GAGARIN PROJECT

DAR Foundation — kanach.consulting

2020 Carbon Footprint

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Executive Summary

kanach.consulting was commissioned by DAR Foundation to report the greenhouse gas (GHG) inventory for Gagarin Project for 2020. This inventory was was produced in accordance with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) [13]. This inventory reports the greenhouse gases produced in, or resulting from activities, within the geographic boundaries of Gagarin Project for the year 2020.

Gagarin Project is a sustainable development program in the Geghamavan, Ddmashen, Zovaber, Tsaghkunk, and Varser communities, and Gagarin settlement of the Republic of Armenia.

Name	Gagarin Project
Country	Armenia
Region	Europe
Inventory year	2020
Geography boundary	City/Municipality
Heating degree days (HDD, °C)	4127.2
Cooling degree days (CDD, °C)	0.4
Land area (km^2) within boundary	179.45
Resident population within boundary	10,618
GDP within boundary	N/A
Type of economy	Agriculture, predominantly cattle
Climate	Cold, hot summer

Table 1: Inventory boundary information for Gagarin Project

Key findings

- In the 2020 inventory year, the communities within Gagarin Project emitted a total of 21,643 tCO_2e. They emitted 2.04 tCO_2e per capita and 121 tCO_2e per km^2.

Sector	GHGs (metric tonnes CO_2e)				% of total
	Scope 1	Scope 2	Scope 3	Total	emissions
Stationary Energy	6,113	815	0	6,928	32.0%
Transportation	1,401	0	0	1,401	6.5%
Waste	638		904	1,542	7.1%
IPPU	0			0	0.0%
AFOLU	11,774			11,774	54.4%
Total	19,925	815	904	21,643	

Table 2: Emissions summary by sector

- The largest source of emissions was the Agriculture sector making up just over 54% of total emissions, of which 98% came from cattle and sheep. It's worth noting that while these products are produced here, the majority are consumed outside of Gagarin Project's boundaries.
- The next largest source of emissions is Stationary Energy making up around 32% of total emissions, of which 35% is from the burning of manure for heat in households.

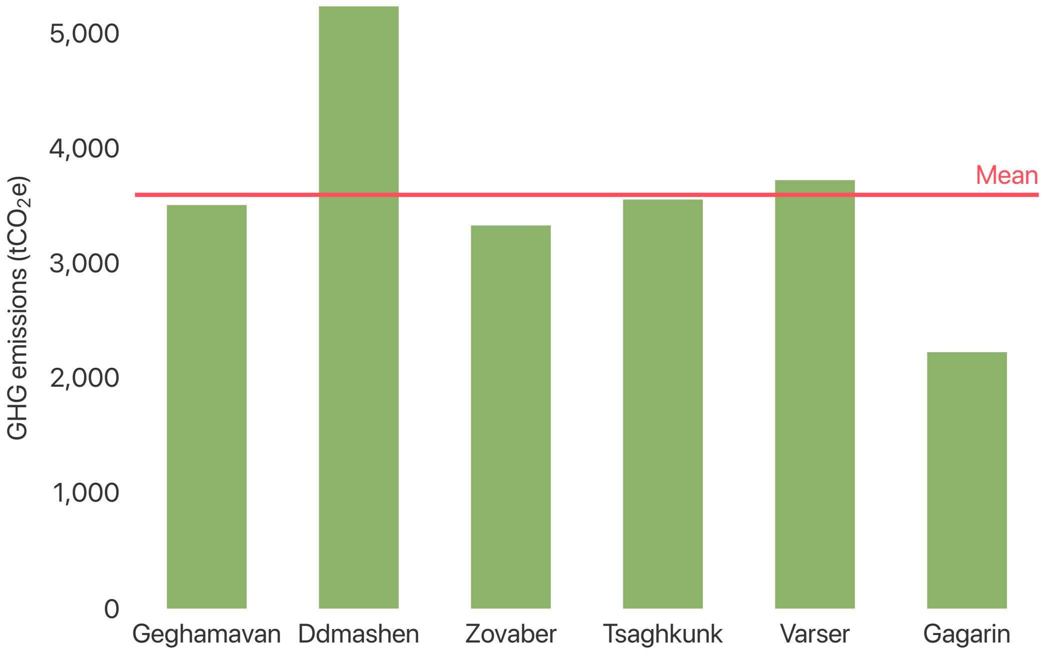
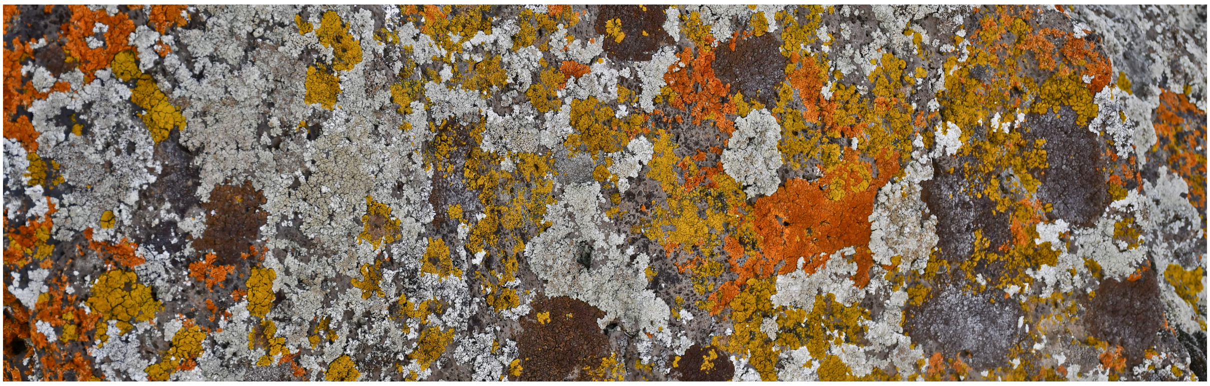


Figure 1: Emissions summary by community

- The mean emissions per community is 3,607 tCO_2e. Geghamavan, Zovaber, Tsaghkunk, and Varser all fall within 7% of this mean, while Ddmashen is about 46% more and Gagarin 38% less. The majority of this variability comes from the difference in population within the communities.



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Methodology

The inventory was compiled with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) [13] using the city-induced framework in the BASIC+ level. This includes emissions from Stationary energy, Transportation, Waste, Industrial processes and product use (IPPU), and Agriculture, forestry, and land use (AFOLU).

The emissions were measured using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [11] and its workbooks.

Emissions reported in this inventory have been rounded to the nearest metric tonne of CO_2e, while calculations done used full accuracy values. As such, sub-totals and totals may not line up with, and take presedence over, calculations from values in this inventory.

Not all emission sources required by the GPC were considered, namely:

- Stationary energy consumption in:
  - Commercial and institutional buildings and facilities
  - Agriculture, forestry and fishing activities
  - Manufacturing industries and construction
  - Non-specified sources
- Railways
- Off-road transportation
- Biological treatment of waste
- Industrial Processes and Product Use (IPPU)
- Land use and land use change
- Aggregate sources and non-CO_2 emission sources on land

These sources were excluded due to the unavailability of adequately accurate emission data, though estimates indicate that they represent a minor share of the total emissions. Nonetheless as a result, this inventory represents emissions closer to a lower boundary.

