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## Research Article

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# Electricity Generation Forecast of Shanghai Municipal Solid Waste Based on bidirectional long and short time memory Model

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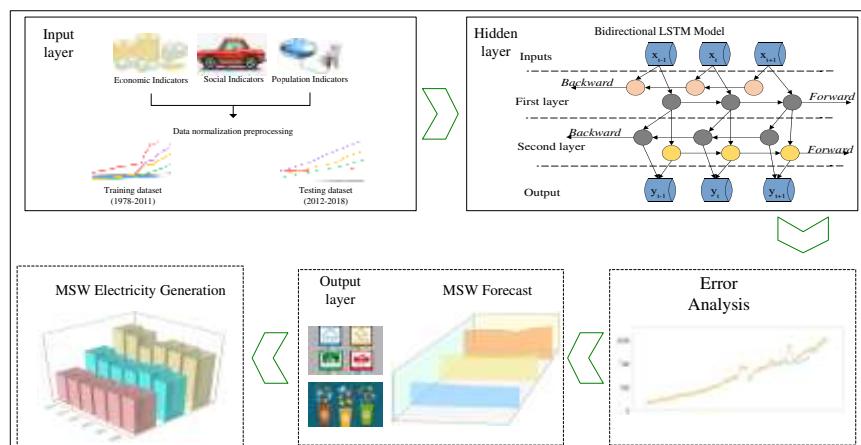
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## Abstract

Accurate prediction of Municipal Solid Waste electricity generation is very important for the fine management of cities. In this study, Shanghai was taken as the research object, and six influencing factors of Municipal Solid Waste production were used as input indexes to realize the effective prediction of Municipal Solid Waste production through constructing a neural network model based on bidirectional long short term memory. At the same time, based on the predicted results and the forecast formula of MSW electricity generation, this study realized the harmless treatment of Municipal Solid Waste in Shanghai. Firstly, the economic, demographic, and social indicators related to Municipal Solid Waste were determined. Secondly, the bidirectional long and short time memory model is used to learn the features of the input indexes. Finally, the electricity generation capacity of Shanghai municipal solid waste in the next six years is predicted with the municipal solid waste electricity generation formula. The experimental results show that, firstly, the MAPE value of the bidirectional long and short time memory combination model established in this paper is 7.390, and the prediction performance of this model is better than that of the other five structural methods. Second, it is predicted that in 2025, the maximum electricity generation of Shanghai Municipal Solid Waste under the three scenarios will be 512752MkW, and the minimum electricity generation of Shanghai Municipal Solid Waste will be 260668MkW. Finally, this paper can be used as a scientific information source for environmental sustainability decision-making of domestic Municipal Solid Waste electricity generation technology.

## Graphic Abstract



**Keywords:** power from biomass; electric power generation ; municipal solid waste (MSW); bidirectional long short-term memory; waste to energy

### **Statement of Novelty**

In this paper, the MSW in Shanghai is taken as the research objective. Six other major GDP, per capita disposable income, per capita consumption expenditure, population density, year-end resident population and the number of urban public transport vehicles are chosen as input indicators, and a method based on bidirectional and long short-term memory networks (BI-LSTM) is proposed to predict the MSW production.

### **1. Introduction**

With the growth of the world population, economic development, and the acceleration of urbanization, MSW has increasingly become the focus of attention (Shareefdeen et al., 2015). At present, the large amount of municipal solid waste and improper disposal are the most challenging environmental problems faced by all countries in the world, and it is also one of the important problems of fine urban management in China. From the source point of view, MSW comes from the garbage collected from family, industry, business, construction, and urban sources, and its production is mainly closely related to human behavior and activities (World-Energy-Council., 2019). From the perspective of urban solid waste treatment methods, they are landfill, incineration, and composting respectively. In the total garbage removal volume, landfill accounts for 52%, incineration accounts for 45%, and composting only accounts for 3% (NBSC, 2018). China urgently needs to accurately predict the amount of municipal solid waste (MSW) production and then accurately predict the power generation of MSW, which can help bridge the gap between a sustainable environment and energy supply. It can not only reduce the amount of waste sent to landfill, but also generate useful electric energy to achieve sustainable urban development (Lausselet C. A. et al., 2016).

In the face of the growing urban living garbage produced by complex challenges, China's urban living garbage management invested a lot of energy and technology development, both to conform to the national policy and try to reduce solid waste landfill area, seeking the right life garbage disposal methods, so the waste incineration power generation in our country urban living garbage management plays a more and more important role, garbage output accurate prediction can meet some energy needs, and ensure the effective management of municipal solid waste, to overcome the environmental pollution. At present, research methods used in the forecast of household waste power generation are mainly divided into the traditional statistical prediction method (Lionel P. Joseph et al., 2020), time series prediction method (Wu et al., 2020), and combination prediction method (Gao S et al., 2020). The traditional statistical forecasting method is based on MSW, and the quality of combustible waste

in MSW is used to calculate and predict the power generation of MSW (Ayodele T.R. et al., 2017). Because the waste composition index is not fixed, the forecast range of MSW power generation is unstable and the accuracy is not high. Time series prediction method effectively solves the complication of statistical methods and has been successfully applied to various complex nonlinear organic solid waste-related problems, with a higher prediction accuracy than the traditional statistical prediction method (Hao-Nan Guo et al., 2020). Although the single model has made a breakthrough in prediction accuracy, it still cannot reach a satisfactory height. On that basis, Miyuru Kannangara et al.(2018) used the combination model of decision tree and neural network to predict the power generation of municipal solid waste in Canada and found that the combined prediction method had better prediction performance compared with the single prediction method. At present, it is urgent to optimize the research basis to predict the power generation of MSW. In the latest research, the deep learning method has been gradually applied to the prediction process of MSW power generation, but the prediction accuracy of the simple short and long time memory neural network model is often lower than that of the combined model prediction method.

