

Article

Economic and Environmental Benefits from Municipal Solid Waste Recycling in the Murmansk Region

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Abstract: Most municipal solid waste (MSW) in Russia is disposed of in landfills, and only a relatively small fraction is recycled. The landfilling of waste leads to greenhouse gas (GHG) emissions, and air and groundwater pollution. However, recently, there have been some initiatives to improve waste management in the country. We assessed the economic and environmental benefits of waste recycling in the Murmansk region, in which a new waste recycling plant has been operating since 2019. We found that MSW recycling in the Murmansk region has induced a small, positive, job creation effect and could potentially lead to a non-negligible reduction in GHG emissions. Extrapolating the results from this case study to the country level, we found that recycling landfilled MSW in Russia could save approximately 154 million tons of GHG emissions in carbon dioxide equivalents annually, which is comparable to the total CO₂ emissions from Algeria. The positive environmental and health-related impacts from the extensive implementation of MSW recycling in the country could be substantial. From this case study, we also learned that one of the biggest challenges for the waste recycling company in the Murmansk region is finding profitable markets for recycled materials. Moreover, due to the high investment and operational costs, recycling MSW led to a substantial increase in communal fees. However, there is potential to make waste recycling more cost effective. Most MSW in the Murmansk region is still separated at the recycling plant, while separating waste at the source could substantially reduce operational costs. Other challenges in the large-scale implementation of MSW recycling in Russia, such as a lack of investments and the population's willingness to recycle waste, are also discussed.

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Keywords: municipal solid waste; recycling; Russia

1. Introduction

As a large economy, Russia is one of the world's biggest producers of waste. A waste management system has still not been implemented in Russia at a large scale; for example, in 2020, only 24% of the total accumulated municipal solid waste (MSW) was recycled and incinerated (Figure 1). The largest fraction of MSW is disposed of in landfills and only a small amount of waste is incinerated; for example, in 2018, approximately 2.2% of MSW was incinerated [1]. Landfilling and incineration of waste are associated with greenhouse gas (GHG) emissions, and air and groundwater pollution [2–4]. Air pollution from waste incineration could result in adverse impacts on health, increasing the risk of morbidity and mortality [5–8]. A bad smell and unpleasant views are other adverse side effects of waste landfills. Recycling waste will not only eliminate the direct environmental and health impacts from incineration and landfilling, but will also reduce natural resource consumption (i.e., water and energy), thereby leading to a more sustainable development pathway.

For a long time, the issues related to waste management were only addressed by non-governmental organizations (NGOs), and were not placed on the Russian policy agenda. Almost all municipal and industrial waste was buried in landfills in Russia, despite the 2014 amendments (458-FZ) to the federal law ‘On Production and Consumption of Waste’, which established the producers’ responsibility towards industrial waste, prohibited landfilling waste with recyclable components, and required regions to arrange ongoing (at least ten years) contracts for waste collection, transport and recycling, through a single regional operator on a competitive basis [9,10]. Recently, however, there have been some positive movements and ongoing initiatives towards taking the waste problem more seriously. As an example of this, the integrated municipal solid waste management strategy sets the tasks of developing an infrastructure for the decontamination and safety of the placement of MSW, in terms of both environment and public health (para. 11), as well as providing economic incentives for the separate collection of MSW (para. 19), and encouraging active involvement of communities in the separate collection and disposal (recycling) of MSW (para. 21). The circular economy, enabled by waste management systems, is an important aspect of the green economy and is also recognized in the Russian green economy debate [11]. One of the examples of ongoing initiatives is the new waste recycling plant (WRP), which was recently built in the Murmansk region and started its operations in 2019. Improving waste management in the Murmansk region and the country could be associated with some business opportunities, resulting in substantial environmental benefits, but it is also associated with some challenges. A better understanding of the economic and environmental consequences of waste recycling might help to further stimulate the design of an effective waste management strategy and action plan in Russia.

The objective of this study is to quantify the economic and environmental benefits of MSW recycling in the Murmansk region. Our analysis is based on interviews conducted with the regional operator, municipal statistical data, and the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. Furthermore, the results from this case study are extrapolated to provide a country’s perspective on potential economic and environmental impacts. The remainder of the paper is structured as follows: Section 2 describes the methodology, Section 3 presents and discusses the results, and the final section provides the conclusions of the study.

