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Carbon budgets in the northern cities

Anthropogenic impact, including carbon emissions, on the climate change is one of the most relevant scientific and social problems since 1992, when the United Nations Framework Convention was adopted. Kyoto (December 1997) and Paris (December 2015) protocols are ratified by the governments of many countries, are the basis for the implementation of national concepts to reduce carbon emissions. In Russia, it is currently being discussed the issue of creating carbon-free zone in Eastern Siberia.

According to the Ministry of Natural Resources and Environment of Russian Federation, the transition to renewable energy sources, the introduction of carbon taxes, tax benefits, subsidies for the use of best available technologies, the growth of forest plantations and the establishment of a carbon market will contribute to this [3]. They consider the proposal to waive the coal power generation in favor of hydro, gas, nuclear power generation and coal chemistry development [13]. However, modern emission-free technologies (nuclear and hydro generation) is still characterized by high environmental and social risks, and require a significant amount of investment in the environment.

The Republic of Sakha (Yakutia) could become the one of the Russian carbon-free zones in the nearest future. The assessment of carbon emission and uptake by natural environment are actual scientific and practical tasks. The evaluation of carbon emission is available only for particular countries or big cities, in overall, based on national statistics. For Russian regions and settlements carbon emissions data are not available yet due to incomplete information about local fuel and energy complexes.

Fuel and energy complex (FEC) is an inter-branch system of extraction and production of fuels and energy (electricity and heat), their transportation, distribution and use. It is composed of the fuel industry (oil, gas, coal mining) and electric and heat power industry.

FEC of Yakutia is a complex, open system because of the vast territory, the availability of different sources of electricity and heat generation. About 40% of the territory of Yakutia (1222 sq km), where about 85% of the population inhabit, are covered by centralized power supply in the Western (mostly hydro generation), the Central (natural gas, coal) and South Yakut energy districts. Most of the territory of the Republic (60%) with a population of about 150 thousand people apply to the North energy district - the zone of decentralized power supply on the basis of

energy sources of low power, mostly diesel power plants (DPP JSC "Sakhaenergo" with a total capacity of 216 MW). It is also being tested renewable energy sources there (solar panels, wind power generation) [10].

The total heat electric capacity of power plants in Central and Southern Yakutia is 2457 Gcal/h. In addition, heat sector includes local boiler houses with relatively small capacity 0,1 Gcal/h to 60 Gcal/h: 1092 boilers (69,9%) – up to 3 Gcal/h; 421 boilers (26,9%) - from 3 to 20 Gcal/h; 42 boilers (3,2%) - from 20 to 100 Gcal/h [12].

The volumes of carbon emissions in Republic of Sakha (Yakutia) were estimated in according with methodology of Intergovernmental Panel on Climate Change (IPCC) [2, 11]. The original data was taken from of Fuel and Energy Balance of the Republic of Sakha (Yakutia). It develops by the Institute of Physical and Technical Problems of the North of the Yakut Scientific Centre of Siberian Branch of the Russian Academy of Sciences, the data are available from 1980 to 2008 [4, 5, 6] (Tab. 1.).

Fuel and energy balance (FEB) is the ratio of production of different types of fuel, power generation (income) and their use in the national economy (expense). Different types of fuel vary in calorific value. Oil and gas have the highest calorific value. In order to calculate FEB, different types of fuel are converted into standard fuel (SF). This method is also applicable for the conversion of heat and electricity power into SF (1 unit of SF has a calorific value of 7000 kcal) [1].