In this study, a bidirectional short and long time memory network (BI-LSTM) combined model was established to predict the municipal solid waste (MSW) production in Shanghai from 2020 to 2025 using six key influencing factors to reduce the uncertainty of the prediction model. Secondly, based on the forecast results of MSW production, this study further predicts the power generation of MSW and puts forward appropriate suggestions for sustainable environmental development. The contributions of this study mainly include three aspects :(1) the combined prediction model of MSW production based on BI-LSTM was established;(2) National economic indicators (GDP, per capita disposable income, per capita consumption expenditure), population indicators (population density, year-end resident population) and social indicators (the number of urban public transport vehicles) are taken as input indicators, and the new combination model is used to improve the prediction accuracy.(3) Combined with the development situation of the region and based on the known data of the forecast result of municipal solid waste production, the electricity generation of municipal solid waste is reasonably predicted, and then the optimization scheme of municipal solid waste disposal is put forward to save the urban land area and improve the environmental quality.

## 2. Literature review

### 2.1 Research on the influencing factors of MSW Electricity generation

Urban solid waste (MSW) power generation is a complex process, mainly including urban solid waste (MSW) production volume transportation, collection and classification, urban solid waste incineration, waste heat power generation, pollutant treatment, and other aspects. The power generation of MSW is mainly affected by the

production of combustible part of MSW in solid waste. The research on the influencing factors of MSW mainly focuses on the three aspects of the economy, society, and population. Among them, the economic indicators commonly used by scholars include GDP(Batool et al.,2008; Linzner and Salhhofer,2014), per capita consumption expenditure, per capita disposable income (Kaza et al., 2018), the consumption level of residents, total retail sales of consumer goods (X. Cuong Nguyen et al., 2021), Social indicators include the number of urban public transport vehicles, green space area, road area and urban green coverage rate (Pauliuk, 2018), while population indicators include population number (Kannangara et al., 2018) and population density (Adamovic 'et al.,2016). The influencing factors of MSW power generation required in this study are determined by scholars' existing research results.

Besides, some scholars have further studied the relationship between MSW production and the main influencing factors. Lakioti et al. (2017) studied the impact of social, economic, and demographic factors on a small scale (i.e., family level or urban unit), and adopted factors including family size, education level, socioeconomic status, and income level (Kamran et al., 2015; Suthar and Singh, 2015), together with age, household employment, and population per household (Bandara et al., 2007; Monavari et al., 2012) and seasons (Kamran et al., 2015). The study of Ogwueleka(2013) shows that solid waste generation is strongly positively correlated with family size, income level, and high-income groups. The family size of high-income groups is significantly different from the daily average per capita household waste output, and the consumption pattern of families will be affected, leading to changes in the composition and quantity of household solid waste. Khan et al.(2016) evaluated household solid waste generation from different socio-economic factors such as education, occupation, family income, and a number of family members. The rate and composition of municipal solid waste were closely related to various socio-economic parameters of the community, and the results showed that the medium socio-economic group produced the largest amount of solid waste. Wang K.F. et al. (2020) by utilizing the method of ESDA analysis, green coverage, the industrial structure, population density of road, the function of urban life garbage output found, technology, population urbanization, and greening coverage harms urban living garbage, and industrial structure, bed number and per capita roads is the density of urban living garbage produced by drivers. Cheng relationship et al. (2020) studied the GDP, population size, education level, gas permeability, and the third industry of indicators such as the relationship with the city life garbage output, found that population growth and urbanization promotes the production of urban living garbage, the increase of gas permeability reduced emissions of urban living garbage, at the same time, the proportion of the tertiary industry and the proportion of urban living garbage has significant positive correlation. The innovative point of this paper is to analyze the power generation of MSW and the main impact indicators.

## **2.2 Research on forecast model of MSW Electricity generation**

The prediction of the power generation of MSW is based on the calculation of the combustible component of MSW. Incineration releases a large amount of heat, and the captured heat is used to generate steam in the boiler, which drives the steam turbine to generate electricity. In the face of severe urban life "garbage siege" situation, to achieve the goal of solid waste treatment, it is necessary to effectively grasp the current situation of household waste production and reasonably deal with the risks and challenges existing in the future increase of household waste. Therefore, the predictive model is applied to solid waste treatment, and the ability of the predictive model to independently acquire and integrate the knowledge system is used to make informed decisions in the new situation of household waste generation in the future.