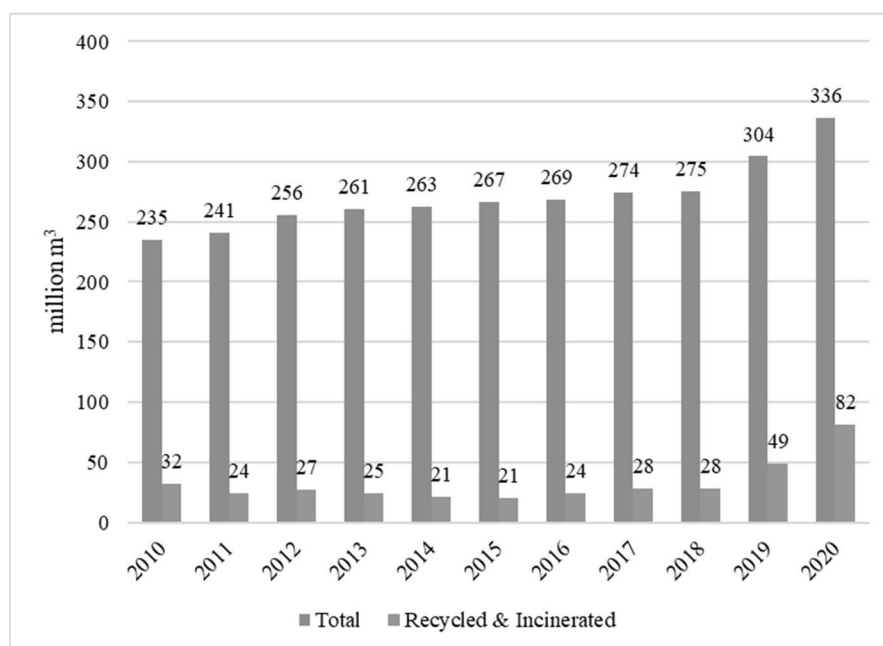


Figure 1. Municipal solid waste in Russia. Source: [12].

2. Materials and Methods

2.1. Job Creation

The data on collected MSW in the Murmansk region are only available for the period of 2003–2020. The average amount of MSW in that region accounted for approximately 256,000 tons per year over the period of 2003–2020 (Figure 2). More than half of that amount (i.e., 65%, on average) was placed in landfills, whereas the remainder was incinerated (i.e., 35%, on average). Unlike many other regions, the Murmansk region has an incinerator. Regarding the waste composition, paper and organic waste contributes the largest part of the total MSW in terms of weight [13] (Figure S1, Supplementary Material).

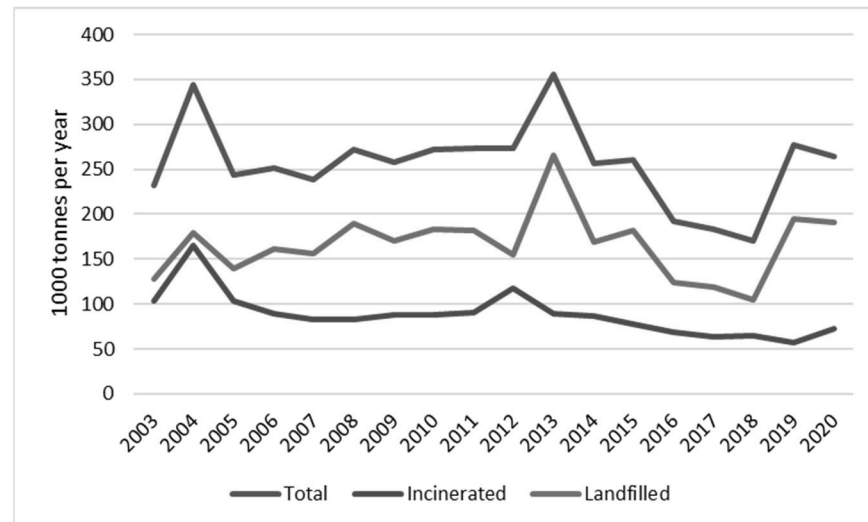


Figure 2. Municipal solid waste in the Murmansk region. Source: [14].

Recently, a waste recycling plant (WRP) was built in Murmansk, which started operating in 2019. A regional operator, which is a private company, is now dealing with collecting and recycling MSW from the entire Murmansk region. In 2019, approximately 26,000 tons, and in 2020, 25,000 tons of MSW were recycled. From 2023, the regional operator planned to recycle around 106,000 tons and to incinerate 120,000 tons of MSW [14].