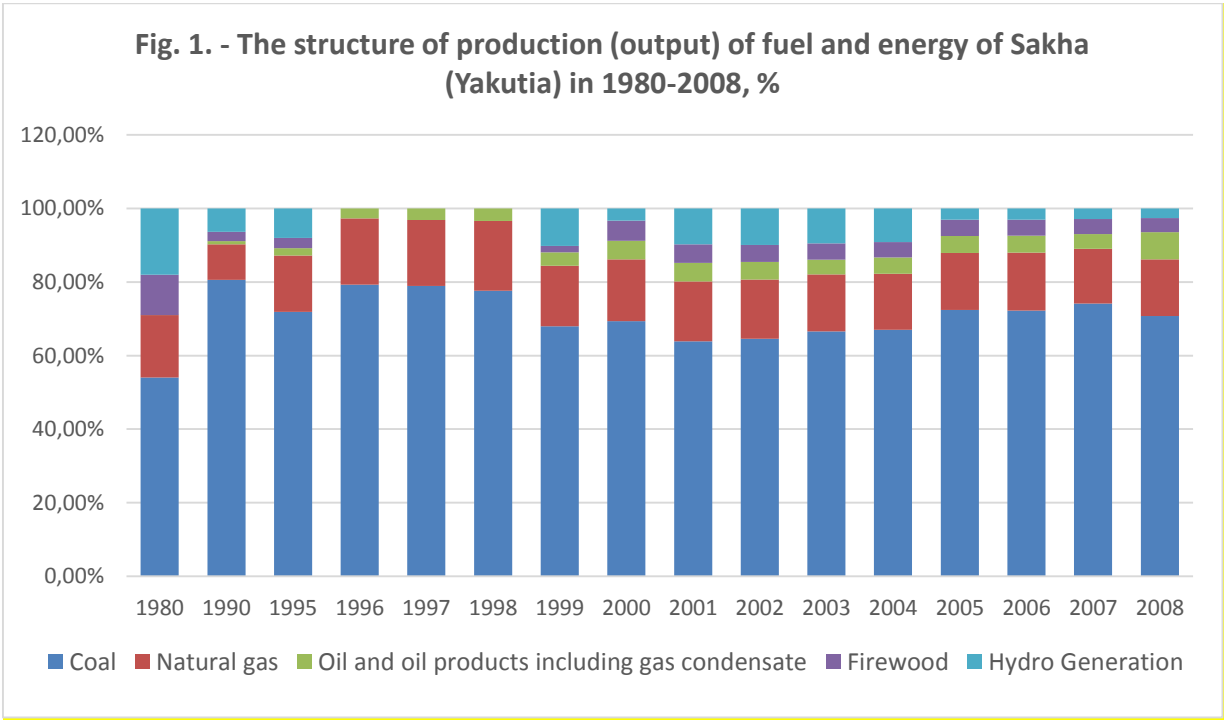
As data shows (Fig. 1) the share of firewood, coal, oil and oil products including gas condensate declined in the structure of internal consumption of fuel and energy in Sakha (Yakutia) in 1980-2008. This is the result of the implementation of the program of gasification of settlements of Yakutia since 2001. In 2000 - 2014, the number of heating plants consuming coal and oil and oil products decreased on 38 % and 37 % respectively. In 2000-2014, the share of boilers gas fueled increased by almost two times, from 16% to 31%. Nevertheless, the share of boilers operating on solid fuel (coal) is still high, in 2000 – 65 %, in 2014 - 54% 7, p. 50].

