysis, two variables with high correlation will not be selected for in the model simultaneously.

Another set of regression analyses was performed to answer research question three. In these analyses, the variables were split into three categories; sociodemographic, geographic and properties that are connected to waste management. The results for these analyses are presented in section 0 of this report.

4.5.3 Pearson's Chi-square Test

This step was taken to answer the first research question: "What characterizes the municipalities with a high recycling rate, and the ones with the lowest one, and how big is the difference between the two groups?". Several Pearson's chi-square analyses were performed to find whether the municipalities with the highest and the lowest recycling rates had some characteristics that could explain why they ended up in their respective end of the scale. This is a common analysis used to check whether two categorical variables are related or not (Field 2009). The municipalities where split into quartiles and the ones with the 25 % highest and 25 % lowest (highest and lowest quartiles) recycling rates were analyzed in the chi-square test.

The test does not rely on the assumption of normal distribution of the data, which makes it a relatively robust test if there are enough samples, which was the case in this study. The assumptions of the Pearson's chi-square test, which were both met in this study, are:

- Independence of data
- Expected number of observations in each cell is greater than 5

To perform the analysis, the *Crosstabs* function in SPSS was used. This function generates a matrix between two categorical variables and carries through a chi-square test to check whether the two variables are associated (Field 2009). Seven different variables were chosen to run through the analysis to check their relationship with the recycling rate. These were selected on basis of which categories were naturally divided into categories. For both waste fractions the population size, income mean, share of population living in densely populated areas, the geographical area of the municipality and the annual waste management fee level per person were selected. In addition, the test was performed for the number of collection days per year with the recycling rate of wet organic waste, and for the amount of plastic sent to material recycling (in tonnes) with the recycling rate for plastic.

When there are more than 2*2 squares in the matrix of a chi-square test, we operate with the indicator value Cramer's V to evaluate the strength of the relationship between the two variables in the test. This indicator takes a value between 0 and 1. A Cramer's V value of 0,1 to 0,3 indicates a weak relationship, while a value between 0,3 and 0,5 reveals a moderate relationship and a Cramer's V value above 0,5 indicates a strong relationship (Fort Collins Science Center 2017). Finally, a significance level of 0,05 was chosen in this analysis as well.

The Pearson's chi-square test was also used to answer research question number two. To study what factors impact the waste management fee, chi-square tests were performed for the highest and lowest level of the fee and a selection of the other variables in the study.

4.5.4 Independent t-test

Further on, testing for association between the highest and lowest levels of recycling rate and the remaining variables that were not included in the chi-square test, was done through an independent t-test. The t-test was used to examine if the mean of two groups differed significantly from one another or not. Because in this study the variables are selected from two independent samples, an independent t-test was performed (Field 2009). The assumptions of this analysis are the following:

- The differences between the sample scores are normally distributed.
- Data are measured at the interval level (at least)
- Variances in the populations are close to equal
- The scores are independent of each other

The hypothesis for the t-test is as follows:

$$H_0: \mu_0 = 0$$
$$H_1: \mu_0 \neq 0$$

The null-hypothesis implies that the means of the two samples are the same. Thus, it is rejected if the means of the two samples do differ, meaning there *is* an association between the two variables. In other words, if a variable has a statistically significant result, we can assume that there is a relationship between the respective variable and whether the municipality ends up in the top or bottom quartile of recycling rate. The significance level is, as before, set to 0,05.

5 Results

5.1 Relationship between selected municipality properties and the highest and lowest levels of recycling rate

5.1.1 Plastic waste

Of the six variables selected for the chi-square test for plastic recycling rate, four variables showed a statistically significant test result; mean income, population, amount of plastic sent to recycling facilities (in tonnes) and the geographical region, all shown in Table 3. In the table, the municipalities with the highest and lowest recycling rates are distributed between the two levels. To show the distribution of each category, two percentage values that add up to a 100 % are given for every category within each analysed variable. The two medium recycling rate quartiles, medium low and medium high, are excluded from the analysis.

The column named “share of total” shows the percentage of the municipalities represented by the category in the respective row. This column is included to show how representative the chi-square results for each category are. A low percentage means that many of the municipalities in the respective category is in the two middle quartiles of recycling rate.

Table 3. Properties associated with lowest and highest recycling rates for plastic waste.*

PROPERTIES	RECYCLING RATE (PLASTIC)			CHI-SQUARE TEST RESULTS			
	Lowest	Highest	Share of total	Df	χ2	P	Cramer's V
WASTE MANAGEMENT FEE (NOK/YEAR)				**4**	**34,186**	**0,000**	**0,403**
≤ 820	46,20 %	53,80 %	12,30 %				
820 - 999	15,00 %	85,00 %	19,00 %				
999 - 1236	41,00 %	59,00 %	18,50 %				
1236 - 1523	62,50 %	37,50 %	26,50 %				
1523 +	72,00 %	28,00 %	23,70 %				
POPULATION				**2**	**11,889**	**0,000**	**0,236**
0-15000	54,20 %	45,80 %	83,64 %				
15001-50000	20,70 %	79,30 %	13,55 %				
500001-100000	66,70 %	33,30 %	2,80 %				
100000+			0 %				
DENSELY POPULATED AREAS				2	4,860	0,088	0,151
low density	46,30 %	53,80 %	37,38 %				
medium density	60,30 %	39,70 %	34,11 %				
high density	42,60 %	57,40 %	28,51 %				
MEAN INCOME				3	1,748	0,626	0,090
low	54,2 %	45,80 %	22,43 %				
medium low	43,3 %	56,70 %	28,04 %				
medium high	50,00 %	50,00 %	28,04 %				
high	45,30 %	45,70 %	21,50 %				
AMOUNT OF PLASTIC RECYCLED (tonnes/year)				**4**	**105,05**	**0,000**	**0,367**
≤ 7,67	95,30 %	4,70 %	29,90 %				
7,67 - 22,01	65,00 %	35,00 %	18,70 %				
22,001 - 39,67	32,40 %	67,60 %	15,90 %				
39,67 - 101,00	16,10 %	83,90 %	14,50 %				
101,00+	8,90 %	91,10 %	21,00 %				
GEOGRAPHICAL REGION				**4**	**49,497**	**0,000**	**0,481**
Eastern Norway	31,00 %	69,00 %	39,25 %				
Southern Norway	31,60 %	68,40 %	8,88 %				
Western Norway	40,50 %	59,50 %	19,62 %				
Trøndelag	100,00 %	0,00 %	4,67 %				
Northern Norway	81,40 %	18,60 %	27,57 %				