To quantify the job creation effect, we used the data collected during the interview with the regional operator in 2019. Specifically, the regional operator provided the information on the number of employees and the capacity of the WRP.

2.2. GHG Emissions

As described below, we calculated emissions from the following three types of MSW treatment: (i) emissions from incineration, (ii) emissions from landfills, and (iii) emissions from recycling. The input data and results are available from the corresponding author on reasonable request.

2.2.1. CO₂ Emissions from Incineration

Emissions from CO₂, CH₄, and N₂O account for more than 90% of GHGs from waste management [15]. The amount of GHG emissions depends inter alia on the type of waste and alternative management strategy; for example, landfilling leads to the release of methane (CH₄), while incineration creates CO₂, CH₄, and N₂O emissions. In our analysis, CO₂ emissions from incineration are estimated using the 2006 IPCC guidelines for National Greenhouse Gas Inventories (hereafter, the IPCC Guidelines). Equation (1) corresponds to Equation (5.2) in the IPCC Guidelines, which is the basic methodology used to calculate CO₂ emissions from incineration. The emission factors are based on the carbon content of waste, which has a fossil origin. Since region-specific values, such as the fraction of fossil

carbon, are not available, the equation is parameterized using the default values of the IPCC Guidelines (see Table 2.4 in the IPCC Guidelines).

$$CO_2 = \sum_j (MSW_j * dm_j * CF_j * FCF_j * OF_j) * \frac{44}{12} \quad (1)$$

where the following apply:

CO₂ is carbon dioxide emissions (gigagram/yr);

MSW_{*j*} is the amount of municipal solid waste of waste type *j* (gigagram/yr);

dm_{*j*} is the dry matter content of waste type *j*;

CF_{*j*} is the fraction of carbon in the dry matter of waste type *j*;

FCF_{*j*} is the fraction of fossil carbon in the total carbon of waste type *j*;

OF_{*j*} is the oxidation factor.

Waste incineration leads to CO₂, CH₄, and N₂O emissions, with substantially larger CO₂ emissions than N₂O and CH₄ emissions. In our analysis, we did not calculate non-CO₂ GHG emissions from incineration because the emission factors of non-CO₂ GHG emissions are relatively small. Moreover, the emission factors for N₂O and CH₄ are very uncertain, as these depend not only on the type of waste but also on the type of incineration facility. It should, however, be noted that N₂O and CH₄ have a substantially larger radiative forcing compared to CO₂ [16]. CO₂ emissions from incineration are estimated for the following three waste categories: paper, textiles, and plastic. In the Murmansk region, paper, plastic, and textiles from the cities of Murmansk and Severomorsk are incinerated, while paper, plastic, and textiles from southern municipalities are landfilled. In our analysis, due to the lack of data on MSW, we used the data on the municipal population to distribute the total amount of paper, plastic, and textiles between incineration and land-filling.

2.2.2. CH₄ Emissions from Landfills

MSW landfills are a large source of CH₄ emissions [17]. In our analysis, CH₄ emissions from landfills were estimated using the IPCC model for solid waste disposal for the following three waste categories: food, paper, and textiles. As mentioned above, we used the data on the municipal population to calculate the amount of paper and textiles that was landfilled. Note that plastic, glass, and metals were also landfilled in the Murmansk region. However, the degradation of these material is very slow, so CH₄ emissions mainly come from the landfilling of food, paper, and textiles. The degradation of organic components in waste could proceed slowly over a few decades; therefore, it is recommended to use a time frame of at least 50 years to calculate the CH₄ from disposed waste. In our analysis, CH₄ emissions from landfills were calculated for 80 years, as this is the default time frame of the IPCC waste model. We used the default values to parameterize the IPCC model for solid waste disposal. To make CH₄ emissions comparable to other types of emissions on a yearly basis, we divided the CH₄ emissions accumulated from landfills in 2003–2020 over 80 years by 17 years. Finally, CH₄ emissions were converted to the carbon dioxide equivalent (CO₂-eq) using a conversion factor of 25.

2.2.3. GHG Emissions from Recycling

Emission factors for direct GHG emissions from recycling processes and indirect emissions from the avoided primary production of materials (hereafter, emission factors for recycling) are taken from Turner et al. (2015). The emission factors for recycling were especially large for metals and textiles (Figure S2, Supplementary Material). These emission factors were used to calculate potential emissions savings from recycling incinerated and landfilled MSW for the following six waste categories: glass, paper, metals, textile, plastic, and food.

