Financial and economic model of waste incineration plant construction

Svetlana Shilkina and Artur Niyazov

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

E-mail: Shilkina@bk.ru

Abstract. Currently, Russia produces 55–60 mln tons of solid domestic waste (SDW) annually. Over 90% of it is sent to landfills and unauthorized junkyards. Processing level in Russia is 5–7%, while the European Union countries process up to 90% of SDW. To date, there are about ten waste incineration plants (WIP) in Russia with low production capacity, which is negligible on a national scale. In contrast, the number of WIPs: in Switzerland – 29, in Japan – 1,900, in Sweden – 21, in Denmark – 32, and the population of these countries is less than that of Russia. It is obvious that new plants are very expensive both at construction and operation phases. The article gives an assessment of economic impact of switching over to SDW processing by WIP-based incineration. A WIP processing 350 thousand tons of SDW per year, including a thermal power plant with 24 MW installed power capacity operated by the energy produced from SDW incineration, is taken as an object for calculation. Such construction is unlikely to be financed at the expense of local budget. Possible involvement of a third-party investor, which would construct and operate the WIP at its own expense against guarantee of certain profitability, is considered in this case. The article provides financial and economic model of this project.

1. Introduction

Today, global environmental issues are urgent for Russia too. We should admit that our country is one of the most polluted countries in the world. This has an impact on quality of living and adversely affects health of the population. Environmental issues in Russia, as well as in other countries of the world, are associated with constantly growing, intense man-made impact on the nature. This negative impact is becoming more and more dangerous and aggressive. These issues are recognized at the highest governmental level. This is evidenced by the Decree of the President of the Russian Federation published in January 2016 on the “Year of Ecology” in 2017 [1] to draw attention of the general public to the Russia’s environmental development issues, preserving biological diversity of wildlife, flora and fauna and, of course, ensuring environmental safety. Please note that one of the most important and urgent tasks in environmental safety, development and functioning of housing and utility complex in Russia is disposal of domestic waste.

2. Materials and methods

Currently, Russia produces 55–60 mln tons of solid domestic waste (SDW) annually [4, 5]. Up to 400 kg of waste per year accounts for a person on the average and the amount of SDW per capita is steadily increasing. Growth of waste generation is inextricably connected with improvement of social
welfare, that is, there is a correlation between GDP per capita dynamics and specific waste generation, and if not resolved, the situation in SDW sector can result in serious environmental implications. SDW processing level in Russia is only 5–7%, while the European Union countries process up to 90% and over. Thus, more than 90% of waste in Russia is sent to landfills and unauthorized junkyards while the amount of accumulated waste is continuously growing. SDW removal and processing/incineration dynamics in Russia, as well as a significant gap between these parameters is very revealing, which is clearly illustrated and shown in Fig. 1.

![Figure 1. Dynamics of SDW removal and processing/incineration in Russia](image_url)

Unlike Russia, a significant reduction in the share of SDW burial due to processing is a general European trend [4, 5]. Comparative statistics on the dynamics of SDW generation and burial on landfills in the EU countries and Russia for the period of 2000–2014, in kg per one inhabitant per year, are shown in Table 1.

| Country | 2000 | 2005 | 2010 | 2012 | 2013 | 2014 | 2014, as % of the year 2000 |
|---------|------|------|------|------|------|------|---------------------------|
| Total by 28 EU countries | generated/collected | 521 | 515 | 503 | 485 | 477 | 475 | 91.17% |
| | buried | 220 | 185 | 154 | 143 | 132 | | |
| Austria | generated/collected | 580 | 575 | 562 | 579 | 578 | 565 | 97.41% |
| | buried | 196 | 65 | 18 | 25 | 23 | 23 | 11.73% |
| Belgium | generated/collected | 612 | 588 | 554 | 460 | 432 | 442 | 72.22% |
| | buried | 91 | 56 | 8 | 5 | 4 | 4 | 4.40% |
| Bulgaria | generated/collected | 612 | 588 | 554 | 460 | 432 | 442 | 72.22% |
| | buried | 400 | 411 | 411 | 318 | 298 | 307 | 76.75% |
| UK | generated/collected | 577 | 587 | 509 | 477 | 482 | 482 | 83.54% |
| | buried | 468 | 374 | 234 | 177 | 164 | 134 | 28.63% |
| Hungary | generated/collected | 446 | 461 | 403 | 402 | 378 | 385 | 86.32% |
| | buried | 366 | 383 | 284 | 263 | 244 | 221 | 60.38% |
| Germany | generated/collected | 642 | 565 | 602 | 619 | 609 | 618 | 96.26% |
| | buried | 167 | 48 | 3 | 1 | 8 | 9 | 5.39% |
| Denmark | generated/collected | 610 | 662 | 673 | 750 | 752 | 759 | 124.43% |
| | buried | 66 | 38 | 23 | 16 | 13 | 10 | 15.15% |
| Spain | generated/collected | 658 | 588 | 510 | 468 | 454 | 435 | 66.11% |
| | buried | 337 | 288 | 318 | 284 | 253 | 240 | 71.22% |
To date, there are about 250 waste-processing plants, 50 waste sorting facilities and only 10 waste incineration plants with low production capacity in Russia.