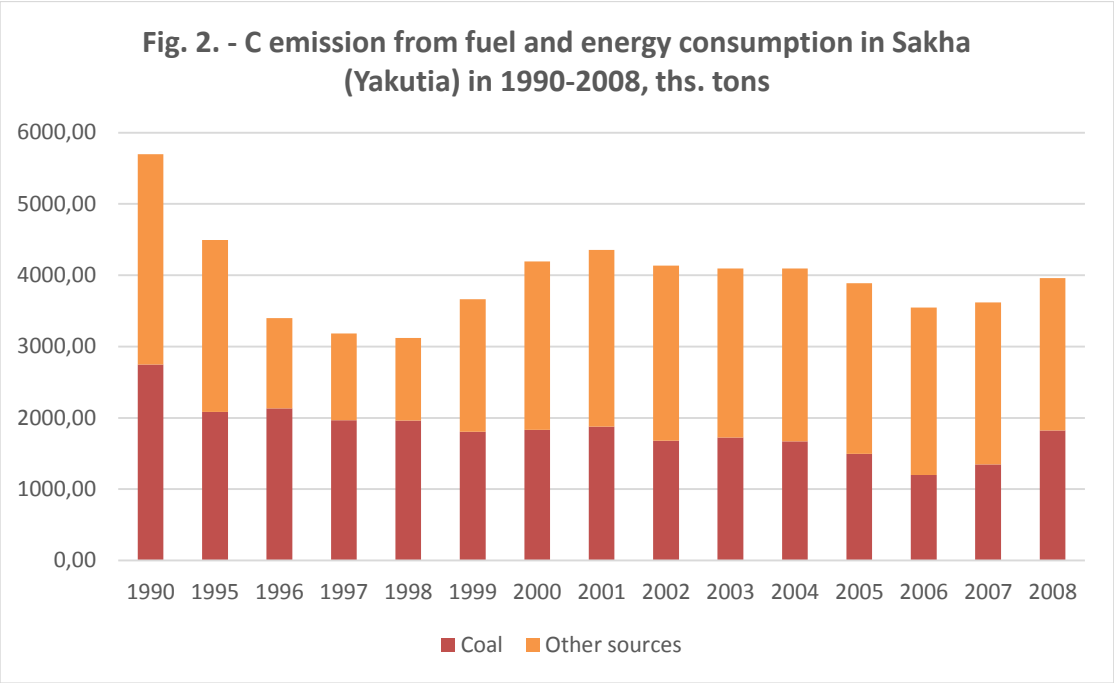
Since natural gas is giving lower carbon emissions than oil and coal, the effect was obtained in dynamics and structure of FEB. Data shows that the carbon emissions due to anthropogenic sources reduced until 2008 (Fig. 2). State programs of heat sector modernization and energy saving including gasification of settlements of Yakutia made a significant contribution to reducing carbon emissions.

Tab.1. - Fuel and energy balance of Sakha (Yakutia) in 2008, ths. tons of SF

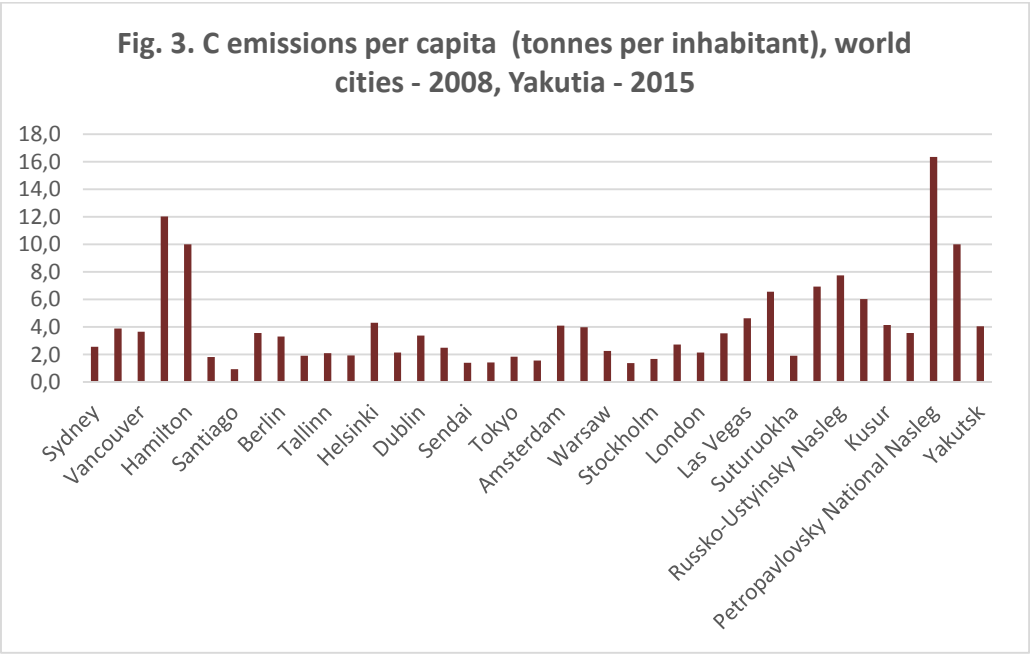
Indicators	Fuel (sources)						Energy		Total
	Coal	Natural gas	Oil and gas condensate	Oil Products	Fire-wood	Hydro Generation	Electricity	Heat energy	
Production (output) of fuel and energy	10066,8	2189,1	1026,8	20,7	545,0	378,1			14226,5
Import of fuel and energy	27,3	0,0		904,5			18,3		950,1
Export of fuel and energy	-8166,8		-761,9				-125,1		-9053,8
Internal consumption	1927,2	2189,1	265,0	925,2	545,0	378,1	-106,8		6122,8
Output of electrical energy	-842,2	-619,8		-263,3		-378,1	948,3		-1155,1
Output of heat energy	-1085,1	-1554,9	-265,0	0,0	-545,0		-67,3	2339,8	-1177,5
Losses of energy and energy consumption by power plants							-165,9	-166,1	-332,0
Net output of energy (motor fuel)		14,4							14,4
Net output of electrical and heat energy				661,9			608,4	2173,7	3444