3. Results and Discussion

3.1. Job Creation

According to the interview with the regional operator, the new WRP employs 280 people to deal with the collection and recycling of MSW. The newly built WRP aims to recycle the MSW, which was originally placed in landfills, from the entire Murmansk region. A certain amount of total accumulated MSW will be incinerated, although the capacity of the WRP allows all the accumulated MSW (i.e., including incinerated waste) to be recycled. According to the interview with the regional operator, there is no direct conflict of interest between the incinerator and waste recycling company because the distribution of MSW for incineration and recycling is administratively regulated. The MSW from remote areas is planned to be incinerated due to the high transportation costs. While the new WRP created jobs for 280 people, those working in landfilling might become unemployed. However, according to the interviews with the regional operator, there was a relatively small number of people employed in landfills, and they worked as security and administrative staff after the WRP started operating in 2019. In addition, 60 new workforces at the WRP are planned to be created, to further secure the jobs of those workers. Thus, none of the people working at landfills have lost their job to date. In total, building the new WRP created 340 jobs. For reference, the total population living in the Murmansk region was approximately 748,000 in 2019 [18], meaning that the job creation effect from waste recycling is small. Taking the average annual amount of landfilled MSW in the Murmansk region for the period of 2003–2020 (166,500 tons), recycling one million tons of landfilled MSW would create 2,042 new jobs (340 divided by 166,500).

Incineration is more labor intensive than landfilling. In the Murmansk region, the number of people working in waste incineration is approximately 170. This implies that if the waste incineration company closed down, and the WRP was also responsible for recycling the incinerated MSW, the job creation effect would account for at least 170 new jobs (i.e., 340 minus 170). Taking the average annual amount of MSW generated for the period of 2003–2020 (256,000 tons) into account, recycling approximately 1,506 tons of waste would create one job (256,000 divided by 170) or 664 new jobs per million tons of waste (170 divided by 256,000 tons). Note that recycling the MSW that is currently incinerated could require an additional workforce at the WRP, which would mean additional jobs (i.e., the employment effect from waste recycling could be even greater). A positive job creation effect from waste recycling is in line with some previous studies, which found that waste recycling could increase employment because the processes of waste recycling are more labor intensive than landfilling [19,20].

In 2020, the total amount of landfilled MSW in Russia was approximately 50 million tons. Taking the employment effect of recycling landfilled MSW in the Murmansk region as an extrapolation factor, recycling landfilled MSW in Russia could result in 102,100 (50 multiplied by 2,042) new jobs. From a country-level perspective, the job creation effect from the waste recycling industry is relatively small; however, it could still be considered as a non-negligible co-benefit of improving waste management in Russia.

3.2. GHG Emissions

Apart from the job creation effect, recycling MSW has positive environmental impacts, as it leads to reductions in GHG emissions. According to our results, recycling the previously landfilled MSW could lead to an annual average reduction in GHG emissions of 515 gigagram (Gg) of CO₂-eq (Table 1). Almost 40% of the emissions savings are attributed to the eliminated CH₄ emissions from landfills, and the remaining emissions savings come from the avoidance of the primary production of materials (Figure 3). CH₄ emissions from landfills mainly consist of emissions from the decomposition of food and paper, which contribute approximately the same amount (i.e., 48–49% of the total CH₄ from landfills), whereas the amount of CH₄ from the decomposition of textiles is very small (i.e., 3% of the total CH₄ from landfills) (Figure 3). The CH₄ emissions from landfilled

MSW in 2013–2020 will increase until 2022, and then continuously decline (Figure S3, Supplementary Material).

Assuming that incinerated MSW would also be recycled, the emissions savings would be scaled up to 697 Gg of CO₂-eq per year. Regarding incineration, the largest emissions savings come from the avoidance of the primary production of materials, which accounts for approximately 82% of the total emissions savings from incineration (Table 1 and Figure 3), and the remaining amount is associated with a reduction in CO₂ emissions from incineration (Figure 3). Regarding the emission attribution of incinerated waste, the largest amount of CO₂ emissions comes from the incineration of plastic (81%), followed by textiles (17%) (Figure 3). Regarding the indirect emissions from the recycling of incinerated waste (i.e., avoided primary production of materials), the largest emissions savings result from recycling textiles (46%) and paper (43%), followed by plastic (12%) (Figure 3).