It should be noted that most of waste is incinerated not in all countries, its major part is sorted and processed and/or reused (Table 2) [4, 5].

**Table 2. Share of SDW incineration in developed countries**

| Country   | Population, mln people | SDW, mln tons per year | Number of WIPs | Share of SDW incinerated, % |
|-----------|------------------------|------------------------|----------------|-----------------------------|
| Switzerland | 7                      | 5.1                    | 29             | 79                          |
| Japan      | 123                    | 44.5                   | 1900           | 72                          |
| Denmark    | 5                      | 3.7                    | 32             | 65                          |
| Sweden     | 9                      | 3.9                    | 21             | 59                          |
| France     | 56                     | 28.6                   | 100            | 41                          |
| Netherlands| 15                     | 7.9                    | 9              | 39                          |
| Germany    | 61                     | 37.7                   | 51             | 33                          |
| Italy      | 58                     | 28.3                   | 51             | 17                          |
| USA        | 248                    | 180.0                  | 168            | 16                          |
| Spain      | 38                     | 16.5                   | 21             | 6                           |
| UK         | 57                     | 27.4                   | 7              | 5                           |
| Russia     | 146                    | 56.5                   | 10             | 2.4                         |

To date, most of the wastes in our country are buried, i.e. they are dumped on open landfills and junkyards, often not even equipped with special protection against pollution of soil, water and surrounding areas. Currently, there are over 14,700 authorized waste sites in the country and they occupy an area of about 4 mln ha [3, 4], which is comparable to the territory of Switzerland and the Netherlands, and 400,000 ha of land are allocated annually to accommodate increasing SDW volumes, which is 40% more than the area of Luxembourg. In addition to withdrawal of considerable land resources from economic turnover, the landfills pollute the atmosphere, surface soil layers, groundwater and earth, adversely affect flora and fauna, and impair living standards at nearby territories. Due to the lack of separate collection and disposal system of toxic components-containing
waste, scale of environmental pollution with hazardous substances is increasing. When dumped on landfills, tons of valuable raw stocks and materials, such as paper, glass, metals, plastic, etc., are irretrievably lost. According to some experts, these components account for more than 40% of SDW, that is, about 15 mln tons per year. According to some estimates, total volume of the market for processing individual components of this waste mass, especially waste paper, which is a larger part, may exceed 1 bln euro annually. The diagrams of SDW composition in different countries are revealing [7], Fig. 2.

![Diagram of SDW composition in some countries](image)

**Figure 2.** SDW composition in some countries

In addition, SDW could be used as alternative fuel at waste incineration plants to generate electric and thermal power.

The nation’s leadership and society agree that waste management requires systemic reforms aimed at reducing negative impact on the environment, improving environmental situation in settlements and increasing efficiency of resource use.

A very revealing example evidencing topicality of the issue is the request of the residents of Balashikha city near Moscow during live call-in with the President of the Russian Federation on June 15, 2017 on elimination of the waste landfill located 20 kilometers from the Kremlin and visible from space. Eight days later, by the direct order of Putin, the landfill operation in the Kuchino microdistrict in Balashikha city was shut down, but the problem was not solved in global terms, since waste flows were simply redistributed to other landfills [8]. While 40 million tons of waste on that landfill have remained in place. According to the Ministry of Environment of Moscow region, fifth part – 11.7 mln tons out of 55–60 mln tons of all SDW generated in Russia per year – accounts for the metropolitan area (3.8 mln tons – vicinities of Moscow, 7.9 mln tons – Moscow). And 6.6 mln tons of domestic waste is removed beyond the Moscow ring highway. Thus, more than 10 mln tons of waste are accumulated in vicinities of Moscow. Since 2013, 24 out of 39 landfills have been closed in the Moscow region. Newly built waste sorting facilities (in 2018–2019) and several waste incineration plants (until 2023) should replace them.

Currently, specific ways of how to dispose SDW divide discussants into irreconcilable opponents. In fact, two options of waste processing are argued: sorting or incineration.