By comparing, selecting, and improving the models, a more accurate prediction model is obtained. Modeling methods mainly include linear regression method (Mushtaq J et al., 2020), support vector machine (Abbasi and Elhanandeh, 2016), artificial neural network (Li Z S et al., 2011; Kolekar et al., 2016; Goel et al., 2017). These models do not fully consider the long-term correlation between the input samples, so the ability to improve the accuracy of the MSW power generation prediction model is also very limited. Sunayana et al. (2021) used nonlinear autoregressive (NAR) to predict the monthly MSW production in Nagpur (India) in 2023, and established a classical multiplication decomposition model with simple linear regression of time series, with a maximum error of 6.34%, overcoming the problem of data availability. Noori et al. (2009) developed an improved support vector machine model combining principal component analysis (PCA) techniques to predict weekly MSW production, whose R<sup>2</sup> was 0.75 and MRE was 3.35%. However, the SVM model is not only a small sample prediction model but also with the increase of training data, it will consume a lot of time and computer performance, affecting the generality of the model. Sun et al. (2017) built ANN neural network model with MATLAB to predict the future domestic waste power generation in Bangkok. In this case, the recursive neural network is introduced to improve the accuracy of MSW power generation prediction. RNN is a deep learning network, which has a recursive link in the network structure. The relationship between samples before and after learning can be considered, which is especially suitable for processing time-series signals. Some scholars have studied various improved methods for gradient explosion and gradient vanishing. The emergence of the LSTM neural network effectively solves the problems existing in the previous models and has achieved considerable results in the field of MSW power generation. Dongjie Niu. (2021) selected LSTM model to make long-term prediction of MSW, and considered static and dynamic change characteristics of MSW, and found that LSTM model had better prediction effect compared with ANN and SVM. At present, it is difficult for a single model to

achieve a better prediction effect, while the method of multi-model fusion is easier to improve the accuracy of the prediction model. Therefore, to accurately predict the power generation of MSW, this study constructed a BI-LSTM combination model to optimize the input indexes and improve the prediction accuracy of the model.

### 3. Methods and data sources

#### 3.1 Study area

Shanghai is China's leading economic city and financial center and is striving to become a top city and center of science and technology in the world. With the sustained, stable, and rapid development of the national economy, the demand for resources and the output of municipal solid waste are increasing day by day, which restricts the sustainable development of cities. How to properly solve the collection, transportation, and treatment of municipal solid waste has become the primary work of the Shanghai environmental protection department. In 2019, the amount of municipal solid waste in Shanghai rose to 10.38 million tons, half of them are burned, and the Shanghai municipal government has been trying to become a mature urban circulation system, set up the big four garbage classification system, the city government also issued the first Chinese city waste management regulations, by following per under the established from the source separation, the final disposal of the entire collection, recycling chain the rule on July 1, 2019, recyclable waste in Shanghai is expected to get better management. It is also important to assess the recycling capacity of recyclable waste so that a recycling system can be optimized.

#### 3.2 Basic Principles of BI-LSTM

To improve the learning ability of the traditional LSTM model, the bidirectional relationship of the input data in the time structure is considered, instead of only using a single direction of the input processing through the LSTM gate. The bidirectional LSTM model takes the current time series data into full consideration when the next information is processed. This two-way processing obtains more structural information through the gate mechanism and enhances the way of information intelligence. The BI-LSTM model encodes the information in the sequence before and after, to obtain the information characteristics of the data before and after, thus improving the generalization ability. The LSTM unit starts from the input sequence, and the reverse form of the input sequence has been integrated into the LSTM network. The BI-LSTM model generated by the forward  $h_t$  and backward layers  $\hat{h}_t$  is shown in Figure 1. Calculate Forward from time 1 to  $t$  time in the Forward layer to get and save the output of Forwarding at each time. Calculate Backward from  $t$  time to 1 time in the Backward layer to get and save the output of the Backward layer at every moment. Finally, the final output can be obtained at each moment by combining the output results at the corresponding moments of the Forward layer and the Backward layer. The mathematical expression is shown in (1)-(3) :

$$h_t = f(w_1 x_t + w_2 h_{t-1}) \quad (1)$$

$$\bar{h}_t = f(w_3 x_t + w_5 \bar{h}_{t-1}) \quad (2)$$

$$\sigma_t = g(w_4 h_t + w_6 \bar{h}_t) \quad (3)$$

Where,  $W_i (i = 1, 2, \dots)$  are six independent weight matrices, as shown below: Input the forward and backward hidden layer weights ( $w_1, w_3$ ), hidden layer to hidden layer weight ( $w_2, w_5$ ), hidden layer forward and backward output layer weight ( $w_3, w_6$ ). These six weights are repeated at each time step.  $\sigma_t$  is the final output value obtained by combining the output of the forward and backward layers.

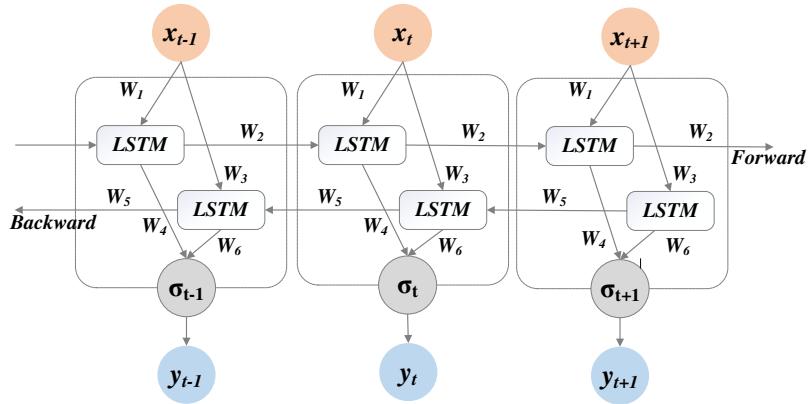


Fig. 1 Structure diagram of BI-LSTM

### 3.3 Study data

Scholars research results based on this study, collect and integrate the available three types of economy, society, and population index six factors namely, GDP, per capita disposable income of city households, at the end of urban household consumption expenditure per capita, the population of permanent residents, urban public transport vehicle operation number and population density of 246 data, data from the Shanghai municipal bureau of statistics released the Shanghai statistical yearbook from 1978 to 2018, data is shown in figure 2.