In relative terms, this implies that recycling one ton of MSW in the Murmansk region would save approximately 2.7 tons of GHG emissions in CO₂-eq annually, which is 0.87 ton per capita per year, on average. For comparison, in 2017, the total CO₂ per capita in Russia accounted for approximately 11 tons [21]. Hence, the contribution of MSW to total GHG emissions in Russia is relatively small compared to other types of emission sources (i.e., power generation and transport). However, when looking at an individual's personal emissions, the emissions savings from MSW recycling are significant compared to the per capita emissions in some other countries; for example, India's CO₂ emissions per capita in 2015 amounted to 1.8 tons [21].

Table 1. Annual average GHG emissions and emissions savings from different types of MSW treatment in the region of Murmansk (in CO₂-eq). Negative emissions from recycling are mainly associated with reductions in the primary production of materials.

Types	Gigagram	Tons Per Ton of MSW	Tons Per Capita
- Landfills	201	1.21	0.25
- Recycling of landfilled MSW	-314	-1.89	-0.39
Total emission savings from recycling landfilled MSW	-515	-3.09	-0.64
- Incineration	32	0.36	0.04
- Recycling of incinerated MSW	-149	-1.69	-0.19
Total emission savings from recycling incinerated MSW	-182	-2.05	-0.23
Overall total emission savings	-697	-2.72	-0.87

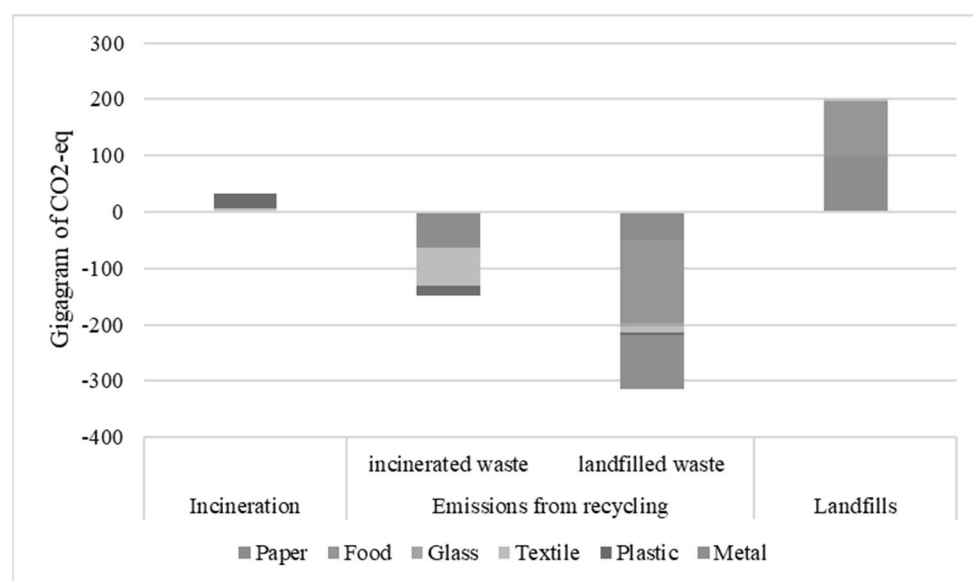


Figure 3. Annual average GHG emissions and emissions savings from different types of MSW treatment and types of waste in the region of Murmansk (in CO₂-eq).

From the country-level perspective, recycling MSW could result in non-negligible emissions savings, due to the large amount of MSW generated in Russia every year; for example, in 2020, approximately 50 million tons of MSW were landfilled in Russia [12]. Using the emission factor for landfilled MSW for the Murmansk region (1.21 tons per ton of MSW), recycling landfilled MSW in Russia would save approximately 60.5 million tons of methane emissions in CO₂-eq every year. When also accounting for the emissions savings from the avoided primary production, the total emissions savings from recycling landfilled MSW amount to approximately 154.5 million tons of GHG emissions in CO₂-eq (50 million multiplied by 3.09 tons per ton of MSW). In comparison, the total CO₂ emissions from Algeria, one of the largest economies in Africa, accounted for approximately 152 million tons of CO₂ in 2018 [21]; the total GHG emissions without land-use change and forestry (LULUCF) in Norway and Sweden in 2018 amounted to approximately 47 and 46 million tons in CO₂-eq, respectively [21]. Note that the emissions savings will further increase when also recycling incinerated MSW in Russia.