Over the past 10–15 years, “swords have been crossed” many times in these discussions but neither of parties has given a “watertight argument” allowing to choose an option. The main arguments of incineration opponents concerning harmfulness of waste combustion products are refuted by the fact that incineration plants are common for Europe. Many of them are located near major cities, and the most famous one is located in the center of the Austrian capital – Vienna, Fig. 3. The Vienna waste incineration plant became a real credit to Austrian capital population. It is both useful for the city and nature in general, and beautiful.
We should keep in mind that safety of such plants is achieved by the strictest adherence to process, long-term environmental education of population, including legislative requirement of waste separate collection. In many European countries, waste is sorted in four, and in some places and in eight categories by residents themselves, i.e. each house has garbage cans nearby for glass, plastic, paper, food waste, metal, etc., and residents pre-separate their garbage into categories. Attempts to introduce such a mechanism in Russia are unlikely to succeed because of low environmental consciousness of the population. In fact, we must start with the ban on garbage chutes in our homes. Moreover, it is very difficult to ensure at least four containers available for pre-separation of domestic wastes in kitchens with an area of 6–8 m².

3. Goals
This article is not aimed at being involved in discussion from the point of environmental impact of a particular solution on waste disposal issue. The proposed article presents preliminary calculations of economic impact for population and/or municipal budgets when switching over to SDW processing by incineration at a constructed incineration plant.

Methods of research. Financial and economic analysis methods were used for the study. A waste incineration plant processing 350 thousand tons of SDW per year, which includes a thermal power plant operated by SDW incineration power with 24 MW installed capacity is chosen as an object for calculation. Due to the fact that no incineration plants have been constructed in Russia in recent years, it is impossible to obtain specific data on the cost of equipment for WIP from open sources. Various sources give approximate enterprise cost parameters depending on its waste processing capacity. Various sources give approximate enterprise cost parameters depending on its waste processing capacity.

The following parameters are taken as initial data for calculations.
1. Plant capacity is 350 thousand tons of SDW disposed per year.
2. Electric power of a turbine operated by SDW incineration energy is 24 MW.
3. Range of plant construction unit cost depending on WIP capacity and manufacturer ranges from 500 to 800 euro per one ton of waste a year, excluding infrastructure (roads, administrative buildings, etc.) and connection to external networks. In the calculations, unit cost of the plant is taken as 700 euro per one ton of waste a year, connection to networks – 10% of plant construction cost. The exact cost will largely depend on WIP location. Euro exchange rate is 70 rubles.
4. Current cost of solid domestic waste disposal in the Moscow region ranges from 300 rubles per a ton of waste VAT inclusive (fixed for SDW landfill “Aleksinskiy Karyer”) up to 1,025 rubles per a ton (for the landfill “Kuchino” in Balashikha city closed in July 2017). Share of waste to be buried (after SDW incineration) is 20% of “incoming” SDW. The calculations assume that the WIP accepts SDW at a rate of one thousand rubles per one ton and disposes unburned part at a rate of 300 rubles per one ton [9].
5. Maintenance service is 2.3% of the plant cost per year. Cost of reagents for smoke purification is taken at a rate of 30% of the annual maintenance service cost.
6. Consumption of electric and thermal power generated for own needs during plant production activities is taken in the amount of 10% of the total output. Enterprise need for gas purchase (for waste incineration), water consumption and cold water drainage during production are insignificant and are taken in the amount of 10 mln rubles per year.

7. Enterprise staff is 40 individuals. Average wage is 25 thousand rubles per month.

8. Expenses for property insurance are 0.3% of residual cost. Property tax rate is 2.2%. Annual depreciation is 6.7% (1/15).

9. Production facility technical specifications: incineration of one ton of waste produces 500 kWh of electric power and 1.5 Gcal of thermal power. Calculations show that WIP construction total cost including connection to external networks exceeds 20 bln rubles:

\[(350 \text{ thousand tons of SDW per year}) \times (700 \text{ euro/ton of SDW}) \times (70 \text{ rubles/euro}) + 10\% \approx 20.5 \text{ bln rubles.}\]

The amount is very considerable for local budget, therefore, possible involvement of a third-party investor, that would construct and operate this facility at its own expense against guarantee of certain profitability, is considered priority in this case.

Of course, investor will first of all determine the main parameters of the project: ratio of equity and borrowed capital for financing, sources of income, main expenditure areas, guaranteed income, potential profit, etc. To be specific, the following facility financing and further operation option is proposed:

1. Construction is financed by investor’s equity funds (20%) and borrowed banking capital (80%). Loan repayment period is 12 years from the date of WIP commissioning. Loan interest rate is 12% per annum subject to annual payment.