Global warming potentials

Though we usually only refer to carbon dioxide (CO_2), there are many greenhouse gases that trap differing levels of heat in the atmosphere. A molecule of methane for instance traps 28 times as much heat as a molecule of CO_2 over a 100 year period. To simplify this we report emissions equivalent to a metric tonne of CO_2, tCO_2e.

For this inventory we have chosen the 100-year GWP coefficients from the IPCC's Fifth Assessment Report [15]

Gas	Formula	GWP values (CO_2e)
Carbon dioxide	CO_2	1
Methane	CH_4	28
Nitrous oxide	N_2O	265

Table 3: GWP values

The remaining GHGs required by the GCP have not been included in this table as no sources emitting them were estimated in this inventory.

Scopes

The GPC provides a method of differentiating emissions generated within and outside of a community's boundaries, as can be seen in Table 4. Direct emissions (Scope 1) are generated within a community due to activities occuring within the community (e.g. burning CNG at homes for heat). Indirect emissions are generated outside of a community due to activities occuring within the community. Indirect emissions fall into two categories: Scope 2 emissions from the use of electricity, heat, steam, and/or cooling consumed within the community; and Scope 3 for all other emissions outside of a community's boundary due to activities within the community.

Scope	Description
Scope 1	Emissions generated within a community's boundary.
Scope 2	Emissions resulting from the use of grid supplied electricity, heat, steam, and/or cooling within the community's boundary.
Scope 3	All other emissions outside of a community's boundary as a result of activities occurring within the boundary.

Table 4: Scope definitions

Emission Factors

See Emission Factor Calculations Appendix for full calculations.

Sectors

Stationary Energy

Four sources of emissions were considered in the Stationary energy section:

- Residential buildings
  - CNG burned for heat
  - Manure burned for heat
  - Grid electricity consumed
- Fugitive emissions from the distribution of CNG to residential buildings.

– Compressed Natural Gas (CNG)

For CNG average yearly consumption values were provided by the Tsaghkunk and Geghamavan municipalities [8,9]. These were then scaled to the remaining communities by population.

*

Source	Geghamavan [8]	Ddmashen	Zovaber	Tsaghkunk [9]	Varser	Gagarin
CNG burned for heat in households (m^3)	240,000	*443,416**	*239,733**	216,000	*268,114**	*276,359**

*Extrapolated by population

Table 5: CNG burned in households for heat

Emission factors were calculated for CO_2, CH_4, and N_2O emissions per m^3 of CNG consumed using the EF in National Greenhouse Gas Inventory Report of Armenia 1990-2017 [Table 2.5-1] [5] and 2006 IPCC Guidelines [11].

$$EF_{CNG-CO_2-m^3} = 2.0356\, kg_{CO_2}/m^3 \quad (1)$$

$$EF_{CNG-CH_4-m^3} = 0.0033\, kg_{CH_4}/m^3 \quad (2)$$

$$EF_{CNG-N_2O-m^3} = 0.00011\, kg_{N_2O}/m^3 \quad (3)$$

—- Fugitive emissions

Emissions from the distribution of CNG was calculated using CIRIS [1], with *Development status: Developing*, and *NCV* and $Density_{CNG}$ values from National Greenhouse Gas Inventory Report of Armenia 1990-2017 [Table 2.5-1] [5].

– Manure

For manure emission factors were calculated for the emissions from manure burned per head of large and young cattle, respectively. Thus the activity data for manure burned was heads of cattle in each community (see AFOLU — Activity Data).

Large cattle manure burned in households for heat:

$$EF_{mb-lc-CO_2-head} = 416.6\, kg_{CO_2}/head \quad (4)$$

$$EF_{mb-lc-CH_4-head} = 1.171\, kg_{CH_4}/head \quad (5)$$

$$EF_{mb-lc-N_2O-head} = 0.113\, kg_{N_2O}/head \quad (6)$$

Young cattle manure burned in households for heat:

$$EF_{mb-yc-CO_2-head} = 297.6\, kg_{CO_2}/head \quad (7)$$

$$EF_{mb-yc-CH_4-head} = 0.836\, kg_{CH_4}/head \quad (8)$$

$$EF_{mb-yc-N_2O-head} = 0.080\, kg_{N_2O}/head \quad (9)$$

– Grid Electricity

For grid electricity average yearly consumption values were provided by the Tsaghkunk and Geghamavan municipalities [8,9]. These were then scaled to the remaining communities by population.

*

Source	Geghamavan [8]	Ddmashen	Zovaber	Tsaghkunk [9]	Varser	Gagarin
Grid electricity consumed in households (kWh)	840,000	1,283,282*	693,964*	480,000	776,120*	799,986*

*Extrapolated by population

Table 6: Grid electricity consumed in households

An emission factor was calculated for total kg CO_2e emitted per kWh grid electricity consumed from National Greenhouse Gas Inventory Report of Armenia 1990-2017 [5].

$$EF_{elec-CO_2e-kWh} = 0.1672\ kg_{CO_2e}/kWh \tag{10}$$

Transport

Only emissions from Road Transportation were considered in the transport sector. They were estimated using a Geographic/Territorial approach which includes all traffic occuring within the communities' boundaries, regardless of origin or destination. Fuel consumption values for the whole of Gegharkunik Region in the year of 2018 [14] were scaled to each community by population in 2018, then scaled to 2020 by the population in 2020.

Fuel	Geghamavan	Ddmashen	Zovaber	Tsaghkunk	Varser	Gagarin
Petrol (litres)	3,776	5,707	3,086	2,094	3,452	3,558
Diesel (litres)	77,642	117,345	63,457	43,060	70,969	73,152
CNG (m^3)	11,225	16,965	9,174	6,225	10,260	10,576

Table 7: Fuels consumed on road transportation

For CNG the emission factors from the Stationary energy section above were used.

For petrol and diesel emission factors were calculated for CO_2, CH_4, and N_2O emissions per litre of fuel consumed using 2006 IPCC Guidelines [11].

$$EF_{petrol-CO_2-litre} = 2.27\ kg_{CO_2}/litre \tag{11}$$

$$EF_{petrol-CH_4-litre} = 0.0011\ kg_{CH_4}/litre \tag{12}$$

$$EF_{petrol-N_2O-litre} = 0.00010\ kg_{N_2O}/litre \tag{13}$$

$$EF_{diesel-CO_2-litre} = 2.68\ kg_{CO_2}/litre \tag{14}$$

$$EF_{diesel-CH_4-litre} = 0.00014\ kg_{CH_4}/litre \tag{15}$$

$$EF_{diesel-N_2O-litre} = 0.00014\ kg_{N_2O}/litre \tag{16}$$

Waste

Three sources of emissions were considered in the Waste section:

- MSW generated within but disposed in UWDSs outside the communities
- MSW generated within but openly burned outside the communities
- Domestic wastewater generated and treated within the communities

– MSW

Emissions from MSW disposed in UWDSs and openly burned were calculated using CIRIS [(1)], with the following parameters:

Field	Value
Region	Asia
Sub-region & Western Asia	Middle East
(SWD) Landfill gas collection efficiency	0%
(SWD) Proportion of landfill gas collected used as energy source	0%
(SWD) Management of landfill	Unmanaged ($<$5 m deep)
(Incineration) Management	Open burning

Table 8: CIRIS waste calculator parameters

A value of 0.22 tonnes/person/year was chosen for the mass of MSW generated from The Republic of Armenia Waste Quantity and Composition Study [p.22] [(10)].