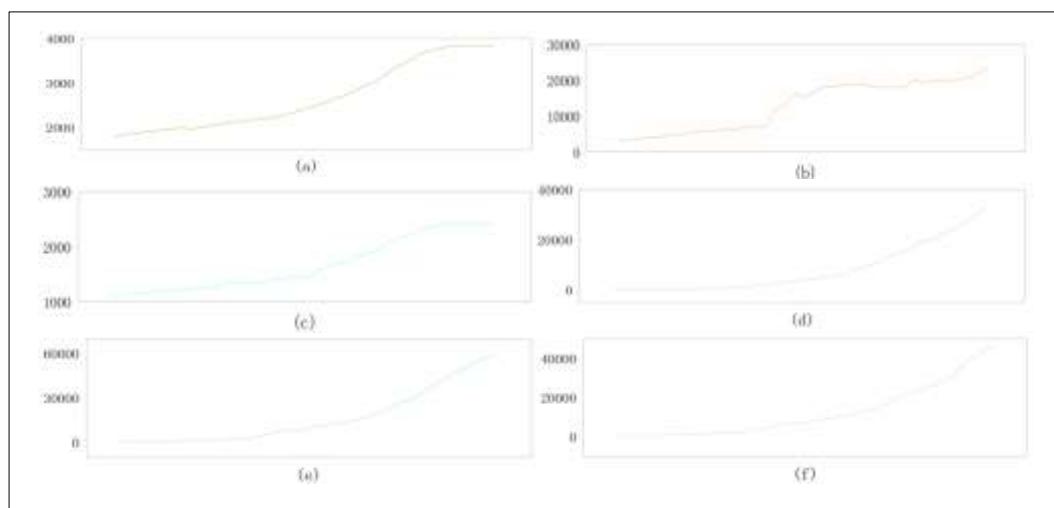


Figure. 2 Raw data

As can be seen from Figure 3 of the original data, the six indicators of regional GDP, number of public transport vehicles, per capita consumption expenditure, per capita disposable income, population density, and the permanent resident population at the end of the year all show an upward trend. See Table 1 for the detailed statistics of the data.

Table 1 Indicator statistics

	max	min	average	Std. dev
MSW	1038	108	474.54	247.95
Gross regional product	32679.87	272.81	8071.50	9595.54
Permanent resident population at year-end	2424	1098	1662.07	470.75
Per capita disposable income of urban households	60231	560	16637.90	18126.98
Per capita consumption expenditure of urban households	46015	488	12127.02	12873.64
Number of urban public transport vehicles operating	23516	2983	13011	6824.21
The population density	3823	1785	2670.78	720.99

### 3.4 Electricity generation of MSW estimation in this study

The incineration of combustible components of refuse releases a lot of heat energy. The captured heat can be used to generate steam in a boiler, which drives a steam turbine to generate electricity. Thus, the useful heat produced in a steam turbine is generated by mass combustion of usable waste parts, Mw<sub>1</sub>(or - organic matter), Mw<sub>2</sub>(paper), Mw<sub>3</sub>(Plastic), Mw<sub>6</sub>(Rubber and Textiles), Mw<sub>7</sub>(wood), can produce electricity per year E<sub>P(INC, M-b)</sub>, can be calculated as follows (Ayodele et al., 2017) :

$$E_{P(INC, M - B)} = \frac{(LHV_w \cdot M_w) \times \eta}{3.6} \quad (4)$$

Where LHV<sub>w</sub> · M<sub>w</sub> is the dot product of two vectors :LHV<sub>w</sub>=[LHV<sub>w1</sub>,LHV<sub>w2</sub>,LHV<sub>w3</sub>,LHV<sub>w6</sub>,LHV<sub>w7</sub>] and M<sub>w</sub>=[M<sub>w1</sub>,M<sub>w2</sub>,M<sub>w3</sub>,M<sub>w6</sub>,M<sub>w7</sub>]. LHV<sub>w</sub> (MJ/kg) is the waste LHV. The LHV(low humidity and high LHV) of biologically dried combustible is shown in Table 2 (Psaltis and Komilis, 2019), where LHV2 (MJ/kg) is the new energy content of biologically dried MSW components.The individual available component Mw can be obtained by using the following methods:

Table 2 Biological drying hypothesis

Waste constituents	Class	Moisture content (%) wb)	Water reduction via biodrying (%)	Organic matter reduction via biodrying (%)	LHV1 (MJ/kg)	LHV2 (MJ/kg)
Organics	W1	54.8	75	16	4.4	11.3
Paper	W2	12.2	60	8	11.7	13.2
Plastics	W3	14.8	35	0	37.7	38.1
Glass and ceramics	W4	2.4	0	0	0.0	0.0

Metal	w5	2.7	0	0	0.0	0.0
Textiles and Rubber	w6	7.8	60	6	17.2	21.0
Wood and others	W7	5.4	45	6	9.8	12.3

$$M_{W(C)} = \frac{\sum_{t=1}^n M_{W(C)}(t)}{n} \quad (5)$$

Where (C) refers to 1, 2, 3, 6 and 7, respectively, to individual waste components: organic matter, paper, plastics, rubber, textiles and wood. Annual electric energy  $E_{P(INC, RDF)}$  It is used through the burning of RDF

$$E_{P(INC, RDF)} = \frac{LHV_{RDF} \times M_{U(INC)} \times \eta}{3.6} \quad (6)$$

The  $LHV_{RDF}$  It is thought to be 17.9 MJ/kg (Psaltis and Komilis, 2019). The conversion efficiency of mass incineration is  $\eta=0.29$  (Gomez et al., 2010) and 0.26 RDF incineration (Haraguchi et al., 2019).  $M_{U(INC)}$ (tons/year) is the average mass of waste burned each year by

$$M_{U(INC)} = \frac{\sum_{t=1}^n M_{U(INC)}(t)}{n} \quad (7)$$

Type,  $M_{U(INC)(t)}$  Is the amount of waste (n)(in tons) available for incineration during the project period. See Figure 3 for the quality of waste composition under different scenarios.