2. 15 year investment capital payback period with profitability of 12% per annum should be ensured. Payments are annuity, i.e. in annually equal installments. The investor pays for bank credit service on its own.

3. Project expenditure items consist of enterprise current cost (staff, maintenance service, taxes, insurance, etc.), including disposal of unburned SDW part (300 rubles per one ton at the “cheapest” landfill).

4. Project income consists of payment received for SDW disposal (at a rate of 1,000 rubles per a ton of SDW), as well as sale of electric and thermal power at current wholesale prices.

5. If current operation profit of the WIP does not provide required profitability for the investor, the budget “additionally pays” subsidies to the investor to reach the agreed income.

6. WIP construction takes two to three years. Operation starts in 2021.

7. Inflation rate as well as projected parameters for electric and thermal power tariffs and gas prices growth are taken from the “Long-term forecast of social and economic development of the Russian Federation up to 2030” (source: Ministry of Economic Development of Russia) [10]. The parameters of the years 2031–2035, which are not determined in the Forecast, are taken at the level of 2030.

4. Study results

Based on the above initial data and WIP construction and operation financing main parameters, a financial model of the project was built. The final calculations are shown in Table 3.

| Table 3. Key figures and main results of calculations based on the financial model |
|-----------------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Macroeconomic figures Source – MED of Russia | Year    | 2017    | 2018    | 2019    | 2020    | 2021    | 2022    | 2023    | 2024    | 2025    |
| Inflation                                     |         | 1.045   | 1.041   | 1.036   | 1.032   | 1.028   | 1.027   |         | 1.021   | 1.020   |
| Thermal power                                 |         | 1.055   | 1.055   | 1.055   | 1.053   | 1.050   | 1.050   |         | 1.021   | 1.021   | 1.021   |
| Gas                                           |         | 1.048   | 1.047   | 1.045   | 1.043   | 1.038   | 1.034   |         | 1.020   | 1.020   | 1.020   |
| Electric power | 1.051 | 1.038 | 1.037 | 1.013 | 1.028 | 1.027 | 0.991 | 0.991 | 0.991 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |

**Capital investments (VAT inclusive), mln rubles**

| Year | 2018 | 2019 | 2020 | 2021 | 2022 |
| --- | --- | --- | --- | --- | --- |
| Disbursement schedule | 100% | 10% | 50% | 40% | |
| Total capital investments, VAT inclusive | 20 541 | 1 784 | 10 169 | 8 587 | |

**Financial results, mln rubles**

| Equity capital | 20% | 356 | 2 033 | 1 717 | |
| Borrowed capital | 80% | 1 427 | 8 135 | 6 869 | |

**Financial results, mln rubles**

| Receipts from sales, | 1 009 | 1 047 | 1 349 | 1 371 | 1 392 |

including by sources of income:

| SDW receiving | 339 | 348 | 439 | 448 | 457 |
| Sale of electric power | 201 | 207 | 232 | 230 | 228 |
| Sale of thermal power | 468 | 491 | 677 | 691 | 706 |
| Prime cost, | 2 315 | 2 298 | 2 104 | 2 087 | 2 070 |

including by categories:

| Gas | 5 | 5 | 7 | 7 | 7 |
| Water | 3 | 3 | 4 | 4 | 4 |
| Waste burial | 20 | 20 | 26 | 26 | 27 |
| Maintenance service | 403 | 414 | 523 | 533 | 544 |
| Reagents for smoke purification | 121 | 124 | 157 | 160 | 163 |
| Staff and insurance premiums | 17 | 18 | 23 | 23 | 24 |
| Depreciation | 1 273 | 1 273 | 1 273 | 1 273 | 1 273 |
| Property tax | 406 | 378 | 70 | 42 | 14 |
| Insurance | 57 | 53 | 11 | 7 | 3 |
| Other expenses | 6 | 6 | 7 | 8 | 8 |
| Revenue from sales | -1 305 | -1 251 | -754 | -716 | -678 |
| Loan interests | 13 049 | 2 084 | 1 902 | 0 | 0 |
| Pre-tax profit | -3 389 | -3 154 | -754 | -716 | -678 |
| EBITDA | -33 | 21 | 518 | 557 | 595 |