A factor of 0.71 for the fraction of MWS sent to UWDS and 0.19 for the fraction of MWS incinerated was chosen from 2006 IPCC Guideline [Gen-1, Volume 5, Chapter 2, Table 2A.1, Russian Federation] [(11)], as specified in National Greenhouse Gas Inventory Report of the Republic of Armenia for 2012 [(3)]

A value of 0.5 was chosen for the fraction of degradable organic carbon which decomposes (DOC_f) from National Greenhouse Gas Inventory Report of Armenia 1990-2017 [(5)]

For waste composition values we chose the mean of the fractions from Kotayk Solid Waste Management — Environmental and Social Due Diligence [Table 1.3] [(12)] for Kotchor and Ahpural villages, due to their close proximity to Gagarin Project's communities.

Waste fractions	% by mass
Food waste	13.5%
Garden waste and other plant debris	18.9%
Paper	3.435%
Cardboard	5.46%
PE plastics	13.025%
Other plastics	1.91%
Metal (not aluminium)	1.72%
Aluminium	0.32%
Glass	7.345%
Bulky waste	2.94%
Concrete, soil, and construction waste	22.33%
Hazardous waste	0%
Electrical and electronic waste	0.78%
Remaining waste	8.34%

Table 9: MSW composition

– Wastewater

Emissions from domestic wastewater were calculated by population using CIRIS [(1)], with the following values:

Field	Value
Proxy country for protein consumption	Armenia
Garbage disposals	No garbage disposals
Climate (wet/dry)	Dry

Table 10: CIRIS wastewater calculator parameters

The following values were chosen from National Greenhouse Gas Inventory Report of Armenia 1990-2017 [5]:

- T_j = Degree of utilization (ratio) of treatment/discharge pathway or system, j
  - 0.95 in dry latrines < 3-5 persons
  - 0.05 in open untreated sewers
- BOD = 50 g/person/day
- Correction factor for industrial discharge = 1

Industrial processes and product use (IPPU)

Emissions from IPPU were not considered.

AFOLU

In the AFOLU sector only emissions from the Livestock sector were considered. A headcount for the following animals were provided by the respective communities' municipalities. Values in *italics** weren't provided by the municipalities and therefore were scaled from the other communities by population.

*

Animal	Geghamavan [8]	Ddmashen [6]	Zovaber	Tsaghkunk [9]	Varser	Gagarin [7]
Cows	476	666	*460**	582	*514**	140
Bulls	24	18	*19**	30	*21**	132
Young cattle	*440**	654	*457**	500	*511**	*129**
Sheep	1,642	2,100	*1,412**	1,555	*1,579**	35
Horses	7	20	*16**	33	*18**	1
Pigs	298	688	*297**	127	*332**	34
Chickens	4,389	10,252	*4,816**	3,427	*5,387**	707

*Extrapolated by population

Table 11: Livestock head count

Emission factors from National Greenhouse Gas Inventory Report of Armenia 1990-2017 [5] were used for enteric fermentation by cows, bulls, young cattle, and sheep.

$$EF_{enteric-cow-CH_4-head} = 68.9\,kg_{CH_4}/head \tag{17}$$

$$EF_{enteric-bull-CH_4-head} = 70.1\,kg_{CH_4}/head \tag{18}$$

$$EF_{enteric-yc-CH_4-head} = 42.3\,kg_{CH_4}/head \tag{19}$$

$$EF_{enteric-sheep-CH_4-head} = 5.6\,kg_{CH_4}/head \tag{20}$$

Emission factors for enteric fermentation by horses and swine, and manure management of cattle, sheep, horses, swine, and chickens were calculated using 2006 IPCC Guidelines [11], and Republic of Armenia's 2010, 2012, 2016, and 2017 Inventories [2,3,4,5].

Enteric fermentation:

$$EF_{enteric-horse-CH_4-head} = 18\,kg_{CH_4}/head \tag{21}$$

$$EF_{enteric-swine-CH_4-head} = 1\,kg_{CH_4}/head \tag{22}$$

Manure management systems (MMS) (CH_4):

$$EF_{MMS-dairy\_cow-CH_4-head} = 9\,kg_{CH_4}/head \tag{23}$$

$$EF_{MMS-other\_cattle-CH_4-head} = 1\,kg_{CH_4}/head \tag{24}$$

$$EF_{MMS-sheep-CH_4-head} = 0.1\,kg_{CH_4}/head \tag{25}$$

$$EF_{MMS-horse-CH_4-head} = 1.1\,kg_{CH_4}/head \tag{26}$$

$$EF_{MMS-swine-CH_4-head} = 2\,kg_{CH_4}/head \tag{27}$$

$$EF_{MMS-chickens-CH_4-head} = 0.01\,kg_{CH_4}/head \tag{28}$$

Manure management systems (MMS) (N_2O), split into *solid (s), liquid (l), pasture (p)*:

$$EF_{MMS-dairy\_cow-l-N_2O-head} = 0.0055\,kg_{N_2O}/head \tag{29}$$

$$EF_{MMS-dairy\_cow-p-N_2O-head} = 0.2112\,kg_{N_2O}/head \tag{30}$$

$$EF_{MMS-bull-l-N_2O-head} = 0.0051\,kg_{N_2O}/head \tag{31}$$

$$EF_{MMS-bull-p-N_2O-head} = 0.1982\,kg_{N_2O}/head \tag{32}$$

$$EF_{MMS-young\_cattle-l-N_2O-head} = 0.0016\,kg_{N_2O}/head \tag{33}$$

$$EF_{MMS-young\_cattle-p-N_2O-head} = 0.0616\,kg_{N_2O}/head \tag{34}$$

$$EF_{MMS-sheep-p-N_2O-head} = 0.0197\,kg_{N_2O}/head \tag{35}$$

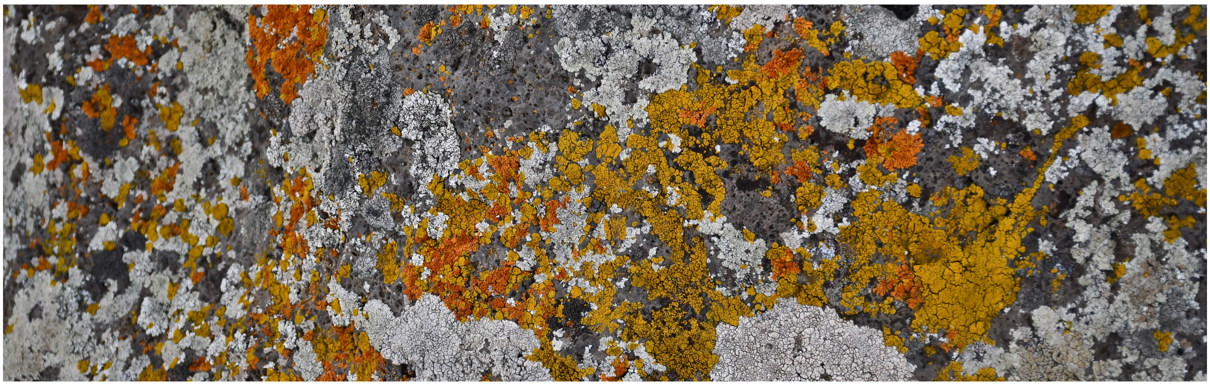
$$EF_{MMS-horse-s-N_2O-head} = 0.1998\,kg_{N_2O}/head \tag{36}$$

$$EF_{MMS-swine-l-N_2O-head} = 0.0032\,kg_{N_2O}/head \tag{37}$$

$$EF_{MMS-swine-s-N_2O-head} = 0.0204\,kg_{N_2O}/head \tag{38}$$

$$EF_{MMS-chickens-l-N_2O-head} = 0.0016\,kg_{N_2O}/head \tag{39}$$

$$EF_{MMS-chickens-s-N_2O-head} = 0.0019\,kg_{N_2O}/head \tag{40}$$



Emissions inventory

During 2020, Gagarin Project emitted a total of 21,643 tCO_2e in BASIC+ Scope 3.

The population in 2020 was 10,618, setting emissions per capita at 2.04 tCO_2e/person. The total area was 179 km^2, setting emissions per area at 121 tCO_2e/km^2.

Looking at the emissions overview, Table 12 (Table 19 for more detailed information), a few things catch the eye. Why is *Stationary Energy* so high? Why is *Transportation* so low? What is *AFOLU* and why is it so high?

GPC Ref	GHG Emissions Source (By Sector)		Total GHGs (metric tonnes CO_2e)				% of total
			Scope 1	Scope 2	Scope 3	BASIC+ S3	emissions
I	Stationary Energy	Energy use	6,113	815	0	6,928	32.0%
		Energy generation supplied to the grid	0				
II	Transportation	All II emissions	1,401	0	0	1,401	6.5%
III	Waste	Waste generated in the city	638		904	1,542	7.1%
		Waste generated outside city	0				
IV	IPPU	All IV emissions	0			0	0.0%
V	AFOLU	All V emissions	11,774			11,774	54.4%
VI	Other Scope 3	All VI emissions			0	0	0.0%
	Total		19,925	815	904	21,643	

Table 12: Emissions summary by sector

Sectors

Stationary Energy

Stationary energy, or energy derived from stationary fuel combustion as well as fugitive emissions released in the process of generating, delivering, and consuming useful forms of energy (eg electricity, heat), forms a large part of Gagarin Project's footprint, roughly 32%.

GPC ref	IPCC ref	Scope	Source	GHGs (metric tonnes CO_2e) CO_2	CH_4	N_2O	$CO_2(b)$	Total	% of sector emissions
I	1		**Stationary Energy**						
I.1	1A4b		**Residential buildings**						
		1	CNG	3,427	155	48	0	3,630	52.4%
		1	Manure	0	164	149	2,085	2,398	34.6%
		2	Electricity	815			0	815	11.8%
1.8	1B2biii5	1	**Fugitive emissions**		85		0	85	1.2%
Total				**4,242**	**404**	**197**	**2,085**	**6,928**	

Table 13: Stationary Energy Emissions

The majority of this is from the burning of compressed natural gas (CNG) and manure for heat, comprising 52.4% and 34.6% of the sector's emissions, respectively. Due to the availability of manure and cheaper prices of CNG compared to electricity, the local population relies on these two fuels for heat.

Usually biogenic emissions of CO_2 (CO_2(b)) are estimated in the land use portion of the AFOLU sector, thus CO_2(b) emissions from other sectors are reported separetely from the scopes and other gases and not counted in emissions totals to prevent double counting. In this inventory we chose to include CO_2(b) emissions from the burning of manure as they represent a sizeable portion of total emissions (11%), and land use changes are not estimated.

Fugitive emissions from the distribution of CNG are lower than Armenia's average, likely due to the communities favoring manure as opposed to CNG for heat.

Transportation

Transportation makes up a surprisingly small portion of emissions, only about 6.5%. This figure includes petrol, diesel, and CNG powered vehicles that operate within the boundaries of the communities.

GPC ref	IPCC ref	Scope	Source	GHGs (metric tonnes CO_2e) CO_2	CH_4	N_2O	Total	% of sector emissions
II	1A3		**Transportation**					
II.1	1A3b		**On-road transportation**					
		1	Petrol	49	1	1	50	3.6%
		1	Diesel	1,193	2	17	1,211	86.5%
		1	CNG	131	6	2	139	9.9%
Total				**1,373**	**8**	**19**	**1,401**	

Table 14: Transportation Emissions

Waste

All municipal solid waste (MSW) is sent to unmanaged waste disposal sites (UWDS), *landfills*, outside of the communities, as a result all emissions are in Scope 3. A little over half of the waste emissions occur due to the MSW being left in the UWDSs where they leech GHGs over time. A portion of the waste in UWDSs is burned resulting in more emissions.

A little under half of the waste emissions occur due to the treatment (or lack thereof) of domestic wastewater. This usually occurs in latrines within the communities boundary and is considered in Scope 1.

GPC ref	IPCC ref	Scope	Source	GHGs (metric tonnes CO_2e)					% of sector emissions
				CO_2	CH_4	N_2O	CO_2(b)	Total	
III	4		Waste						
III.1	4A	3	Solid waste disposal		774		76	774	50.2%
III.3	4C	3	Incineration and open burning	110	2	18		130	8.4%
III.4	4D	1	Wastewater treatment and discharge		487	151		638	41.4%
Total				110	1,263	169	76	1,542	

Table 15: Waste Emissions

Agriculture, Forestry, and Other Land Use (AFOLU)

Gagarin Project, being a set of mostly rural settlements in Armenia, has a very heavy reliance on agriculture, particularly livestock.