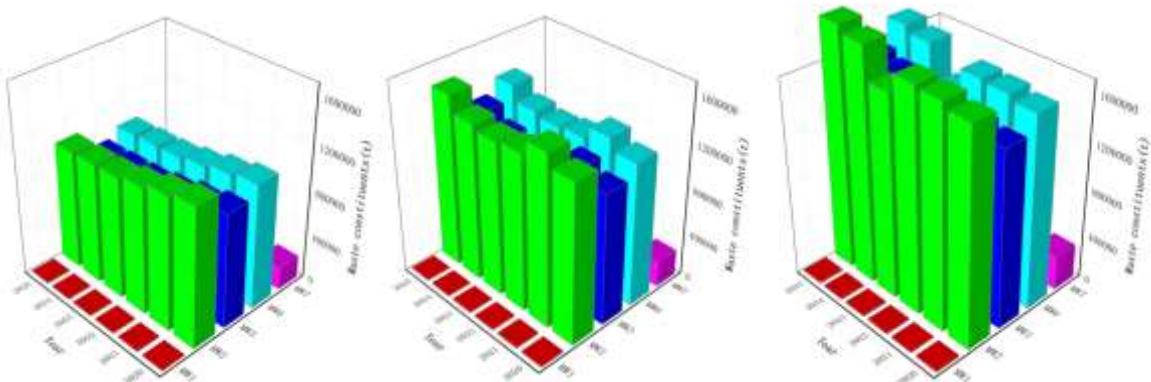


Fig.3 Quality of waste composition under different scenarios

### 3.5 Performance Indicators

Mean absolute percentage error (MAPE), root mean square error (RMSE) and mean absolute error (MAE) were used to evaluate the prediction performance and fitting degree of the model constructed in this paper. MAPE, RMSE and MAE are used to measure the difference between the simulated data and the model data, and the value range is. When the predicted value is in complete agreement with the real value, it is equal to 0. The greater the error, the greater the value.  $[0, +\infty)$

The calculation formula of average absolute percentage error is shown in (8).

$$MAPE = \frac{100\%}{n} \sum_{i=1}^n \left| \frac{\hat{y}_i - y_i}{y_i} \right| \quad (8)$$

The root mean square error calculation formula is shown in (9).

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (\hat{y}_i - y_i)^2} \quad (9)$$

The calculation formula of average absolute error is shown in (10).

$$MAE = \frac{1}{n} \sum_{i=1}^n |\hat{y}_i - y_i| \quad (10)$$

Where,  $\hat{y} = \{\hat{y}_1, \hat{y}_2, \dots, \hat{y}_n\}$  is the predicted value,  $y = \{y_1, y_2, \dots, y_n\}$  is the true value, and  $n$  is the number of indicator variables.

## 4. Results

### 4.1 Model accuracy

To effectively appraise the performance of BI-LSTM in MSW prediction, this paper adopts traditional machine learning and deep learning prediction methods as a comparative experiment. Based on the same input time series, the learning conditions of each model are tested, and their errors are compared and analyzed. In the experiment, support vector regression (SVR), gate regression unit (GRU), bidirectional and support vector regression (BI-SVR), bidirectional and gate regression (BI-GRU) were used to predict the time series, and a comparative test was carried out. Besides, the proportion of training set to test set was the same as that of the BI-LSTM model, and 5 comparative experiments were conducted. To objectively evaluate and describe the performance of the six prediction models, the prediction errors of each model are calculated according to the above formulas. The experimental results of MAE, MAPE, and RMSE of the original test set are shown in Table 3.

Among the six prediction model algorithms, LSTM has the largest prediction error, and the traditional SVR algorithm is second only to the LSTM algorithm. The values of MAE, RMSE, and MAPE of LSTM and SVR are 163.23, 19.42, 176.32, and 163.28, 19.32, 183.24 respectively. Compared with the traditional SVR algorithm, the MAPE value of the BI-SVR prediction algorithm is significantly decreased, and the prediction accuracy is significantly improved, among which the MAPE value of the BI-SVR algorithm and SVR algorithm are 14.32 and 19.32, respectively. Compared with BI-GRU and BI-SVR, the GRU and SVR algorithms have little change, but they also play a role in improving the prediction performance of the model. Compared with other algorithms, the prediction error of the BI-LSTM combined model is the smallest, and the MAPE value is 7.390.