*Significant results are typed in bold

The share of the population living in densely populated areas and the population's mean income were not found to be significantly associated with the highest or lowest plastic recycling rate.

The level of the waste management fee was one of the variables related to the plastic recycling rate levels ($\chi 2$-value=105,046, ($\chi 2>1$)). It is a moderate to strong relationship between the two (Cramer's V=0,403), and the tendency is that the highest levels of the fees are related to a low recycling rate (72 %). The fee level with the highest level of representation in the municipalities with the highest recycling rate is the second lowest level, namely from 820 to 999 NOK per inhabitant.

The amount of plastic sent to material recycling facilities also showed a significant association with the highest and lowest recycling rates, though with a moderate relationship strength (Cramer's V > 0,300). A low total tonnage of plastic waste sent to recycling is associated with a low recycling rate. An explanation for this can be that many of the municipalities that have no sorted plastic fraction (which means they have a plastic recycling rate of zero), are in the category of lowest quartile. These municipalities will in most cases not have any plastic sent to material recycling. In other words, the connection between the two variables (is direct and) could be expected.

Population size of the municipalities is also significantly associated with the level of recycling rate for plastic. This variable also had a relatively weak relationship with the recycling rate (Cramer's V = 0,236), but the significance level of p=0,000 indicates a clearly significant result. The smaller municipalities are relatively evenly distributed in the two quartiles of recycling rates. The medium sized municipalities, however, are heavily represented in the highest recycling rate quartile (79,3 %).

The property with the strongest relationship with the level of recycling rate for plastic was the geographical area in which the municipality is placed (Cramer's V = 0,481). The tendency for this characteristic is that the municipalities in the southern counties are more represented in the municipalities with the 25 % highest recycling rates for plastic, while the counties in Trøndelag and Northern Norway are more represented in the 25 % lowest recycling rates.

5.1.2 Wet organic waste

As seen in the results presented in Table 4, only two of the six tested properties had a statistically significant association with the recycling rate for wet organic waste.

Table 4. Properties associated with lowest and highest recycling rates for wet organic waste*

PROPERTIES	RECYCLING RATE (WET ORGANIC)			CHI-SQUARE TEST RESULTS			
	Lowest	Highest	Share of total	Df	χ2	p	Cramer's V
WASTE MANAGEMENT FEE (NOK/YEAR)				4	2,312	0,679	0,105
≤ 820	54,00 %	46,00 %	24,04 %				
820 - 999	52,10 %	48,90 %	21,64 %				
999 - 1236	39,50 %	60,50 %	20,67 %				
1236 - 1523	52,60 %	47,40 %	18,27 %				
1523+	50,00 %	50,00 %	15,39 %				
POPULATION				3	2,177	0,537	0,101
0-15000	48,50 %	51,50 %	78,97 %				
15001-50000	51,40 %	48,60 %	16,36 %				
500001-100000	80,00 %	20,00 %	2,34 %				
100000+	60,00 %	40,00 %	2,34 %				
MEAN INCOME				3	2,018	0,569	0,097
low	51,90 %	48,10 %	25,23 %				
medium low	48,10 %	51,90 %	24,30 %				
medium high	42,20 %	57,80 %	21,03 %				
high	55,60 %	44,40 %	29,44 %				
DENSELY POPULATED AREAS				2	1,293	0,524	0,078
low density	52,80 %	47,20 %	33,65 %				
medium density	44,90 %	55,10 %	36,49 %				
high density	53,10 %	46,90 %	29,91 %				
ANNUAL NO. OF COLLECTION DAYS FOR WET ORGANIC WASTE				**2**	**7,065**	**0,029**	**0,182**
≤ 26 days	42,60 %	57,40 %	76,64 %				
27-37 days	60,00 %	40,00 %	21,02 %				
37 days+	61,70 %	38,30 %	2,34 %				
GEOGRAPHICAL REGION				**4**	**11,700**	**0,020**	**0,234**
Eastern Norway	58,20 %	41,80 %	31,31 %				
Southern Norway	18,20 %	81,8 %	5,14 %				
Western Norway	49,40 %	50,60 %	36,92 %				
Trøndelag	61,30 %	38,70 %	14,49 %				
Northern Norway	30,80 %	69,20 %	12,15 %				

*Significant results are typed in bold

The annual number of collection days was one of the factors associated with the recycling rate for wet organic waste ($\chi2=7{,}065$ and $p=0{,}029$). However, it is evident that the significant association strength is low (Cramer's V=0,182). A low number of collections per year is related to a higher recycling rate (57,40 %), while a medium and higher number of collections is related to a lower recycling rate (60 % and 61,7 % respectively) of the wet organic waste.