GPC ref	IPCC ref	Scope	Source	GHGs (metric tonnes CO_2e)			% of sector emissions
				CH_4	N_2O	Total	
V	3		AFOLU				
V.1	3A		Livestock				
	3A1		Enteric fermentation				
	3A1a	1	Cattle	9,141		9,141	77.6%
	3A1c	1	Sheep	1,305		1,305	11.1%
	3A1f	1	Horses	48		48	0.4%
	3A1h	1	Swine	50		50	0.4%
3A1 Sub-total				10,544	0	10,544	89.6%
	3A2		Manure management				
	3A2a	1	Cattle	797	221	1,018	8.7%
	3A2c	1	Sheep	23	44	67	0.6%
	3A2f	1	Horses	3	5	8	0.1%
	3A2h	1	Swine	99	11	111	0.9%
	3A2i	1	Poultry	8	18	26	0.2%
3A2 Sub-total				931	299	1,230	10.4%
Total				11,475	299	11,774	

Table 16: AFOLU Emissions

A staggering 46.9% of total emissions comes from the cattle industry (both enteric fermentation and manure management of cattle). If we add the emissions resulting from the burning of cattle manure, we see that around 58% of all emissions in Gagarin Project are related to cattle. However, even though the emissions occur in Gagarin Project, the products driving these high numbers of cattle (dairy, meat) are mostly consumed outside of the boundary.

Intensity Indicators

Comparing Gagarin Project to Armenia in Table 17, we see some interesting trends.

Region	tCO_2e per capita	tCO_2e per km^2
Gagarin Project (2020)	2.04	121
Armenia (2017) [5]	3.40	341

Table 17: GHG Intensity Indicators for Gagarin Project

Per capita

Per capita, Gagarin Project has a 40% lower carbon footprint than that of Armenia, as expected from rural communities. Surprisingly though there is quite a bit of variablity in per capita emissions within Gagarin Project, with one community (Tsaghkunk) having higher emissions per capita than Armenia overall.

Per unit area

Per area, Gagarin Project has a 65% lower carbon footprint than that of Armenia. This is expected due to its low population density.

Communities

On the whole the communities had relatively similar total GHG emissions with a mean of 3,607 tCO_2e. Geghamavan, Zovaber, Tsaghkunk, and Varser all fall within ± 7 % of the mean, while Ddmashen is about 46 % more and Gagarin 38 % less.

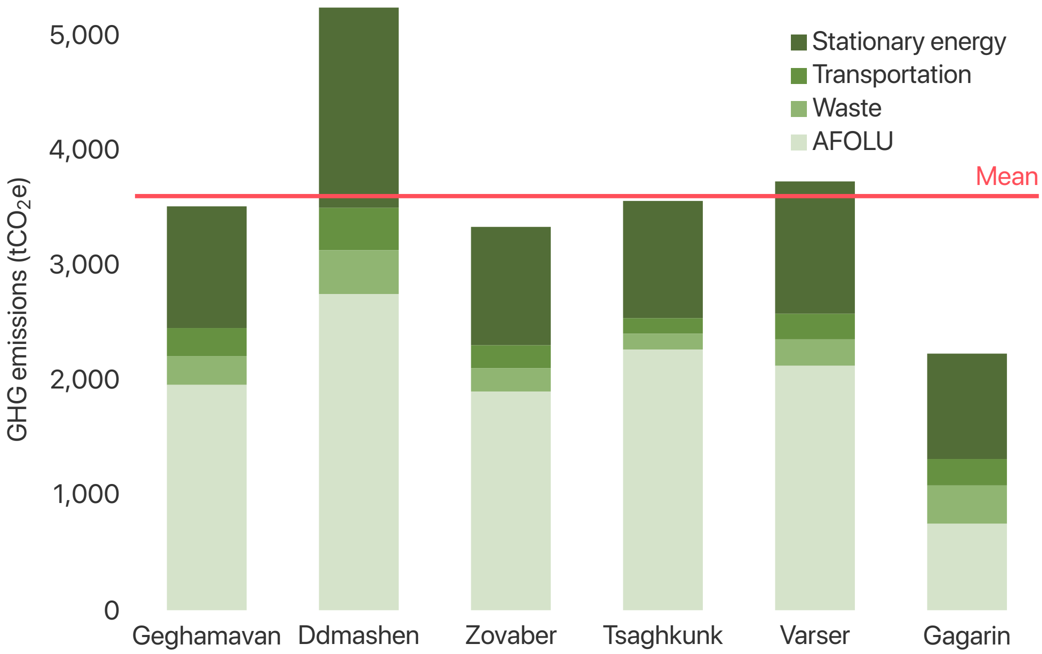


Figure 2: Emissions by community

This difference in total emissions is due in large part to the differences in population and land area.

Boundary	Geghamavan	Ddmashen	Zovaber	Tsaghkunk	Varser	Gagarin
Land area (km^2)	31.28	43.45	28.76	37.89	36.59	1.48
Population	1,850	2,796	1,512	1,026	1,691	1,473

Table 18: Inventory boundary information for Gagarin Project

Per capita

Regarding per capita emissions, the mean is 2.04 $tCO_2e/person$. Geghamavan, Ddmashen, Zovaber, and Varser all fall within ± 8 % of the mean, while Gagarin is 37 % less and Tsaghkunk a staggering 71 % more.

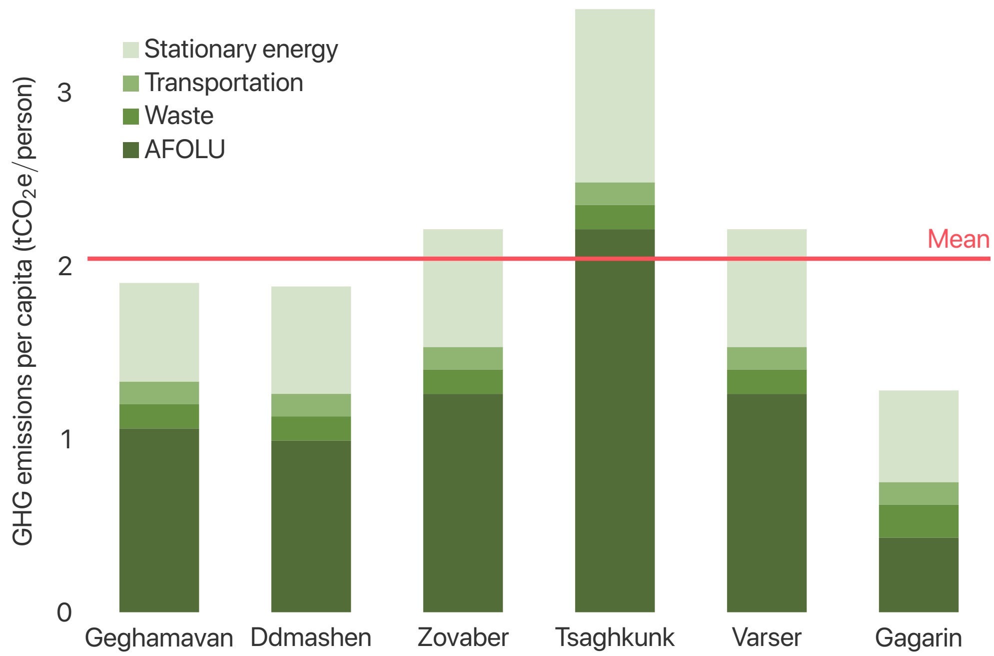


Figure 3: Emissions per capita by community

AFOLU, particularly cattle, makes up the largest portion of emissions for all communities but Gagarin. Geghamavan, Ddmashen, Zovaber and Varser all have a similar number of cattle with respect to their population, resulting in level emissions per capita, while Tsaghkunk has a much higher, and Gagarin a much lower number of cattle resulting in their respective differences.