**Required profitability of the investor and subsidy assistance, mln rubles**

| Invested capital | 20 541 |
| Annuity payment | 45 239 | 3 016 | 3 016 | 3 016 |
| Annuity income tax | 0 | 0 | 436 | 436 | 436 |
| Operating costs (without depreciation) | 1 041 | 1 025 | 831 | 814 | 798 |
| Investor’s RGP (required gross proceeds) | 4 058 | 4 042 | 4 283 | 4 266 | 4 249 |
| Proceeds without subsidies | 1 009 | 1 047 | 1 350 | 1 371 | 1 393 |
| Subsidy | 44 048 | 3 049 | 2 994 | 2 933 | 2 895 | 2 856 |
| Subsidy in terms of SDW disposal cost, rubles/ton | 8 710 | 8 556 | 8 380 | 8 271 | 8 161 |

For clarity, we present some calculation results in the form of plots.
5. Conclusion. Findings

First of all, it should be noted that EBITDA resulting from the calculation is positive, i.e. plant operation activity, without taking into account service and attracted investment capital repayment cost, is profitable. However, there is always a price to pay and the facility cannot appear “out of nowhere”.

Therefore, the calculations take into account construction costs repayment.

At existing waste disposal and thermal-electric power generation prices, construction of a new waste incineration plant is cost-inefficient. Such a project will not be repaid without significant subsidies. In fact, the budget should pay the investor more than twice the cost of the plant as subsidies for the first 15 years of operation. To increase project profitability, it is necessary to reduce the project costs and/or increase the revenue items. Since it is currently impossible to find ways to reduce operating costs for current activity of the WIP without detailed analysis of production process, the main way of reducing the expenditure items is to find an opportunity to independently finance the project by the budget, without borrowed capital. This will allow to reduce the total amount of...
investment expenditures more than two times. However, the amount of 20 bln rubles should be provided within two to three years at the first stage of construction.

Increase in the project revenue items is possible by increasing proceeds from sales due to tariff growth. Table 4 shows the results of calculations showing the level of increase in the cost for each income source needed to ensure project breakeven. Only one parameter changes in each option, while the value of the other two is kept at the level of initial calculations.

| Income source                      | Product cost in the basic option, rubles | The cost required to ensure project breakeven, rubles | Growth of product cost, % |
|------------------------------------|------------------------------------------|-----------------------------------------------------|--------------------------|
| SDW receiving, rubles/ton          | 1 000                                    | 8 350                                                | 835%                     |
| Sale of electric power, rubles/kW*h| 1.35                                     | 18.70                                                | 1 385%                   |
| Sale of thermal power, rubles/Gcal | 950                                      | 5 600                                                | 589%                     |

Table 4. New tariffs by WIP income sources for project breakeven

Taking into account that such tariffs (subject to annual confirmation by different authorities) should be provided to the investor within 15 years of plant operation. After assessing risks, investor will likely not agree to participate in such project. Alternative way to raising tariffs in the form of multibillion subsidies from the budget is even less attractive, because the project becomes “administrative” rather than market-based. Moreover, investor becomes a major debtor of banks for a long period, provided that loan repayment entirely depends on the budget.

Nevertheless, waste issue in major cities of the country central regions become not just “hot”, but “burning”. Before long we are likely to experience an environmental disaster similar to that in Ukraine (Lvov city, 2016), when shutdown of a local landfill due to its overflowing resulted in Lvov being strewn with litter, since utility providers had to remove it for hundreds or even thousands of kilometers. Sooner or later (but no one really wants it becomes “too late”), our government realizes that we cannot solve this issue without government involvement, including financing most of the costs. In terms of waste processing, we have to follow Europe anyway. To illustrate the direction Fig. 6 clearly shows the situation with regard to SDW generation and burial in landfills in the EU countries and Russia as of 2014. (the data are taken from the table 1 at the article beginning).

Figure 6. Ratio of SDW generation and burial in landfills in the EU countries and Russia as of 2014, kg per inhabitant per year
Thus, taking into account the above, it may safely be said that it is necessary to decide immediately at the highest level on state financing of waste sorting, -processing, incineration facilities or their combination.

Reports about centralized allocation of funds in the amount of 243.4 bln rubles for construction of four waste incineration plants in Moscow region and one in Tatarstan give grounds for hope to break the deadlock. It is assumed that 50% of investments will be returned through increased payments of the wholesale power market, 50% — at the expense of the regional consumers. Based upon calculations of the association NP Market Council, consumers will pay 300.7 bln rubles in 2020–2035 for incineration thermal power plants capacity [11, 12].

Unfortunately, there still is no specific information on estimated incineration capacity of projected WIPs, but if we take for example the plant parameters from this article, then 30 plants will be required for complete processing (incineration) of waste in the Moscow region (with a capacity of 350 tons of waste a year).

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