Investment in building the waste management system in the Murmansk region accounted for approximately USD 37 million for the period of 2013–2019 [14]. Given the assumption that the new WRP in the Murmansk region will operate for the next 20 years, by saving around 515,000 tons of CO₂-eq each year, the new WRP would be beneficial, even at a carbon price of USD 5 per ton for a discount rate of 4%.

3.3. Challenges

There are some challenges in the large-scale implementation of MSW recycling, which should be considered when further developing and designing the Russian waste recycling policy.

First, the installation of the new WRP in the Murmansk region led to a substantial increase in communal fees. For example, in Murmansk, recycling MSW led to a two times increase in communal fees, which is especially problematic for low-income groups [22]. Recycled waste becomes a resource that could be further re-used. In that regard, recycling leads to some reductions in cost [23,24]. However, recycling is a costly procedure compared to landfilling, especially if landfilling is not charged or is charged with a small fee. In the Murmansk region, an increase in communal fees was required to pay off the investment cost and cover the operational costs. Implementing MSW recycling at the country level would require massive investments in building WRP and the required infrastructure; for example, the investment in building a waste management system in the Murmansk region accounted for approximately USD 37 million for the period of 2013–2019 [14]. A lack of funding could slow down the expansion of waste recycling in the country.

Second, although a few places in Murmansk are equipped with waste-specific collection containers (i.e., MSW can be separated by type), most waste is still separated at the WRP. However, separating waste at the source is a more economically efficient option. An example of this is a field study conducted by Greenpeace Russia in Saint Petersburg, Babanin (2008), which found that separating MSW at the source could reduce the cost of waste recycling by half, and the amount of waste-material rejects could decline by three times compared to when MSW is separated at a WRP [25].

Third, the willingness of the population to separate MSW could still be relatively low; for example, according to a survey conducted by Aladyshkina et al. (2019), only 33–36% of the urban population of Nizhny Novgorod is willing to separate solid waste [26].

Fourth, according to the interviews, the regional operator finds it difficult to find profitable markets for recycled materials, which could make it challenging to further up-scale the recycling of waste. A solid stream of recycled materials is required before anyone can invest in them as a raw material, and the government could help to balance the supply and demand by supporting new business opportunities to make use of these new material streams.

Note that the above-mentioned challenges are general and relevant for all Russian regions, but to different extents; for example, the willingness of the population to separate

MSW might differ by region and could change over time. Some regions could find it more difficult to find profitable markets for recycled materials because of the high transportation costs. Increasing communal fees for waste recycling will be more problematic for the regions with a larger low-income population; therefore, those regions might need more financial support from the state. Furthermore, in Russia, incineration is considered to be a form of “recycling”; therefore, it is expected that the relative amount of incinerated MSW will increase, especially in remote regions.

4. Conclusions

Landfilling and incinerating MSW lead to GHG emissions, and local air and groundwater pollution. At present, a relatively small share of the total accumulated MSW is recycled in Russia (e.g., ~24% was recycled and incinerated in 2020). However, there are some positive tendencies towards improving waste management in the country (e.g., federal and regional legislation). We quantified some economic and environmental impacts of recycling MSW in the Murmansk region, which recently built a new WRP. We found that, on balance, recycling MSW induced a positive job creation effect in that region, since the number of people involved in waste recycling is substantially greater than in landfills and incineration; for example, we found that recycling one million ton of landfilled MSW could create approximately 2042 new jobs. Additionally, the emissions saving effect is considerable; for example, recycling landfilled MSW in the Murmansk region could annually save approximately 515 Gg of GHG emissions in CO₂-eq, which is 3.1 tons of Gg per ton of MSW. From the country-level perspective, emissions savings are non-negligible. A simple extrapolation of the case study of the Murmansk region shows that the annual emissions savings from recycling landfilled MSW in Russia could be comparable to the total annual CO₂ emissions of Algeria, one of the largest economies of Africa.

We also identify some challenges associated with the management of MSW in the Murmansk region. The communal fee was increased, and the regional operator found it difficult to find profitable markets for recycled materials. However, recycling MSW at the source could potentially address these two problems by reducing the operational costs. At the country level, a lack of investment and the potentially low willingness of the population to separate waste could further challenge an expansion of waste recycling. Investigating regional differences is an interesting avenue for future research.