As Transportation and Waste emissions are based only on population (apart from wastewater emissions for Gagarin), the per capita emissions for these sectors are the same.

Stationary energy is roughly the same for all the communities, apart from Tsaghkunk once again which is higher than the norm due to the higher mass of cattle manure burned in homes for heat.

Per unit area

Per unit area emissions paint a much different picture. The mean is 121 tCO_2e/km^2, and Geghamavan, Ddmashen, Zovaber, Tsaghkunk, and Varser all fall within ± 22 % of the mean, while Gagarin is 1,154 % above the mean.

This large outlier is due to Gagarin being an urban settlement and having a much smaller boundary area (only 0.6 % of Gagarin Project's total area) while still keeping a modest number of cattle.

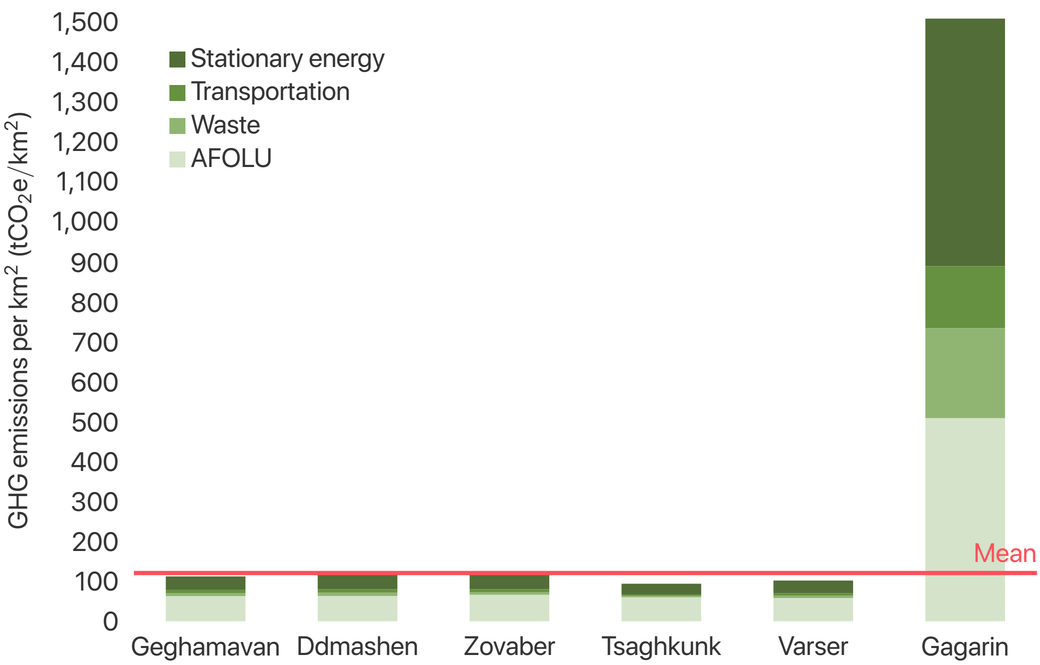


Figure 4: Emissions per km^2 by community

Abbreviations

AFOLU	agriculture, forestry, and other land use
BOD	biochemical oxygen demand
CH_4	methane
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2(b)	carbon dioxide from biogenic sources
DOC	degradable organic carbon
EF	emission factor
GDP	gross domestic product
GHG	greenhouse gas
GP	Gagarin Project
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GWP	global warming potential
IPCC	Intergovernmental Panel on Climate Change
IPPU	industrial processes and product use
MMS	manure management system
MSW	municipal solid waste
N_2O	nitrous oxide
NCV	net calorific value
tCO_2e	tonnes of carbon dioxide equivalent
UWDS	unmanaged waste disposal site

Glossary

Activity data	A quantitative measure of a level of activity that results in GHG emissions. Activity data is multiplied by an emission factor to derive the GHG emissions associated with a process or an operation. Examples of activity data include kilowatt-hours of electricity used, quantity of fuel used, output of a process, hours equipment is operated, distance traveled, and floor area of a building.
Biogenic emissions (CO_2(b))	Emissions produced by living organisms or biological processes, but not fossilized or from fossil sources.
CO_2e or CO_2 equivalent	The universal unit of measurement to indicate the global warming potential (GWP) of each GHG, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate the climate impact of releasing (or avoiding releasing) different greenhouse gases on a common basis.
Emission	The release of GHGs into the atmosphere.
Emission factor(s)	A factor that converts activity data into GHG emissions data (e.g., kg CO_2e emitted per liter of fuel consumed, kg CO_2e emitted per kilometer traveled, etc.).
Gagarin Project	A sustainable development program in the Geghamavan, Ddmashen, Zovaber, Tsaghkunk, and Varser communities, and Gagarin settlement of the Republic of Armenia.
Geographic boundary	A geographic boundary that identifies the spatial dimensions of the inventory's assessment boundary. This geographic boundary defines the physical perimeter separating in-boundary emissions from out-of-boundary and transboundary emissions.
Global warming potential	A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2.
Greenhouse Gases	For the purposes of the GPC, GHGs are the seven gases covered by the UNFCCC: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulphur hexafluoride (SF_6); and nitrogen trifluoride (NF_3).
Grenhouse gas inventory	A quantified list of a city's GHG emissions and sources.
In-boundary	Occurring within the established geographic boundary.
Inventory boundary	The inventory boundary of a GHG inventory identifies the gases, emission sources, geographic area, and time span covered by the GHG inventory.
Out-of-boundary	Occurring outside of the established geographic boundary.
Proxy data	Data from a similar process or activity that is used as a stand-in for the given process or activity without being customized to be more representative of that given process or activity.
Reporting year	The year for which emissions are reported.
Scope 1 emissions	GHG emissions from sources located within the city boundary.
Scope 2 emissions	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary.
Scope 3 emissions	All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

Appendix

Emission factor calculations

Stationary energy

– Compressed Natural Gas

The CO_2 emission factor for CNG was calculated using:

$$\mathrm{EF}_{\mathrm{CNG-GHG-m^3}} = \mathrm{EF}_{\mathrm{CNG-GHG-TJ}}\ \mathrm{NCV}_{\mathrm{CNG}}\ \rho_{\mathrm{CNG}} \tag{41}$$

where:

$$\mathrm{EF}_{\mathrm{CNG-GHG-m^3}} = \text{GHG specific emission factor per m}^3 \text{ CNG burned } [\mathrm{kg_{GHG}/m^3_{CNG}}] \tag{42}$$

$$\mathrm{EF}_{\mathrm{CNG-GHG-TJ}} = \text{GHG specific emission factor per TJ energy released from CNG } [\mathrm{kg_{GHG}/TJ}] \tag{43}$$

$$\mathrm{NCV}_{\mathrm{CNG}} = \text{net calorific value of CNG } [\mathrm{TJ/kg_{CNG}}] \tag{44}$$

$$\rho_{\mathrm{CNG}} = \text{density of CNG } [\mathrm{kg_{CNG}/m^3_{CNG}}] \tag{45}$$