Table 3 Performance comparison of the six prediction models

The model name	MAE	MAPE	RMSE
SVR	163.28	19.32	183.24
GRU	173.82	17.32	163.23
LSTM	163.23	19.42	176.32
Bi-SVR	128.32	14.32	132.73
Bi-GRU	123.53	18.32	125.53
Bi-LSTM	42.31	7.390	63.32

## 4.2 Predicted MSW generation

### 4.2.1 Scenarios setting

The study sets different scenarios and calculates the values of each index according to different scenarios, and then inputs the index data series under different scenarios into the prediction model to reduce the uncertainty of the model prediction. Combined with the historical data of the six indicators and the related planning of macro-economy, consumption, and population indicators, the characteristics and trends of each indicator were analyzed reasonably, to effectively predict municipal solid waste production. Based on different economic development conditions, three scenarios were established to predict the municipal solid waste (MSW) output in Shanghai from 2020 to 20256. Scenario 1 is the low-growth scenario, which will continue to maintain the recent development trend of the country and reasonably calculate the lowest non-negative growth rate of social-economic, and demographic indicators according to the historical growth rate of the data series, to predict the amount of MSW production in Shanghai. The second scenario is the benchmark growth scenario, which is based on the average year-on-year growth rate of all indicators from 1978 to 2018, which is more consistent with the development status quo, and the development trend of each indicator feature from 2019 to 2023 will also be more accurate. Scenario 3 is the high-growth scenario, which maintains a high growth rate change trend according to the changes in historical data series. Based on the data characteristics from 1978 to 2018, this study calculated the average year-on-year growth rate of each indicator and increased it by 1.2 times based on the average growth rate. The growth rates of data series in different scenarios are shown in Table 4.

Table 4 Growth rate of each indicator under different situations

Scene category	The population density	Number of urban public transport vehicles in	Permanent resident population at year-end	Gross regional product	Per capita disposable income	Per capita consumption expenditure

operation						
Scenario 1	0.0014	0.0125	0.0081	0.0137	0.0173	0.0334
Scenario 2	0.0020	0.0593	0.0280	0.0230	0.0210	0.0480
Scenario 3	0.0121	0.0745	0.0254	0.0353	0.0346	0.0545

#### 4.2.2 Forecast results of MSW prediction

In this study, by comparing the error values of a single prediction model and combined prediction model of MSW production, it was found that the BI-LSTM model had the highest prediction accuracy, and the BI-LSTM combined model was used to forecast the municipal MSW production of Shanghai in six years (from 2020 to 2025). The index characteristics under different scenarios mentioned above were input into the optimal prediction model to reasonably predict the municipal solid waste (MSW) output in Shanghai. The predicted results of MSW production under different situations are shown in Fig. 4. The first scenario shows a slow decline in MSW production, from 10.38 million tons in 2019 to 8.82 million tons in 2025. In Scenario 2, the changing trend of Shanghai MSW production was relatively gentle, decreasing from 10.38 million tons in 2019 to 11.36 million tons in 2023, and then turning point, increasing to 12.84 million tons in 2025. Overall scenario 3 is dominated by an upward trend, from 10.38 million tons in 2019 to 17.35 million tons in 2025. In conclusion, by 2025, Shanghai's municipal solid waste output will fluctuate between 8.82 million tons and 17.35 million tons.

In the scenario of baseline growth and high growth rate, although the urban solid waste production will appear at an inflection point in 2023, it will show an overall upward trend. To solve the urban waste problem, speed up the growth, promote economic and social development, in the "difference" a new stage of development, the thought of socialism with Chinese characteristics in Xi Jinping new era as a guide, fully implement the party's in the 19th and the 19th session of 2, 3, plenary meeting spirit, accelerate the living garbage classification on the classification, classified collection, classification, transport, construction of facilities for treating, filling capacity gap, improve the urban environmental infrastructure, improve the ecological environment, improve the governance ability modernization, promote the formation and adapt to economic and social development of living garbage classification and processing system, and comprehensively promote incineration capacity building; In areas where the daily garbage collection volume exceeds 300 tons, the development of incineration-oriented garbage treatment methods should be accelerated, and incineration treatment facilities should be built in advance to meet the requirements of household garbage collection volume. By 2023, "zero landfills" of untreated household garbage should be achieved.

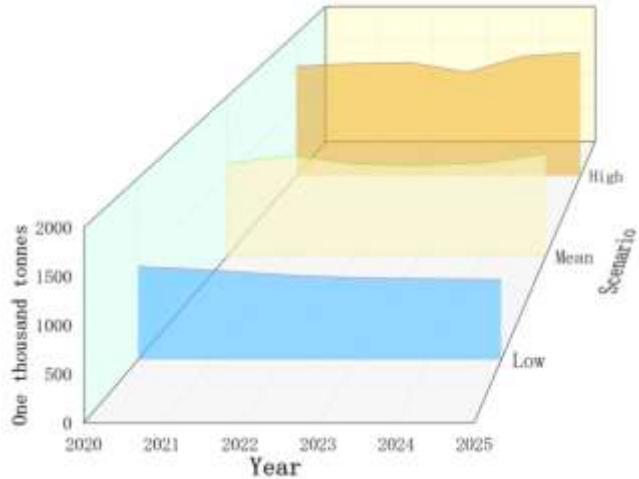


Figure. 4 Scenario prediction of municipal solid waste production in Shanghai

#### 4.3 Predicted MSW Electricity generation

During the 14th Five-Year Plan period, Shanghai will continue to improve the waste incineration capacity, which will become an important method for the disposal of MSW in the future. Therefore, it is very important to reasonably predict the power generation of MSW and improve the disposal efficiency of MSW. Based on the BI-LSTM combination model, this study predicted the amount of municipal solid waste (MSW) production in different scenarios and used the calculation formula of garbage power generation to predict the amount of electricity generated by the disposal of MSW. The estimated results are shown in Figure 5.