This analysis is subject to several limitations. The incineration and landfilling of MSW could lead to air and groundwater pollution, thereby inducing adverse health impacts. The positive health impacts from MSW recycling are not quantified in this study. In this regard, the benefits of recycling MSW are certainly underestimated in our analysis. The estimated impacts on GHG emissions are also uncertain, since the emission factors are not specific to the Murmansk region. In that regard, the extrapolated impacts of MSW recycling for the entire country are also likely to be biased. Moreover, this study focuses solely on MSW in the Murmansk region, in which the total accumulated MSW is relatively small compared to mining waste. Recycling industrial waste could result in substantially greater job creation and emission-saving effects.

Supplementary Materials: The following are available online at www.mdpi.com/article/10.3390/su131910927/s1. Figure S1: Composition of MSW in the Murmansk region in 2009–2013, Figure S2: Emission factors, Figure S3: CH₄ emissions from landfilled MSW in the Murmansk region in 2003–2020 (Gigagram of CO₂-eq).

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Data Availability Statement: Data can be obtained from the corresponding author upon request.

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References

1. Ministry of Natural Resources and Ecology. State Report about the Ecology Situation in the Russian Federation. Государственный доклад «О состоянии и об охране окружающей среды Российской Федерации в 2018 году». 2018. Available online: <https://gosdoklad-ecology.ru/2018/obrashchenie-s-otkhodami-proizvodstva-i-potrebleniya/tverdye-kommunalnye-otkhody/> (accessed on 15 August 2021).
2. Iravanian, A.; Ravari, S.O. Types of Contamination in Landfills and Effects on the Environment: A Review Study. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *614*, 012083, doi:10.1088/1755-1315/614/1/012083.
3. IPCC. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013; p. 1535.
4. Ferronato, N.; Torretta, V. Waste Mismanagement in Developing Countries: A Review of Global Issues. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1060, <https://doi.org/10.3390/ijerph16061060>.
5. Mataloni, F.; Badaloni, C.; Golini, M.N.; Bolignano, A.; Bucci, S.; Sozzi, R.; Forastiere, F.; Davoli, M.; Ancona, C. Morbidity and mortality of people who live close to municipal waste landfills: A multisite cohort study. *Int. J. Epidemiol.* **2016**, *45*, 806–815, doi:10.1093/ije/dyw052.
6. Mattiello, A.; Chiadini, P.; Bianco, E.; Forgione, N.; Flammia, I.; Gallo, C.; Pizzuti, R.; Panico, S. Health effects associated with the disposal of solid waste in landfills and incinerators in populations living in surrounding areas: A systematic review. *Int. J. Public Health* **2013**, *58*, 725–735, doi:10.1007/s00038-013-0496-8.
7. Tait, P.W.; Brew, J.; Che, A.; Costanzo, A.; Danyluk, A.; Davis, M.; Khalaf, A.; McMahon, K.; Watson, A.; Rowcliff, K.; et al. The health impacts of waste incineration: A systematic review. *Aust. New Zealand J. Public Health* **2020**, *44*, 40–48, doi:10.1111/1753-6405.12939.
8. Vinti, G.; Bauza, V.; Clasen, T.; Medlicott, K.; Tudor, T.; Zurbrugg, C.; Vaccari, M. Municipal Solid Waste Management and Adverse Health Outcomes: A Systematic Review. *Int. J. Environ. Res. Public Health* **2021**, *18*, 4331, doi:10.3390/ijerph18084331.
9. Bushueva, Y. New Waste Legislation in Russia Leads to More Wasted Opportunities. Blog Post on the Natural Step Website, 22 March 2017. Available online: <http://www.naturalinterest.fi/en/new-waste-legislation-in-russia-leads-to-more-wasted-opportunities/> (accessed on 15 August 2021).
10. CMS. Russia Introduces Waste Producer Responsibility. CMS Law-Now, 26 January 2015. 2015. Available online: http://www.cmslawnow.com/ealerts/2015/01/russia-introduces-waste-producer-responsibility?cc_lang=en (accessed on 15 August 2021).
11. Ivanova, I.; Levchenko, L. “Green” economy: The essence, principles and prospects [“Зеленая” экономика: сущность, принципы и перспективы]. *Her. Omsk. Univ. Ser. Econ.* **2017**, *58*, 19–28.
12. Ministry of Natural Resources and Ecology. State Report about the Ecology Situation in the Russian Federation. Государственный доклад «О состоянии и об охране окружающей среды Российской Федерации в 2020 году». 2021. Available online: <http://www.mnr.gov.ru/upload/iblock/880/Госдоклад-2020.pdf> (accessed on 15 August 2021).
13. Klyuchnikova, E. 2.1 Attachment to the article “Ecological and economic situation of sustainable development and policy measures of municipalities” .2.1. ПРИЛОЖЕНИЯ к статье «Эколого-экономические проблемы устойчивого развития и их решение на уровне муниципальных образований». 2013. Available online: <http://www.municipal-sd.ru/sites/default/files/2.1.add-kluchnikova.pdf> (accessed on 15 August 2021).
14. Murmansk Regional Government. Reports about Ecological Situation in the Murmansk Region in 2003–2020. Доклад о состоянии и об охране окружающей среды Мурманской области в 2003–2020 году. 2020. Available online: <https://gov-murmansk.ru/region/environmentstate/> (accessed on 15 August 2021).
15. Turner, D.A.; Williams, I.D.; Kemp, S. Greenhouse gas emission factors for recycling of source-segregated waste materials. *Resour. Conserv. Recycl.* **2015**, *105*, 186–197, doi:10.1016/j.resconrec.2015.10.026.
16. Etminan, M.; Myhre, G.; Highwood, E.J.; Shine, K.P. Radiative forcing of carbon dioxide, methane, and nitrous oxide: A significant revision of the methane radiative forcing. *Geophys. Res. Lett.* **2016**, *43*, doi:10.1002/2016gl071930.
17. Kormi, T.; Ali, N.B.H.; Abichou, T.; Green, R. Estimation of landfill methane emissions using stochastic search methods. *Atmospheric Pollut. Res.* **2017**, *8*, 597–605, doi:10.1016/j.apr.2016.12.020.
18. FSSS. Federal State Statistics Service. Population in the Murmansk Region. 2021. Available online: <https://murmanskstat.gks.ru/folder/72764> (accessed on 15 August 2021).
19. EEA. Earnings, Jobs and Innovation: The Role of Recycling in a Green Economy — European Environment Agency. 2011. Available online: <https://www.eea.europa.eu/publications/earnings-jobs-and-innovation-the> (accessed on 19 February 2021).
20. EPA. 2020 Recycling Economic Information (REI) Report. 2020. Available online: <https://www.epa.gov/smm/recycling-economic-information-rei-report-and-methodology> (accessed on 15 August 2021).
21. Climate Watch. CAIT data. GHG Emissions. Washington, DC: World Resources Institute. Available online: [Climatewatchdata.org/ghg-emissions](https://climatewatchdata.org/ghg-emissions). 2020. Available online: [Climatewatchdata.org/ghg-emissions](https://climatewatchdata.org/ghg-emissions) (accessed on 15 August 2021).