The values for $\mathrm{EF}_{\mathrm{CNG-CO_2-TJ}}$, $\mathrm{NCV}_{\mathrm{CNG}}$, and ρ_{CNG} were taken from National Greenhouse Gas Inventory Report of Armenia 1990-2017 [Table 2.5-1] (5) for the year 2017. The values for $\mathrm{EF}_{\mathrm{CNG-CH_4-TJ}}$ and $\mathrm{EF}_{\mathrm{CNG-N_2O-TJ}}$ were taken from 2006 IPCC Guideline [Gen-1, Volume 2, Chapter 3, Table 3.2.2] (11).

$$\mathrm{EF}_{\mathrm{CNG-CO_2-TJ}} = 56{,}871.87\ \mathrm{kg_{CO_2}/TJ} \tag{46}$$

$$\mathrm{EF}_{\mathrm{CNG-CH_4-TJ}} = 92\ \mathrm{kg_{CH_4}/TJ} \tag{47}$$

$$\mathrm{EF}_{\mathrm{CNG-N_2O-TJ}} = 3\ \mathrm{kg_{N_2O}/TJ} \tag{48}$$

$$\mathrm{NCV}_{\mathrm{CNG}} = 47.64\ \mathrm{TJ/Gg} \tag{49}$$

$$\rho_{\mathrm{CNG}} = 0.7513\ \mathrm{kg/m^3} \tag{50}$$

Combining (41), (46), (47), (48), (49), and (50) we get:

$$\mathrm{EF}_{\mathrm{CNG-CO_2-m^3}} = 2.0356\ \mathrm{kg_{CO_2}/m^3_{CNG}} \tag{51}$$

$$\mathrm{EF}_{\mathrm{CNG-CH_4-m^3}} = 0.0033\ \mathrm{kg_{CH_4}/m^3_{CNG}} \tag{52}$$

$$\mathrm{EF}_{\mathrm{CNG-N_2O-m^3}} = 0.00011\ \mathrm{kg_{N_2O}/m^3_{CNG}} \tag{53}$$

Note the different units for mass in (44) and (49).

– Petrol

The emission factor for petrol was calculated using:

$$\frac{kg_{CO_2}}{liter_{petrol}} = \frac{kg_{CO_2}}{TJ}\frac{TJ}{liter_{petrol}} \tag{54}$$

$$= \frac{kg_{CO_2}}{TJ}\frac{TJ}{kg_{petrol}}\text{density}_{\text{petrol}} \tag{55}$$

The values for *carbon, methane*, and *nitrous oxide content*, and *NCV* are from 2006 IPCC Guideline [Gen-1, Volume 2, Chapter 3, Table 3.2.1] and [Gen-1, Volume 2, Chapter 3, Table 3.2.1] (11).

$$\text{carbon content} = 69,300\ \frac{kg_{CO_2}}{TJ} \tag{56}$$

$$\text{methane content} = 33\ \frac{kg_{CH_4}}{TJ} \tag{57}$$

$$\text{nitrous oxide content} = 3.2\ \frac{kg_{N_2O}}{TJ} \tag{58}$$

$$\text{NCV} = 0.0000443\ \frac{TJ}{kg_{petrol}} \tag{59}$$

$$\text{density}_{\text{petrol}} = 0.74\ \frac{kg_{petrol}}{m^3} \tag{60}$$

Electricity

Total emissions

GPC ref	IPCC ref	Scope	GHG Emissions Source (By sector and Sub-sector)	GHGs (metric tonnes CO_2e) CO_2	CH_4	N_2O	Total tCO_2e	CO_2(b)
I	1		**Stationary Energy**					
I.1	1A4b		**Residential buildings**					
I.1.1		1	Emissions from fuel combustion within the city boundary	8,922	593	449	9,965	0
I.1.2		2	Emissions from grid-supplied energy consumed within the city boundary	0	0	0	1,184	0
I.1.3		3	Transmission and distribution losses from grid-supplied energy	NE	NE	NE	NE	NE
I.2	1A4a		**Commercial and institutional buildings and facilities**					
I.2.1		1	Emissions from fuel combustion within the city boundary	NE	NE	NE	NE	NE
I.2.2		2	Emissions from grid-supplied energy consumed within the city boundary	NE	NE	NE	NE	NE
I.2.3		3	Transmission and distribution losses from grid-supplied energy	NE	NE	NE	NE	NE
I.3	1A2		**Manufacturing industries and construction**					
I.3.1		1	Emissions from fuel combustion within the city boundary	NE	NE	NE	NE	NE
I.3.2		2	Emissions from grid-supplied energy consumed within the city boundary	NE	NE	NE	NE	NE
I.3.3		3	Transmission and distribution losses from grid-supplied energy	NE	NE	NE	NE	NE
I.4	1A1		**Energy industries**					
I.4.1		1	Emissions from energy production used in power plant auxiliary operations within the city	NO	NO	NO	NO	NO
I.4.2		2	Emissions from grid-supplied energy consumed by energy industries	NO	NO	NO	NO	NO
I.4.3		3	Emissions from transmission and distribution losses from grid-supplied energy used in power plant auxiliary operations	NO	NO	NO	NO	NO
I.4.4		1	Emissions from energy generation supplied to the grid	NO	NO	NO	NO	NO
I.5	1A4c		**Agriculture, forestry and fishing activities**					
I.5.2		2	Emissions from grid-supplied energy consumed within the city boundary	NE	NE	NE	NE	NE
I.5.1		1	Emissions from fuel combustion within the city boundary	NE	NE	NE	NE	NE
I.5.3		3	Transmission and distribution losses from grid-supplied energy consumption	NE	NE	NE	NE	NE