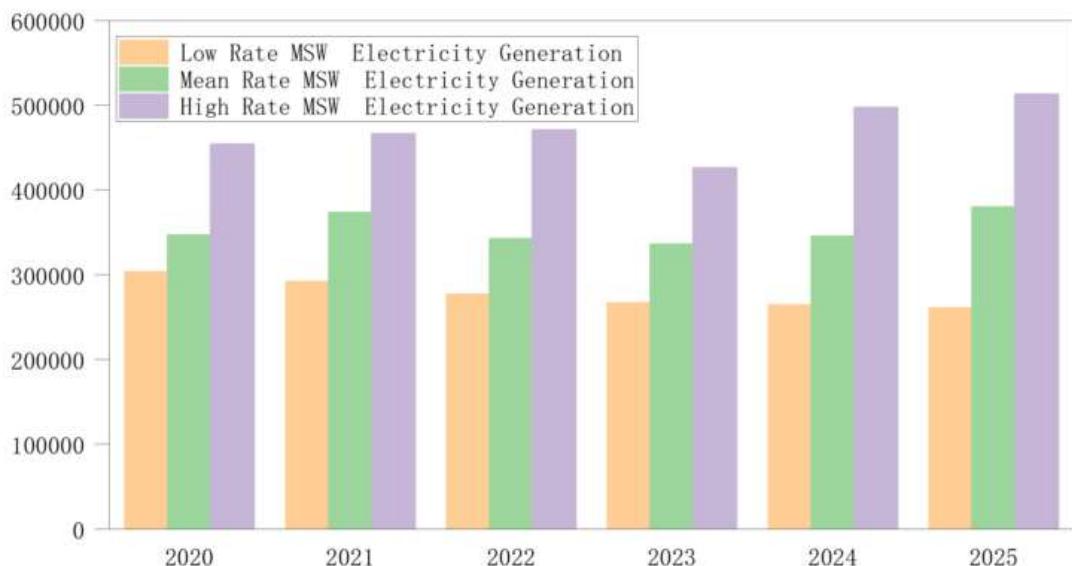


Fig. 5 Urban solid waste power generation under different scenarios

Under the low growth rate scenario, the power generation of Shanghai MSW shows a decreasing trend, and its power generation decreases from 303,217MkW in 2020 to 260,668MkW in 2025. Under the baseline growth rate scenario, the power generation of Shanghai municipal solid waste (MSW) remains stable, and the power generation of Shanghai municipal solid waste (MSW) fluctuates between

335731MkW and 379474MkW. Under the scenario of a high growth rate, the power generation of Shanghai municipal solid waste (MSW) will continue to rise. It is expected that the power generation of Shanghai municipal solid waste will decrease by the end of 2023, but overall, the power generation of Shanghai municipal solid waste will continue to increase, which is expected to reach 512,752MkW in 2025. These results indicate that MSW power generation has great energy potential.

## 5. Discussion

### 5.1 Analysis of forecast results of MSW

The continuous growth of municipal solid waste production in Shanghai in the future may be related to the following aspects. First, China's economy has enjoyed sustained and rapid growth. At the present, China's economic development model is changing from high-speed development to high-quality development, which has laid a foundation for the growth of MSW. Second, the increase of municipal solid waste is related to the rapid growth of the population. With the continuous development of cities, the population is constantly increasing. Population increase is bound to form more production activities and consumption materials, resulting in a large number of household garbage. Third, the improvement of urban construction level and the expansion of the scale, the continuous improvement of the collection and transportation facilities of household garbage, expand the range of household garbage collection and transportation, leading to the rapid growth of urban household garbage, which makes it urgent for the government to reasonably plan and use the value of municipal household garbage. Fourth, Shanghai residents living standards improve promoted the per capita disposable income and spending, Shanghai urban households consumption expenditure per capita increased from 488 yuan in 1978 to \$2018 in 46015, Shanghai urban households per capita disposable income increased from 560 yuan in 1978 to \$2018 in 60231, people purchasing power increased, and an increase in the number and variety of promoting consumption, to produce more of urban living garbage.

### 5.2 Analysis of forecast results of MSW Electricity generation

The factors affecting the generation of power generation of municipal solid waste in Shanghai are complicated, but the amount of municipal solid waste lays a solid foundation for the growth of municipal solid waste generation. The municipal solid waste (MSW) production in Shanghai shows a strong growth trend, which leads to the continuous growth of MSW power generation. MSW power generation is generated by the mass combustion of combustible components of usable MSW, so the amount of MSW production is a decisive factor in the power generation of MSW. There is a direct correlation between the amount of municipal solid waste (MSW) production and the six influencing indicators, so there is an indirect correlation between the power generation of MSW and the six influencing indicators. The population index in this paper includes the permanent resident population and

population density at the end of the year. In three different scenarios, the rise of the permanent resident population and population density at the end of the year has a promotion effect on the power generation of MSW. The economic indicators in this paper include regional GDP, per capita disposable income, and per capita consumption expenditure. Under three different scenarios, the three indicators will show an upward trend in the next six years, which will also accelerate the growth of municipal solid waste power generation. The two are positively correlated.

Improper disposal of MSW affects public health and causes harm to residents in the surrounding areas. Landfill can cause odor in different degrees, dust, wind garbage, visual noise, noise, and congestion, it also causes dissipation and pollution of land resources, the landfill of conversion efficiency is too low, 47% of the landfill leachate inappropriate problems, lead to high concentrations of pollutants, the processing is difficult (Mian et al., 2016). Due to greenhouse gas emissions, leachate, and overpopulation city land usability problems, do not conform to the requirements of the sustainable development of the environment, be badly in need of a shift from the traditional way of landfill waste power generation, compared with landfill, waste into energy, or municipal solid waste incineration power generation is a good alternative to fossil fuel combustion, the method of the technology in our country, the development of the city life garbage disposal and its resource-oriented utilization has got a big promotion, can be used as a sustainable alternative. Urban waste combustion is actually cleaner than many fossil fuels (Murtala AM. Etal.,2012), which promotes the use of domestic waste as renewable energy to generate electricity, so as to reduce the dependence on fossil fuels.