22. Korotkaj, J. Pay or Not? How Much and Whom? [Платить или нет? Сколько и кому?]. Double Two Apatity [Дважды Два Апатиты]. *Newsp. Artic.* 2019. Available online: <http://gazeta2x2.ru/?p=82180> (accessed on 15 August 2021).
23. De Feo, G.; Polito, A.R. Using economic benefits for recycling in a separate collection centre managed as a “reverse supermarket”: A sociological survey. *Waste Manag.* **2015**, *38*, 12–21.
24. Hoogmartens, R.; Eyckmans, J.; Van Passel, S. Landfill taxes and Enhanced Waste Management: Combining valuable practices with respect to future waste streams. *Waste Manag.* **2016**, *55*, 345–354, doi:10.1016/j.wasman.2016.03.052.
25. Babanin, I. Waste Revolution: How to solve the problem of municipal waste at least cost. МУСОРНАЯ РЕВОЛЮЦИЯ: Как решить проблему бытовых отходов с минимальными затратами. *Greenpeace* **2008**, *29*, 1–22.
26. Aladyshkina, A.; Lakshina, V.; Leonova, L. Study of Willingness of Nizhny Novgorod Citizens to Separate Collection of Solid Municipal Waste. Страницы из Сборник РОЭЭ 2019-2. 2019. Available online: <https://elibrary.ru/item.asp?id=41211228> (accessed on 15 August 2021).