Geographical region is also related to the level of recycling for wet organic waste ($\chi2=7{,}065$ and $p=0{,}029$). For this waste fraction, Eastern Norway and Trøndelag have a higher proportion of cases in the lowest recycling rate quartile (58,2 % and 61,3 % respectively). Municipalities in Southern and Northern Norway, on the other hand, have far more municipalities in the higher quartile than the lowest (81,8 % and 69,2 % respectively), while Western Norway is closed to evenly distributed between the two.

5.1.3 Significance of difference in means between highest and lowest quartiles of recycling rates

In the independent t-test, ten variables were significantly related to the plastic recycling rate results in the t-test ($p<0{,}05$), shown in Table 5. These could all be explanatory properties for which municipalities end up in the quartiles with the highest and lowest recycling rates of plastic. Six of the variables are sociodemographic properties of the municipalities.

For the wet organic dataset, eight variables were statistically significant and the null hypothesis of an equality of means can be thrown for these. The main difference from the results of the t-test for plastic recycling rate is the overweight of geographic properties. Of the sociodemographic properties, only unemployment rate is not significantly correlated with the highest and lowest recycling rates of wet organic waste.

Table 5. Mean difference between of highest and lowest recycling rates*

PROPERTIES	INDEPENDENT T-TEST RESULTS			
	t-value	**Df**	**p**	**Mean difference between highest and lowest quartile**
PLASTIC WASTE				
Age 25 to 40	-2,487	203,4	**0,014**	-0,008
Age 59+	3,160	212	**0,002**	0,018
Living alone	3,920	195,5	**0,000**	0,015
Inhabitants per household	-2,306	212	**0,022**	-0,042
Detached houses	1,416	212	0,158	0,021
Duplex houses	-0,707	202,56	0,480	-0,004
Row houses	-1,515	212	0,131	-0,009
Apartment buildings	-2,412	200	**0,017**	-0,014
Basic education	2,002	212	**0,047**	0,014
Higher education	-2,069	212	**0,040**	-0,014
Unemployment rate	1,317	170,2	0,189	0,002
Share of expenses to hire external services	3,736	195,9	**0,000**	0,216
Opportunities	0,374	212	0,709	0,988
Household waste per inhabitant	-4,767	211	**0,000**	-0,059
Household waste to recycling	-5,149	209	**0,000**	-0,031
WET ORGANIC WASTE				
Age 25 to 40	0,066	212	0,948	0,000
Age 59+	-0,077	212	0,939	-0,000
Living alone	1,472	212	0,143	0,006
Inhabitants per household	-0,014	212	0,989	-0,000
Detached Houses	-7,215	151	**0,000**	-0,117
Duplex Houses	4,957	204	**0,000**	0,025
Row Houses	6,658	157	**0,000**	0,043
Apartment buildings	4,897	134	**0,000**	0,036
Basic education	-0,135	212	0,983	-0,001
Higher education	0,126	212	0,900	0,001
Unemployment rate	3,659	212	**0,000**	0,006
Share of expenses to hire external services	2,489	188	**0,014**	0,153
Opportunities	0,998	212	0,319	2,642
Household waste per inhabitant	1,022	192	**0,308**	0,012
Household waste to recycling	-8,403	210	**0,000**	-0,041

*Significant results are typed in bold.

5.2 Exploring properties explaining the difference in recycling levels

5.2.1 Plastic waste

Three predictor variables have a statistically significant impact on the plastic recycling rate in households (Table 6). The mass of household waste per inhabitant (β=0,340) and share of the household waste in total sent to material recycling (β=0,286) both have a positive impact on the plastic recycling rate. The beta values for these two indicate how many percent the recycling rate will increase if the share of waste to recycling treatment increases one percent or the amount of total household waste increases with one tonne. In other words, a tonne increase in the total waste per inhabitant will give an increase in the recycling rate for plastic of 0,34 %, ceteris paribus. Likewise, a 1 % increase in the share of waste sent to recycling will give a 0,286 % increase in the recycling rate for plastic waste. These values are averages for all municipalities. The waste management fee correlates negatively with the recycling rate; the higher the fee, the less of the total plastic waste will be recycled. When the waste management fee in a municipality increases by 1 NOK, the recycling rate for plastic waste decreases by 0,121 %.

Table 6. Properties potentially impacting the plastic waste recycling rate*

INDEPENDENT VARIABLE	COEFFICIENT (β)	SIGNIFICANCE LEVEL (p)	RANK IN STEPWISE REGRESSION MODEL
Population	0,009	0,841	
Age 25-40	0,035	0,476	
Age 59+	-0,057	0,255	
Mean income	-0.019	0,698	
Densely populated areas	-0,013	0,787	
Inhabitants per household	0,015	0,756	
Living alone	-0,061	0,219	
Detached houses	0,029	0,550	
Duplex houses	-0,067	0,154	
Row houses	-0,014	0,768	
Apartment buildings	0,004	0,930	
Basic level of education	0,038	0,425	
Higher level of education	-0,034	0,472	
Unemployment rate	-0,033	0,481	
Share of expenses to hire external services	-0,059	0,214	
Waste management fee	-0,121	**0,011**	3
Opportunities	-0,020	0,664	
Household waste per inhabitant	0,340	**0,000**	1
Household waste to recycling	0,286	**0,000**	2

*Significant results are typed in bold

The multiple regression model for the plastic waste recycling rate can be expressed by the following equation:

$$recyclingrate_p = \beta_0 + 0{,}340 w_{inhb} + 0{,}286 w_{recy} + -0{,}121 fee + \varepsilon$$

The goodness of fit predictors for the model indicate a relatively weak association between recycling rate and the three predictor variables (R^2 = 0,224 and R^2_a= 0,217) and the model is not specifically explanatory for the household recycling level of plastic in Norwegian municipalities, but is still the most explanatory of the models in the study. However, the results of the model indicate a clear tendency of waste management properties explaining more of the recycling rate than both geographic and sociodemographic properties of Norwegian municipalities. A possible explanation for this is that waste per inhabitant and total waste to recycling are closely tied to how long the municipality have had a recycling fraction for plastic. This time variable is, however, is not included in this study.