Source: Energy strategy of the Republic of Sakha (Yakutia) for the period till to 2030/ Government of the RS (Y). Yakutsk; Irkutsk: Media holding "Yakutia", etc.; 2010. – 328 p.



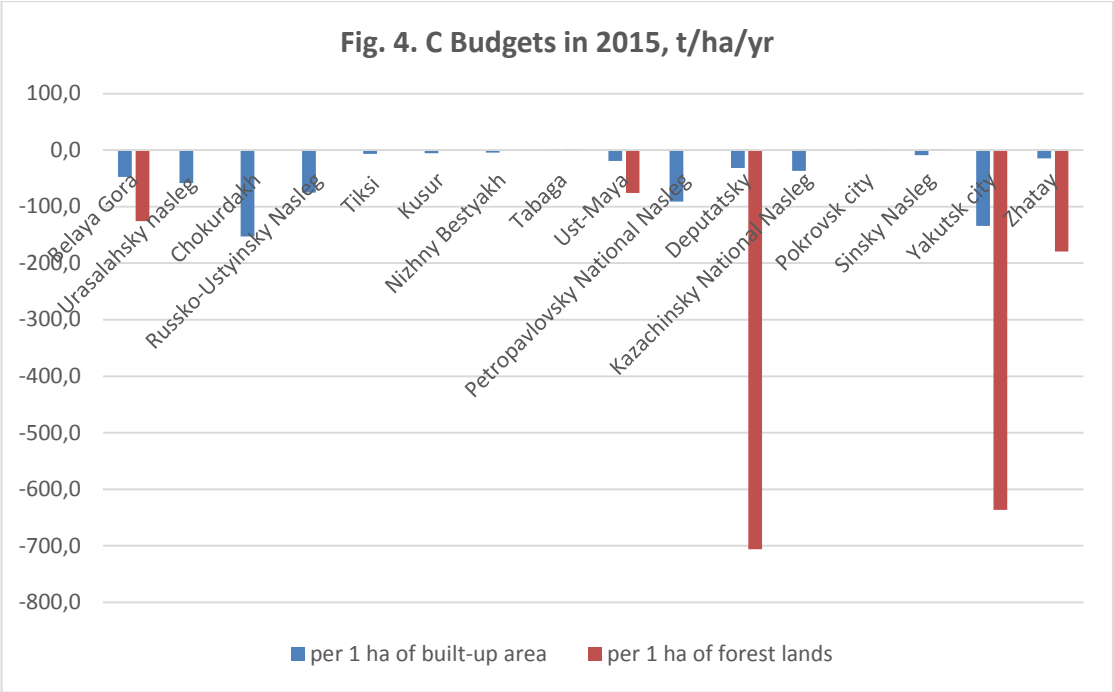


However, energy saving measures only partly offset the growth of carbon emissions since 2006. This is due to several factors including increase of volumes of housing construction and the growth of consumption of heat energy. Main reason is the growth of natural gas and oil extraction by companies-suppliers of the pipeline ESPO. If prior to the project ESPO the share of mining of fuel (coal, gas, oil) in total emission of pollutions in Sakha (Yakutia) was 5-8%, but now it has increased to 30 %, primarily due to extraction of oil. The oil and gas sector has the lowest proportion of trapped pollutants [8].



