Supplementary Information

1. Emission Factors of Construction Materials

The materials for construction wastewater treatment units considered in this study are cement, steel, timber, medium sand, gravel, cast iron pipe, steel pipe and fittings, and reinforced concrete pipe. According to the Inventory of Carbon & Energy (ICE) Database (version 1.6a), “cradle-to-gate” embodied energy and carbon coefficients for construction materials are estimated from the typical fuel mix in the relevant UK industries, as listed in Table S1 [1].

Table S1. Carbon coefficients of construction materials by ICE.

Construction Materials	Embodied Energy (MJ/kg)	Embodied Carbon(kg CO_2/kg)
Cement	4.600	0.830
Steel	24.400	1.770
Sawn timber	8.500	0.460
Medium sand	0.100	0.005
Gravel	0.100	0.005
Cast iron pipe	34.400	2.700
Steel pipe and fittings	34.400	2.700
Reinforced concrete pipe	1.080	0.153

Since the embodied energy coefficients carry a higher accuracy than the embodied carbon coefficients in ICE, the embodied energy coefficients are selected for adjustment to fuel mix of relevant industries in China. Lu and Price [2] calculated the industrial CO_2 emissions based on the industrial fuel mix, low caloric value of fuels [3] and CO_2 emission factor of corresponding fuel (Table S3 [4,5]). Materials aforementioned are falling into three main industrial categories: Timbers, Woods, Bamboo, Rattan, Palm and Straw Products; Non-metallic Mineral Products; Ferrous Metals. The aggregate CO_2 emission coefficients (kg CO_2/MJ) for these three industries are 0.083, 0.088, 0.090. By multiplying the aggregate industrial carbon emission coefficients with embodied energy coefficients of materials (products), carbon coefficients of materials for construction of the wastewater treatment facilities can be calculated (Table S4).

Table S2. Low caloric values by fuel.

Fuel Type	Low Caloric Values	Unit
Raw coal	20,908	TJ/Mt
Cleaned coal	26,344	TJ/Mt
Washed coal	15,373	TJ/Mt
Coke	28,435	TJ/Mt
Coke oven gas	17,981	TJ/billion cubic meters
Other gas	8,418	TJ/billion cubic meters
Other coking products	33,778	TJ/Mt
Crude oil	41,816	TJ/Mt
Gasoline	43,070	TJ/Mt
Kerosene	43,070	TJ/Mt

Table S2. *Cont.*

Fuel Type	Low Caloric Values	Unit
Diesel	42,652	TJ/Mt
Fuel oil	41,816	TJ/Mt
LPG	50,179	TJ/Mt
Refinery gas	46,055	TJ/Mt
Other petroleum products	38,368	TJ/Mt
Natural gas	38,931	TJ/billion cubic meters

Table S3. Carbon coefficients by Fuel and CO_2 emission factors by fuel.

Fuel Type	Carbon Coefficient (t C/TJ)	CO_2 Emission Factor (t CO_2e/TJ)
Coal	25.8	95
Coke	29.5	108
Coke oven gas	13.0	48
Other gas	13.0	48
Other coking products	21.6	79
Crude oil	20.0	73
Gasoline	18.9	69
Kerosene	19.6	72
Diesel	20.2	74
Fuel oil	21.1	77
LPG	17.2	63
Refinery gas	18.2	67
Other petroleum products	21.6	79
Natural gas	15.3	56

Table S4. CO_2 emission factors of construction materials.

Construction Materials	Embodied Energy of Materials (MJ/kg) [1]	Aggregated Industrial CO_2 Coefficient (kg CO_2/MJ) [2]	CO_2 Emission Factors of Construction Materials (kg CO_2/kg)
Cement	4.60	0.088	0.4048
Steel	24.40	0.090	2.1960
Sawn timber	8.50	0.083	0.7055
Medium sand	0.10	0.088	0.0088
Gravel	0.10	0.088	0.0088
Cast iron pipe	34.40	0.090	3.0960
Steel pipe & fittings	34.40	0.090	3.0960
Reinforced concrete pipe	1.08	0.088	0.0950

In order to reduce the uncertainties of the result, validation of the estimated emission factors of construction materials is usually required. Ecoinvent is widely used in LCA studies, so it can be used to validate the estimated emission factors in this study. As there is limited access to Ecoinvent by the authors, only emission factors of cement, steel, timber and reinforced concrete pipe from Ecoinvent can be used for validation. The results of emission factors of construction materials from Ecoinvent and this study were listed as shown in Table S5. Emission factors of timber and reinforced concrete pipe estimated in this study are very close to those from Ecoinvent. Although the other two emission factors are very different from those from Ecoinvent, they are still in the same order of magnitude. Higher average energy consumption level of Chinese steel manufactures could be the reason why emission factor of steel in this study higher is higher than that of Ecoinvent While Chinese cement industry has been undergoing large scale of upgrading on energy conservation, and the average output energy consumption has been advanced significantly, therefore, it might be contributed to the relatively lower emissions factors of cement.