5.2.2 Wet organic waste

Four variables influenced the wet organic recycling rate significantly (Table 7), three of them positively and one negatively. First, municipalities with high shares of waste going to recycling in general have higher recycling rates for their wet organic waste fraction in households (β=0,390). An increase of one percent in the share of waste sent to recycling facilities will increase the recycling rate for wet organic waste with 0,39 %. The unemployment rate was the second variable entered into the model (β=0,176), and a 1 % increase in unemployment will lead to a 0,176 % increase in the recycling rate. Thirdly, a high share of population living in detached houses (β=0,145), is related to a high recycling rate for wet organic waste, with a one percent increase in giving 0,145 % increase in the outcome variable. Municipalities with a high number of collection days for wet organic waste will, on the other hand, have a negative effect on the recycling rate for wet organic waste. In theory, increasing the number of collection days by one day will decrease the recycling rate for wet organic waste by 0,111 %.

Table 7. Properties impacting the wet organic waste recycling rate*

INDEPENDENT FACTOR	COEFFICIENT (β)	SIGNIFICANCE LEVEL (p)	RANK IN STEPWISE REGRESSION MODEL
Population	0,034	0,555	
Age 25-40	0,064	0,275	
Age 59+	-0,057	0,308	
Mean income	-0,002	0,961	
Densely populated areas	0,116	0,105	
Inhabitants per household	-0,025	0,600	
Living alone	0,025	0,608	
Detached houses	0,145	**0,003**	3
Duplex houses	-0,020	0,765	
Row houses	-0,054	0,562	
Apartment buildings	0,129	0,168	
Basic level of education	-0,046	0,490	
Higher level of education	0,045	0,499	
Unemployment rate	0,176	**0,000**	2
Share of expenses to hire external services	-0,083	0,090	
Waste management fee	0,088	0,078	
Opportunities	-0,070	0,140	
Household waste per inhabitant	0,050	0,287	
Household waste to recycling	0,390	**0,000**	1
Annual no. of collection days for wet organic waste	-0,111	**0,022**	4

*Significant results are typed in bold

The resulting multiple regression model from the analysis can be expressed through the following equation:

$$recyclingrate_{wo} = \beta_0 + 0{,}390 w_{recy} + 0{,}176 unemp + 0{,}145 detached - 0{,}111 days + \varepsilon$$

The goodness of fit predictors for this model, R^2 = 0,191 and R^2_a= 0,182 are even lower than that of recycling rate for plastic waste, indicating that less of the variance in recycling rate for wet organic waste is explained by the regression model.

5.3 Which category of properties has the strongest correlation with the recycling rates?

5.3.1 Plastic waste

Three of the socioeconomic variables were significantly correlated with the plastic recycling rate; the share of the total population living alone, number of people per household and share of the population aged above 59 are all negatively correlated with the recycling rate (

Table 8). This separate model gives a lower goodness of fit than the main model where all variables were included, with $R^2 = 0{,}043$ and $R^2_a = 0{,}036$. Municipalities with a high share of the population living alone or above 59, or with a high number of people per household, are likely to have a lower recycling rate for plastic than municipalities with lower shares or values, ceteris paribus. The share of people living alone has the biggest effect of the three, and a 1 % increase in this share will give a 0,436 % decrease in the plastic recycling rate.

Table 8. Sociodemographic properties' impact on plastic waste recycling rate*

INDEPENDENT FACTOR	COEFFICIENT (β)	SIGNIFICANCE LEVEL (p)	RANK
Age 25-40	0,049	0,619	
Age 59+	-0,128	**0,029**	3
Mean income	-0,180	0,060	
People per household	-0,436	**0,004**	2
Living alone	-0,481	**0,001**	1
Basic level of education	0,105	0,073	
Higher level of education	-0,100	0,089	
Unemployment rate	0,015	0,769	

*Significant results are typed in bold

There was no significant correlation between the geographical factors and the plastic recycling rate (Table 9). Consequently, no regression model was generated. For this reason, the correlation matrix of those properties was included to show the non-significance. For all six variables, p > 0,05 which means there is no statistically significant correlation between the geographic variables and the recycling rate for plastic. This was expected as none of these variables had significant results were significantly related to the recycling rates in the regression analysis.

Table 9. Correlation coefficients for geographical properties and plastic waste recycling rate*

INDEPENDENT VARIABLES	PEARSON CORRELATION COEFFICIENT	SIGNIFICANCE LEVEL (p)
Population	0,008	0,435
Densely share	0,021	0,332
Detached houses	-0,009	0,429
Duplex houses	0,020	0,341
Row houses	0,020	0,342
Apartment building	0,031	0,263

The waste management properties regression model has the same goodness of fit as the main regression model for the plastic recycling rate (R^2 = 0,224 and R^2_a = 0,217), with the same three variables being correlated with the plastic recycling rate (Table 10). They also have the same beta values as in the main model, implying that they have the same impact on the recycling rate for plastic.

Table 10. Waste management properties' impact on plastic waste recycling rate*

INDEPENDENT VARIABLES	COEFFICIENT (β)	SIGNIFICANCE LEVEL (p)	RANK IN STEPWISE REGRESSION MODEL
Household waste to recycling	0,286	**0,000**	2
Household waste per inhabitant	0,340	**0,000**	1
Opportunities	-0,020	0,664	
Share of expenses to hire external services	-0,059	0,214	
Annual waste management fee	-0,121	**0,011**	3

*Significant results are typed in bold

These results confirm the results from the main model of the study, in that the waste management properties explain more of the variation in the recycling rate for plastic than both the geographic and demographic properties.