Table 19: GHG emissions report for Gagarin Project

GPC ref	IPCC ref	Scope	GHG Emissions Source (By sector and Sub-sector)	GHGs (metric tonnes CO_2e)				
				CO_2	CH_4	N_2O	Total tCO_2e	CO_2(b)
I	1		**Stationary Energy**					
I.6	1A5a		**Non-specified sources**					
I.6.1		1	Emissions from fuel combustion within the city boundary	NE	NE	NE	NE	NE
I.6.2		2	Emissions from grid-supplied energy consumed within the city boundary	NE	NE	NE	NE	NE
I.6.3		3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NE	NE	NE	NE	NE
I.7	1B1		**Fugitive emissions from mining, processing, storage, and transportation of coal**					
I.7.1		1	Fugitive emissions from mining, processing, storage, and transportation of coal within the city boundary	NO	NO	NO	NO	NO
I.8	1B2		**Fugitive emissions from oil and natural gas systems**					
I.8.1		1	Fugitive emissions from oil and natural gas systems within the city boundary	0	85	0	85	0
II	1A3		**Transportation**					
II.1	1A3b		**On-road transportation**					
II.1.1		1	Emissions from fuel combustion on-road transportation occurring in the city	1,368	8	19	1,395	0
II.1.2		2	Emissions from grid-supplied energy consumed in the city for on-road transportation	NE	NE	NE	NE	NE
II.1.3		3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	NE	NE	NE	NE	NE
II.2	1A3c		**Railways**					
II.2.1		1	Emissions from fuel combustion for railway transportation occurring in the city	NE	NE	NE	NE	NE
II.2.2		2	Emissions from grid-supplied energy consumed in the city for railways	NE	NE	NE	NE	NE
II.2.3		3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	NE	NE	NE	NE	NE
II.3	1A3d		**Waterborne navigation**					
II.3.1		1	Emissions from fuel combustion for waterborne navigation occurring in the city	NO	NO	NO	NO	NO
II.3.2		2	Emissions from grid-supplied energy consumed in the city for waterborne navigation	NO	NO	NO	NO	NO
II.3.3		3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	NE	NE	NE	NE	NE

Table 19 (Cont.): GHG emissions report for Gagarin Project

GPC ref	IPCC ref	Scope	GHG Emissions Source (By sector and Sub-sector)	CO_2	CH_4	N_2O	Total tCO_2e	CO_2(b)
				GHGs (metric tonnes CO_2e)				
II	1A3		Transportation					
II.4	1A3a		Aviation					
II.4.1		1	Emissions from fuel combustion for aviation occurring in the city	NO	NO	NO	NO	NO
II.4.2		2	Emissions from grid-supplied energy consumed in the city for aviation	NO	NO	NO	NO	NO
II.4.3		3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	NE	NE	NE	NE	NE
II.5	1A3e		Off-road transportation					
II.5.1		1	Emissions from fuel combustion for off-road transportation occurring in the city	NE	NE	NE	NE	NE
II.5.2		2	Emissions from grid-supplied energy consumed in the city for off-road transportation	NE	NE	NE	NE	NE
II.5.3		3	Emissions from transboundary journeys occurring outside the city, and T and D losses from grid-supplied energy use	NE	NE	NE	NE	NE
III	4		Waste					
III.1	4A		Solid waste disposal					
III.1.1		1	Emissions from solid waste generated in the city and disposed in landfills or open dumps within the city	NE	NE	NE	NE	NE
III.1.2		3	Emissions from solid waste generated in the city but disposed in landfills or open dumps outside the city	205	569	0	774	76
III.1.3		1	Emissions from waste generated outside the city and disposed in landfills or open dumps within the city	NE	NE	NE	NE	NE
III.2	4B		Biological treatment of waste					
III.2.1		1	Emissions from solid waste generated in the city that is treated biologically in the city	NE	NE	NE	NE	NE
III.2.2		3	Emissions from solid waste generated in the city but treated biologically outside of the city	NE	NE	NE	NE	NE
III.2.3		1	Emissions from waste generated outside the city boundary but treated in the city	NE	NE	NE	NE	NE
III.3	4C		Incineration and open burning					
III.3.1		1	Emissions from waste generated and treated within the city	NE	NE	NE	NE	NE
III.3.2		3	Emissions from waste generated within but treated outside of the city	110	2	18	130	0
III.3.3		1	Emissions from waste generated outside the city boundary but treated within the city	NE	NE	NE	NE	NE

Table 19 (Cont.): GHG emissions report for Gagarin Project

GPC ref	IPCC ref	Scope	GHG Emissions Source (By sector and Sub-sector)	GHGs (metric tonnes CO_2e)				
				CO_2	CH_4	N_2O	Total tCO_2e	CO_2(b)
III	4		**Waste**					
III.4	4D		**Wastewater treatment and discharge**					
III.4.1		1	Emissions from wastewater generated and treated within the city	0	487	151	638	0
III.4.2		3	Emissions from wastewater generated within but treated outside of the city	NE	NE	NE	NE	NE
III.4.3		1	Emissions from wastewater generated outside the city boundary but treated within the city	NE	NE	NE	NE	NE
IV	2		**Industrial Processes and Product Use (IPPU)**					
IV.1	2A, B, C, E	1	Emissions from industrial processes occurring in the city boundary	NE	NE	NE	NE	NE
IV.2	2D, F, G, H	1	Emissions from product use occurring within the city boundary	NE	NE	NE	NE	NE
V	3		**Agriculture, forestry, and other land use (AFOLU)**					
V.1	3A	1	Emissions from livestock	0	12,221	275	12,496	0
V.2	3B	1	Emissions from land	NE	NE	NE	NE	NE
V.3	3C	1	Emissions from aggregate sources and non-CO_2 emission sources on land	NE	NE	NE	NE	NE
VI			**Other Scope3**					
VI.1		3	Other Scope 3	NE	NE	NE	NE	NE

Table 19 (Cont.): GHG emissions report for Gagarin Project

References

[1] *City Inventory Reporting and Information System (CIRIS)*. C40 Cities.

[2] *National Greenhouse Gas Inventory Report of the Republic of Armenia 2010*. RA Ministry of Nature Protection, Yerevan, Armenia, 2014.

[3] *National Greenhouse Gas Inventory Report of the Republic of Armenia for 2012*. RA Ministry of Nature Protection, Yerevan, Armenia, 2015.

[4] *National Greenhouse Gas Inventory Report of the Republic of Armenia for 2016*. RA Ministry of Environment, Yerevan, Armenia, 2019.

[5] *National Greenhouse Gas Inventory Report of Armenia 1990-2017*. RA Ministry of Environment, Yerevan, Armenia, 2020.

[6] *Ddmashen Municipality*. EV Consulting, 2020.

[7] *Gagarin Municipality*. EV Consulting, 2020.

[8] *Geghamavan Municipality*. EV Consulting, 2020.

[9] *Tsaghkunk Municipality*. EV Consulting, 2020.

[10] LL Bolagen. *The Republic of Armenia Waste Quantity and Composition Study*. Yerevan: AUA Acopian Center for the Environment and AUA Manoogian-Simone Research Fund, American University of Armenia, 2020.

[11] Simon Eggelston, Leandro Buendia, Kyoko Miwa, Todd Ngara, and Kiyoto Tanabe. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. IGES, Tokyo, Japan, 2006.

[12] ESIA. *Kotayk Solid Waste Management - Environmental and Social Due Diligence*. Ministry of Urban Development of the Republic of Armenia, November 2011.

[13] World Resources Institute, C40 Cities, and ICLEI. *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories. standard for cities*. GHG Protocol, 2014.

[14] Statistical Committee of the Republic of Armenia. *4. Transport and tourism*. ArmStatBank, 2020.

[15] Core Writing Team, Rajendra K. Pachauri, and Leo Meyer. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 2014.