Table S5. Emission factors of construction materials from Ecoinvent and the estimation of the study.

Construction Materials	Ecoinvent Database(kgCO_2e/kg)	Estimation in This Study(kgCO_2e/kg)
Cement	0.77	0.4048
Steel	1.11	2.196
Timber	0.72	0.7055
Sand	n/a	0.0088
Gravel	n/a	0.0088
Cast iron pipe	n/a	3.096
Steel pipe and fittings	n/a	3.096
Reinforced concrete pipe	0.12	0.09504

Note: n/a indicates that emission factors of those construction materials are not available for this study due to limited access to Ecoinvent Database.

2. Production of Dry Sludge

The production of dry sludge is calculated as shown in Equation (S1).

$$\Delta X = \frac{[YQ(S_o - S_e] - K_d V X_v}{f} + f_1 Q(SS_o - SS_e) \quad \text{(S1)}$$

where,

ΔX, dry sludge production, kg/day;

Y, biomass yield, kg VSS/kg BOD_5, Y = 0.6;

S_o, the influent BOD_5 level in the biological treatment unit, kg/m^3;

S_e, the effluent BOD_5 level in the biological treatment unit, kg/m^3;

K_d, decay rate, d^{-1}, $K_d = 0.05$;

V, working volume of biological treatment unit, m^3;

X_v, mixed liquid volatile suspended solid, g/L;

f, ratio of mixed liquid volatile suspended solid to mixed liquid suspended solid, f = 0.5−0.75 for sewage;

f_1, suspended solid-to-sludge ratio, g MLSS/g SS, when no pretreatment unit exists f_1 = 0.7; When there is a pretreatment unit f_1 = 0.5;

SS_o, influent suspended solid level in the biological treatment unit, kg/m^3;

SS_e, effluent suspended solid level in the biological treatment unit, kg/m^3.

3. Calculation of Biogas Production

The production of biogas by anaerobic digestion is determined by the amount of digested biosolids and the biogas production rate. The amount of digested biosolids is calculated based on Equation (S2) and biogas production is determined by Equation (S3).

$$X = (1 - P_1) \times V_1 \times P_v \times P_d \tag{S2}$$

where, X, digested biosolids in anaerobic digester, kg/day;

P_1, moisture content of raw sludge fed into digester, %;

V_1, amount of raw sludge before digestion, m^3/day;

P_v, organics content of raw sludge, %; 65% in this study;

P_d, percentage of sludge to be digested, %; 50% in this study.

$$q = a \times X \tag{S3}$$

where, q, biogas production, m^3/day;

a, biogas production rate, m^3/kg biosolids; 0.9 m^3/kg biosolids in this study;

X, digested biosolids in anaerobic digester, kg/day.

References

1. Hammond, G.; Jones, C. *Inventory of Carbon and Energy (ICE) Version 1.6a*; University of Bath: Bath, UK, 2008. Available online: www.bath.ac.uk/mech-eng/sert/embodied/ (accessed on 13 November 2014).
2. Lu, H.; Price, L. China's industrial carbon dioxide emissions in manufacturing subsectors and in selected provinces. In *ECEEE Industrial Summer Study, Arnhem, the Netherlands, September 11-14, 2012;* LBNL Paper LBNL-5575E, Lawrence Berkeley National Laboratory: Berkeley, CA, USA, 2013. Available online: http://escholarship.org/uc/item/917755dp (accessed on 15 November 2014).
3. *China Energy Statistical Yearbook 2013*; National Bureau of Statistics of the People's Republic of China, China Statistics Press: Beijing, China, 2013.
4. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Energy Workbook (Volume 2)*; Intergovernmental Panel on Climate Change (IPCC): New York, NY, USA, 1997.
5. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual (Volume 3)*; Intergovernmental Panel on Climate Change (IPCC): New York, NY, USA, 1997.