5.3.2 Wet organic waste

For the separate regression analyses of the wet organic waste fraction, the results are relatively different from the findings in section 5.2.2.

None of the sociodemographic properties proved to be significantly related to the wet organic recycling rate, and these variables are presented in a correlation coefficient matrix (Table 11). These results contrasts with the unemployment rate being significantly impacting the recycling rate in the main regression for wet organic waste. This can be explained by the fact that in regression models all independent variables affect each other, and thus the results can differ, depending on which variables are included.

Table 11. Correlation coefficients for sociodemographic properties and wet organic waste recycling rate

INDEPENDENT VARIABLES	PEARSON CORRELATION COEFFICIENT	SIGNIFICANCE LEVEL (p)
Age 25-40	0,017	0,360
Age 59+	-0,023	0,318
Mean income	0,029	0,275
People per household	0,010	0,417
Living alone	-0,024	0,309
Basic level of education	0,008	0,431
Higher level of education	-0,008	0,438
Unemployment rate	0,068	0,081

The separate model for geographic properties, with a goodness of fit R^2 = 0,046 and R^2_a = 0,039 are resented in Table 12. Three geographic properties have significant results. The share of the population living in densely populated areas impacts the recycling rate positively (β=0,272), while the share of people living in detached duplex (β=-0,166) and row houses (β=-0,187), both have a negative correlation with the recycling rate. The share of people living in detached houses, which was the one of the variables included in the main model in section 5.2.2, was not statistically significant in this separate analysis (p=0,496).

Table 12. Geographic properties' impact on recycling rate for wet organic waste*

INDEPENDENT FACTOR	COEFFICIENT (β)	SIGNIFICANCE LEVEL (p)	RANK IN STEPWISE REGRESSION MODEL
Population	-0,020	0,701	
Densely populated areas	0,272	**0,000**	2
Detached houses	0,071	0,496	
Duplex houses	-0,166	**0,005**	1
Row houses	-0,187	**0,013**	3
Apartment buildings	0,049	0,470	

*Significant results are typed in bold

Like for the plastic recycling rate, waste management properties seem to explain the most of the variance in the recycling rate for wet organic waste (R^2 = 0,172 and R^2_a = 0,163), shown in Table 13. An interesting result from this separate analysis is that the waste management fee has a positive correlation with the recycling rate. This is in contrast to the results for the plastic waste recycling rate. The share of a municipality's waste management expenses being spent on external services is negatively correlated with the recycling rate for wet organic waste. This indicates that a higher expenditure on external services, can give a lower recycling rate for wet organic waste.

Table 13. Waste management properties' impact on recycling rate for wet organic waste*

INDEPENDENT FACTOR	COEFFICIENT (β)	SIGNIFICANCE LEVEL (p)	RANK IN STEPWISE REGRESSIN MODEL
Opportunities	-0,074	0,122	
Annual no. of collection days for wet organic waste	-0,087	**0,082**	2
Share of expenses to hire external services	-0,107	**0,033**	4
Waste management fee	0,125	**0,011**	3
Household waste per inhabitant	0,027	0,582	
Household waste to recycling	0,390	**0,000**	1

*Significant results are typed in bold

5.4 Which properties explain differences in the level of waste management fee?

Mean income of inhabitants, the share of population in densely populated areas, the number of collection days for wet organic waste and the geographical region in which the municipality is situated, are all variables associated with a municipality's level of the waste management fee (Table 14).

Mean income after taxes has a moderate to strong relation to the waste management fee level (Cramer's V = 0,416). Municipalities with a low income mean, tends to have a high waste management fee (74,1 %). For the municipalities with a high income, we see the opposite, with 80,4 % being among the lowest level of waste management fee. For the two middle levels of income, the municipalities are more equally divided between the lowest and highest quartiles of waste management fee.

For municipalities where a low share of the population lives in densely populated areas, a majority has a high waste management fee (68,9 %), while the municipalities with a higher share of the population living in densely populated areas tend to have a lower waste management fee (67,8 %) (Table 14). The geographical region variable also has a significant association with the level of the waste management fee ($\chi 2$=17,413 and p=0,002). Eastern and Northern Norway have more municipalities representing them in the lower waste management fee (64 % and 60 % respectively), while the three other regions tend to have higher management fees. Considering that Northern Norway has some of the least densely populated municipalities in the country, this result does not comply with the results for the "densely populated areas"-variable.

Table 14. The properties associated with lowest and highest waste management fee levels*