Global economic development has led to increased demand for energy, and the energy supply chain is overburdened. Fossil fuel reserves have been developed to meet high energy demand, and their burning is becoming a major source of environmental pollution. There is therefore an urgent need to find safe, renewable, and sustainable sources of energy. Waste to energy can be considered as an alternative energy source that is both economically and environmentally sustainable. Domestic waste power generation is considered a kind of renewable energy, and waste-to-energy is a win-win strategy that can not only eliminate waste but also generate energy, which has attracted extensive attention from all over the world (Samoila et al., 2017). MSW is a major contributor to the development of renewable energy and a sustainable environment. These data on power generation from MSW under three scenarios indicate that MSW incineration can be an option to contribute a larger share in the national energy matrix. In addition, the growth of mass incineration of national energy will support the insertion of intermittent renewable energy, which is required to provide a stable output of energy to the national system. Thus, MSW has a vital role to play in offsetting fossil fuel consumption and increasing the share of renewable energy.

Garbage electricity generation is one of the main methods of biomass power generation, October 22, 2016, the national ministry and the National Development and Reform Commission and other departments jointly issued "on further strengthening of urban living garbage incineration work opinion", first affirmed the household garbage incineration, and puts forward the "planning first, speed up the construction, repair as soon as possible on city life garbage disposal shortboard", "will be treated as waste incineration facilities as the maintenance of public security, promoting the construction of ecological civilization, improve the ability of government governance, and strengthen the construction of urban planning have been the focus of the management", highlights the national firm support to the determination of the burning garbage disposal. In December 2016, the National Energy Administration proposed the "Development Layout and Construction Key Points" in the "Thirteenth Five-Year Plan" for BiomASS Development, which put forward: "We encourage the construction of waste incineration cogeneration projects. Accelerate the application of modern waste incineration treatment and pollution prevention and control technologies to improve the environmental protection of waste incineration power generation. Strengthen publicity and public opinion guidance to avoid and reduce the NIMBY effect."It further reflects the country's high attention to biomass energy. In September 2020, the National Development and Reform Commission issued the "Implementation Plan for Improving the Construction and Operation of Biomass Power Generation Projects" to clarify the subsidy methods for new projects in the transitional period. In October 2020, the Ministry of Finance and other departments issued the Supplementary Circular on Subsidy Funds to the Opinions on Promoting the Healthy Development of Non-Water Renewable Energy Power Generation. The state provides practical financial support for renewable energy generation. A series of national policies will boost the generation of municipal solid waste in the future.

The development of existing MSW power generation technology will be the main trend of MSW treatment in China in the next few years, and incineration plant is likely to further develop into the mainstream application. Because of the diversity of MSW, how to effectively convert MSW into energy is the main challenge faced at present. In terms of controlling the generation of MSW, the government must strive to standardize the classification and collection of MSW nationwide, so as to achieve a balance between urbanization and waste flow. For example, we can learn from the practice of developed countries and set up a garbage collection system. There is a huge amount of municipal solid waste in China. Therefore, improving the treatment and recycling efficiency of municipal solid waste is of great positive significance to environmental protection, resource conservation, economic development, and human health protection. To further discuss the environmental protection measures of municipal solid waste treatment in order to popularize the power generation

technology of solid waste. The ideal MSW treatment technology should be a cost-effective system that promotes recycling, reduces emissions, and solves MSW treatment problems in a sustainable manner. Prudent policies should therefore be adopted to strengthen prevention, reuse, and recycling while promoting waste-generating electricity generation.

## 6. Conclusion

Improper disposal of municipal solid waste (MSW), as a significant environmental problem, restricts regional and national economic development and people's happy life. Accurate prediction of municipal solid waste production and reasonable estimation of municipal solid waste power generation can help the environmental sanitation administrative departments to plan the scale of household waste disposal facilities and land use and avoid the waste of land resources. This study first collected six indicators variables, then indicators that GDP, the number of public transport operating vehicles, the per capita consumption expenditure, per capita disposable income, population density, and at the end of the population of permanent residents as input variable input BI - LSTM combination model to forecast the Shanghai city life garbage output, and finally with the help of urban living garbage power calculation formula of a reasonable estimate of Shanghai city life garbage output, through the experiment to the following conclusion:

(1) The power generation capacity of MSW is related to the gross regional product, the number of public transport operating vehicles, per capita consumption expenditure, per capita disposable income, population density, and the permanent resident population at the end of the year, which can be used as the input variable of the model to effectively predict the power generation capacity of MSW.

(2) In this study, BI-LSTM combined model was selected to predict the municipal solid waste (MSW) production in Shanghai. The experimental results show that the MAPE of the combined prediction model is 7.390. Compared with machine learning and a single prediction model, this model can predict the MSW production in Shanghai more accurately.

(3) With the help of the calculation formula of municipal solid waste (MSW) power generation and combined with the predicted amount of municipal solid waste (MSW) production above, a reasonable power generation in Shanghai municipal solid waste (MSW) can be obtained. Based on the changes of MSW production and power generation obtained from the research, exploring new technologies and maximizing the utilization of MSW will be the main goals in the future.

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