Tab.2. - C Budgets of settlements of Republic of Sakha (Yakutia) in 2015

№		C emission, t/yr	C emission per capita (2015), t/yr	C emission per 1 ha of built-up area of settlement (2015), t/yr	C uptake, t/ha/yr [13]	C Budget (forest lands), t/ha/yr	C Budget (built-up area of settlement), t/ha/yr
1	Belaya Gora	13806,08	6,57	48,31	0,7	-125,45	-47,61
2	Urasalahsky nasleg (Suturuokha)	806,58	1,91	58,87	0,7		-58,17
3	Chokurdakh	14659,42	6,92	153,34	0,7		-152,64
4	Russko-Ustyinsky Nasleg	982,81	7,74	76,19	0,7		-75,49
5	Tiksi	27459,71	6,03	7,21	0,7		-6,51
6	Bulunsky National (Evenk) Nasleg (Kusur)	5258,24	4,15	6,42	0,7	-0,70	-5,72
7	Nizhny Bestyakh	3083,73	0,85	6,02	1,6		-4,42
8	Taragaysky nasleg (Tabaga)	695,20	0,82	1,16	1,6	1,53	0,44
9	Ust-Maya	10093,98	3,57	20,81	1,6	-76,05	-19,21
10	Petropavlovsky National Nasleg	15435,14	16,33	92,43	1,6		-90,83
11	Deputatsky	28972,48	10,00	32,48	0,7	-705,95	-31,78
12	Kazachinsky National Nasleg	4773,52	3,86	37,59	0,7		-36,89
13	Pokrovsk city	13530,79	1,50	1,46	1,6	0,19	0,14
14	Sinsky Nasleg	2892,03	3,21	10,83	1,6	1,53	-9,23
15	Yakutsk city	1282797,19	4,06	135,72	1,6	-636,61	-134,12
16	Zhatay	8136,41	0,88	16,44	1,6	-179,21	-14,84
	Total	**1 433 383,33**	**4,00**	**52,54**			
	On average, the Republic of Sakha (Yakutia)	**3 961 082,09**	**4,13**				



The share of settlements selected for analysis in the project COPERA («C budget of ecosystems and cities and villages on permafrost», Belmont Forum) is 36.2% of all C emissions in Yakutia (Tab. 2.).

The world dynamics of C emissions for major cities [14] shows that indicator significantly increases for cities located in the North and South, compared with cities located in temperate climates. Comfort of living conditions is the main reason of greater generation and consumption of energy. The volumes of C emissions per capita in Yakutian settlements significantly higher than in world cities, including Northern cities, due to the more extreme climate and low efficiency of the local FEC (Fig. 3).

C budgets for Yakutian settlements and cities were obtained in according with local environment (Fig. 4). C uptake for tundra is 0.7 t/ha/yr, for taiga - 1.6 t/ha/yr [9]. The data shows that C budgets depend on quantity and density of population, local climate (annual temperature), capacities of energy plants and kind of fuel used for energy generation, area of forest and tundra lands surrounding the city. One more factor is the presence in the city of large power plant providing energy not only for habitants, but also for other settlements (the case of Yakutsk).

Conclusions

1. Estimation of the anthropogenic C emissions based on the fuel and energy balance analysis is the way for obtaining data for regions of Russia.

2. Factor analysis is needed for a more accurate assessment of the impact of different processes on the general dynamics of C emission in the region or city.

3. C emissions per inhabitant depends on the climate conditions and energy efficiency of city.

4. C budgets depend on the population, the local climate and environment, and characteristics of local energy systems.

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