PROPERTIES	WASTE MANAGEMENT FEE			CHI-SQUARE TEST			
	Lowest	Highest	Share of total	Df	χ2	p	Cramer's V
MEAN INCOME				**3**	**35,584**	**0,000**	**0,416**
low	25,90 %	74,10 %	28,16 %				
medium low	41,70 %	58,30 %	23,30 %				
medium high	52,30 %	47,70 %	21,36 %				
high	80,40 %	19,60 %	27,18 %				
POPULATION				3	1,219	0,748	0,077
≤15000	51,80 %	48,20 %	81,55 %				
15001-50000	41,40 %	58,60 %	14,08 %				
500001-100000	42,90 %	57,10 %	3,40 %				
100000+	50,00 %	50,00 %	0,97 %				
DENSELY POPULATED AREAS				**2**	**18,74**	**0,000**	**0,302**
low share	31,10 %	68,90 %	35,92 %				
medium high share	54,80 %	45,20 %	35,44 %				
high share	67,80 %	32,20 %	28,64 %				
SHARE OF EXPENSES TO EXTERNAL SERVICES				2	1,387	0,500	0,086
no external services	47,10 %	52,90 %	36,36 %				
external treatment	41,20 %	58,80 %	9,09 %				
external treatment and collection	53,90 %	46,10 %	54,55 %				
AMOUNT OF PLASTIC RECYCLED				4	6,483	0,166	0,177
≤ 7,667	45,20 %	54,80 %	15,05 %				
7,668 - 22,000	39,00 %	61,00 %	19,90 %				
22,001 - 39,667	65,10 %	34,90 %	20,87 %				
39,668 - 101,000	52,20 %	47,80 %	22,33 %				
ANNUAL NO. OF COLLECTION DAYS FOR WET ORGANIC WASTE				**2**	**6,329**	**0,042**	**0,175**
less than 27 days	57,80 %	42,20 %	49,51 %				
27-37 days	34,30 %	65,70 %	16,99 %				
more than 37 days	46,40 %	53,60 %	33,50 %				
GEOGRAPHICAL REGION				**4**	**17,413**	**0,002**	**0,291**
Eastern Norway	64,00 %	36,00 %	36,41 %				
Southern Norway	33,30 %	66,70 %	7,28 %				
Western Norway	36,70 %	63,30 %	29,13 %				
Trøndelag	25,00 %	75,00 %	7,77 %				
Northern Norway	60,00 %	40,00 %	19,42 %				

*Significant results are typed in bold

As could be expected, the value of the waste management fee is not independent of the annual number of collection days for wet organic waste, even though the relationship is weak to moderately strong. A small number of collection days is more represented in the lowest fee-quartile than the highest. More unexpectedly, those municipalities with 27-37 collection days per year tend to have a higher level of management fee (65,7 %) than the municipalities with more than 37 collection days (53,6 %). A possible explanation for this is that for those municipalities without an own waste fraction for wet organic waste, the collection of wet organic waste-variable implies collection of residual waste. For those municipalities, weekly collections will not necessarily cost much more than for municipalities that have 27-37 collections of wet organic waste in addition to the residual waste.

To answer research question two, the results of section 5.1 also need to be considered. The level of the waste management fee did not have a statistically significant correlation with the level of recycling rate for wet organic waste. For plastic, the highest fee levels are more likely to be related to the lowest quartile of recycling rates than the highest. This is also found in the regression analysis in section 5.2.1. The above gives reason to conclude that other properties of the municipalities explain more of the level of the cost of waste management for inhabitants' than a high recycling rate. At the minimum, we can conclude that a higher management fee does not automatically give a high recycling rate. The strongest relation in the chi-square analysis for the waste management fee is the mean income of the municipalities' population, and the share of population living in densely populated areas. These, and the number of collection days of wet organic waste, as well as the geographical region in which a municipality is situated are all properties that correlate with the highest and lowest waste management fees.

6 Discussion and conclusion

6.1 The results in context of existing literature

The main objective of this study was to examine if variations in recycling rates for plastic and wet organic waste between Norwegian municipalities can be explained by differences in sociodemographic, geographic and/or waste management properties. The results partly confirm the hypothesis; Norwegian households' recycling rates of plastic and wet organic waste do vary with sociodemographic, geographic and waste management factors of their respective municipality. The analyses showed that waste management variables explain more of the variance in recycling rates than the sociodemographic and the geographic variables. None of the variables were, however, strongly associated with the differences in recycling rates. Thus, they were only moderately explanatory for the variation in the recycling rates.

In addition, the highest and lowest waste management fee levels seem to be related to several properties. For plastic, the recycling rate is negatively correlated with the waste management fee and a high level of the fee is associated with the lowest recycling rates. From this we can conclude that an increase in the fee is not necessary to increase the recycling rate, or that the cost connected to an increase in the recycling rate is not reflected in the waste management fee. The results of this study can be useful for national and local governing officials when deciding on new recycling policies and household recycling programs, and when improving the existing programs.

The results in this study confirm the findings of Starr and Nicolson (2015), in that the waste management properties are the most represented in the regression analyses for both waste fractions. Their results indicated that in general, the waste management variables explain some more of the variance in recycling rates than the contextual (sociodemographic and geographic) variables. The separate analyses of this study also confirmed this finding, with the waste management properties' regressions being the most explanatory of the variance in recycling rates for both waste fractions. This is to be expected, as policies, information and implementation of waste management systems is highly likely to stimulate the recycling rate. One explanation for this could be that municipalities that have had a recycling system for a longer period of time is more likely to have higher amounts of waste being recycled, and a higher recycling rates naturally follow.

However, some sociodemographic and geographic properties were significant and influences the recycling rates. One of the sociodemographic variables that impact the plastic recycling rate is the share of the population living alone, which had a negative correlation with the outcome variable. Miafodzyeva and Brandt (2013) found the opposite correlation, namely that one-person families affects the recycling performance positively. Their explanation for this was that people who live alone usually have more available room for the recycling bins than households with two or more people. This is a probable explanation for why the "number of people per household"-variable also negatively correlates with the recycling for plastic in this study. However, the "living alone"-variable affects recycling rate negatively in this study, and this could be explained by the personal characteristics and traits of people living alone. According to SSB, the largest share of people living alone are situated in Oslo and in smaller communities, typically in Northern Norway (SSB 2011). People living alone are also typically older and younger age groups, which could explain their efforts in recycling.

Another variable that influences recycling rates, particularly for wet organic waste, are the different types of houses people live in. The share of the population living in detached houses, duplex houses and row houses are all explanatory for the wet organic waste recycling rate. The results indicate that people living in detached houses contribute to a higher recycling rate, while the other two types of houses contribute to a lower recycling rate of wet organic waste. These are, like the "living alone"-variable, properties that can be explained by the available space in the house, and the different characteristics of people living in the different types of houses. A family that moves from a row house to a detached house is not necessarily going to change its recycling performance to the better, as it will probably have the same opportunity cost and opinion of recycling.

Furthermore, the results suggest that mean income of the population does not correlate with the recycling rates of plastic or wet organic waste. This confirms what Hage and Söderholm (2008) found in their study on plastic recycling performance for Swedish households; that the population's income could not explain differences in recycling rates. Most studies on recycling behaviour, however, usually find a correlation between both of these variables and the households' recycling performance. Miafodzyeva and Brandt (2013) concluded in a meta-analysis that in a majority of studies, income is significantly correlated with recycling behaviour. In other words, the results of this study show the opposite of what is usually found for income and its relation to household recycling rates. However, the correlation found by Miafodzyeva and Brandt (2013) is not constant across the studies in the meta-analysis, and results from 4 out of 16 studies found non-significant results for income, similar to the results in this study. The results are, in other words, ambiguous, and it is difficult to say why the income proves significant in some studies, and in others not.

Another interesting result of this study is that a higher unemployment rate of a municipality is associated with a higher household recycling rate for wet organic waste. This was also found by Hage and Söderholm (2008), for plastic packaging in Sweden. An explanation could be that the opportunity cost of the time spent recycling is important for recycling efforts, as unemployed people have more time available and therefore do not value their spare time as high as employed people. If this was entirely valid, however, the income variable should have been significant, with the opportunity cost increasing with the income.

Age only proved significant in the separate analysis for sociodemographic variables and plastic recycling rate, where the share of the population aged above 59 is negatively correlated with the recycling rate. The three significant variables in that separate analysis, however, were not very explanatory for the variance of the recycling rate, and the results cannot be given much emphases. Hage and Söderholm (2008) found that age is insignificant and (Miafodzyeva & Brandt 2013) in their meta-analysis found that whether age is significantly correlated with recycling behaviour varies quite a lot. Mikkelborg (2017) found, however, that the age group between 25 and 40 stands out for having the lowest recycling efforts for plastic, while the age group of 60+ stand out as the age group with the highest efforts in recycling wet organic waste and plastic waste. This last remark is the opposite of the results for the people aged above 59 in this study.

The results of the t-tests showed significant results for many of the variables, but because the differences in the mean was quite small, these have not been given too much emphasis.

For this study, the recycling rate for plastic has a moderately strong relationship to the waste management fee, and the implications are that higher waste management fees are associated with lower recycling rates. Overall, the same is seen from the regression analyses for plastic recycling rate, where the waste management fee negatively correlates with the recycling rate. Consequently, this study confirms the findings of Raadal et al. (2016), since a higher waste management fee appears to be more associated with other properties of the municipalities rather than a high level of recycling rate. Only in the separate regression analysis for wet organic waste, does a high waste management fee seem to be associated with a high recycling rate. This can indicate that the fee is oppositely correlated with the plastic recycling rate and the wet organic recycling rate. However, the separate analyses have not been given as much emphases as the main regressions.

Raadal et al. (2016) found that the size and location of a municipality explain more of the variation in the total operational costs and annual waste management fee than the recycling rates for wet organic and plastic in households. This means that municipalities with high recycling rates do not necessarily lead to high costs for the municipality, as long as the system is organised and operated in the most efficient way possible. As shown in Table 14, mean income of the population, the share of population that live in densely populated areas and the number of collection days for wet organic waste and the geographical location for the municipalities are all variables that are associated with a municipality's level of the waste management fee. A low share of people living in densely populated areas are related to high management fees, and so are some geographical regions. This is likely connected to the fact that bigger distances demand more transportation and logistic organisation than areas where people live closer together. Geographic variables, like urbanisation rate and the distance between municipality and the recycling industry, did not impact collection rates for plastic packaging in Swedish municipalities (Hage & Söderholm 2008). Sidique et al. (2010) also did not find any significant correlation between the population density and the recycling rates.

Another important point about the annual fee for officials and the population to notice is that the level of the cost should not be a limiting factor for increasing recycling rates. According to Raadal et al. (2016) the waste management fee on average consists of about a 1,8 % of annual total living expenses for Norwegian households. Therefore, the cost of recycling should not be overrated as an explanatory factor, nor as an obstacle when trying to improve a municipalities' recycling rate. Folz (1999) concluded that the costs for a recycling system normally is a viable alternative compared to the costs of collecting residual waste collection and disposal of this waste. This is important to achieve the recycling goals Norway is committed to through the European Economic Area agreement.

6.2 Robustness of the results and potential for improvement

6.2.1 Potential for improvement

As mentioned previously in the report, using national data as the denominator when calculating the recycling rate leads to inaccurate results and problems of interpreting the models, because some will have a recycling rate of more than 100 %. However, it is a useful way to compare the municipalities, which was the purpose in this study.

Even though the study includes variables that break some of the assumptions of the statistical analyses, the transformed versions of the variables were not included in the analyses. This could make the regression analysis some more explanatory, in terms of goodness of fit, than the results presented here. However, it was found that it did not change the results in a significant amount with regards to the goodness of fit of the model and the made the results more difficult to interpret, thus, the transformed variables were not included.

6.2.2 Sources of potential error

A potential weakness of the KOSTRA system is that the municipalities reports the waste related data and might interpret the methodologies and definitions differently. This can be a problem because it is not a homogenous system for collecting data (Skjema 23 for waste data). Although SSB offers instructions for filling out the forms with explanations of what the different terms mean and imply, the officials in different municipalities may understand the terms and implications differently. Additionally, when a municipality changes the staff responsible for the KOSTRA reporting, the data for the municipality may change from one year to another just because they interpret the forms differently. For example, gardening waste might have been included in the wet organic waste fraction in one period and not in other periods. In other cases, the share of total expenses spent on external services, some municipalities have a value above 100% which can be due to a misunderstanding of what “external services” imply. However, SSB emphasises that they perform several controlling measures to secure that the data is of high quality. Using electronic forms, controlling the information when receiving the data and performing consistency control for the data connected to accounting, are all actions that ensure this (SSB 2017c). It is important when comparing values and data that it is done on an equivalent basis. Therefore, it is essential that the numbers for each section of the forms are reported as correctly as possible.

According to SSB, another possible explanation that some municipalities have large fluctuations in total waste amounts in KOSTRA between years is due to lack of systems for weighing and recording the data (SSB 2017d). It occurs mostly in smaller municipalities and should not affect the values for national data. There is an average data deficiency of 2 % in the final data published on June 15^{th} every year.

Another source for error is regarding the reported weight and contamination of the waste fractions. As Xu et al. (2016) states, the presence of contamination in the wet organic waste and plastic waste can cause several problems of measuring. The fractions containing other types of waste can be stopped from use in production of biogas and other things. Thus, the contaminated fractions might not even be valid as wet organic waste, and is treated as residual waste. This would, in turn, impact the calculations of GHG emissions from the wet organic waste treatment.

6.3 Recommendations for use of the results

The results of the study can be used by waste management authorities nationally and locally, and waste management companies (Avfall Norge) when making decisions regarding implementing and improving recycling systems and practice in Norwegian municipalities.

When it comes to the waste management fee level, the general perception that a high recycling rate is associated with a high waste management fee is not correct. This is important to remember when considering and deciding on policies and measures for recycling systems, as a system can be made more efficient without increasing the operational costs and the waste management fee. Of the properties that did prove to relate to the high or low levels of the waste management fee, however, only one is in the hands of waste management officials directly, namely the annual number of collection days for wet organic waste. Even though it might be contra-intuitive, a lower annual number of collection days for the fraction seems to be associated with a lower fee. Thus, if the goal is to achieve a waste management fee that is as low as possible, implementing a 26 days collection per year (every second week) could be a possible alternative. However, the effect of implemented measures can vary greatly from one municipality to another, with type of collection transport they currently use, the efficiency of their current system and the distances between households and the waste treatment facilities. Additionally, as (Raadal et al. 2016) stated, implementing several measures on both waste fractions alongside each other will be the most efficient, as it is difficult to separate the two and the effects different measures will have on the recycling rates.

Folz and Hazlett (1991) stated that if sociodemographic properties of the municipalities are important for the recycling efforts of households, local and national officials and planners should have to lower their expectations of improvements in recycling rates. This is important because the policies implemented to increase the recycling rates might not give the same results of increased recycling rates in all areas. Norwegian authorities should take this into account when deciding on measures to be taken in the waste management, as sociodemographic properties are hard or impossible for authorities to change. Even though some sociodemographic variables have significant results, however, quite a low amount of the variance in recycling rates are explained by these types of factors, and thereby they should not put too much weight on the significance of sociodemographic and geographic properties of the municipalities. However, waste management policies can be changed, and should always be a priority.

A useful alternative in this regard, could be to initiate larger educational and incentive campaigns specifically aimed at the groups of the population that are not likely to recycle. This is supported by (Raadal et al. 2016), stating that communicating the value and functions of recycling is an important policy when the goal is to increase the recycling performance. Successfully communicated information will both attract more users and sustain the motivation of the households with a high recycling performance.

6.4 Further work on the topic

As previously mentioned, using national values as the denominator when calculating the recycling rates, the outcome variable does show a somewhat inaccurate picture. If municipal data of actual generated waste of plastic and wet organic waste is published in the future, it is recommended to perform a similar study again. This is likely to give more accurate results when analysing systematic differences between the municipalities.

Further on, some variables that were not included in this research could be interesting to include in a similar study. Examples of such properties are gender, what kind of recycling system is implemented in each municipality and the amount of time a recycling system has been in place in the municipality. Hage and Söderholm (2008) also included the distance between municipalities and the recycling industry, which could be interesting to include in the case of Norway as well. Distances within a municipality can also prove important for the waste management fee, and could be interesting to examine as it is connected with the variables that proved to be associated with the levels of the fee in this study.

A discriminant analysis of the variables included in the study could be performed to check the results of the regression analyses and chi-square tests of this study.

Another interesting analysis for the datasets would be a cluster analysis for the municipalities to categorize the municipalities. If this is possible, it would be a good method of upscaling the results of this thesis, in an attempt to have a set of municipalities where similar policies and program changes could work in a similar way. This could prove to be useful officials and decisionmakers when improving and developing the waste management programs.

Examining whether there is a correlation between the two recycling rates studied in this thesis could also be interesting. There could be underlying reasons for the differences in what properties impact the two fractions' recycling rates. There is also a possibility that implementing a recycling system for both waste fractions could be more efficient in terms of recycling rates than only implementing one of them.

6.5 Concluding remarks

In conclusion, waste management properties influence the recycling rates in Norwegian households more than sociodemographic and geographic properties. Waste management authorities should, however, keep in mind that sociodemographic and geographic properties of the municipalities may affect how successful implementation and/or improvement of a recycling system will be. Operational costs and waste management fee should not be an obstacle when implementing measures to increase the recycling rate, as a higher recycling rate is not necessarily associated with a higher waste management fee. Hopefully, the results will be helpful in trying to adjust recycling programs and systems to increase the recycling rates.

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