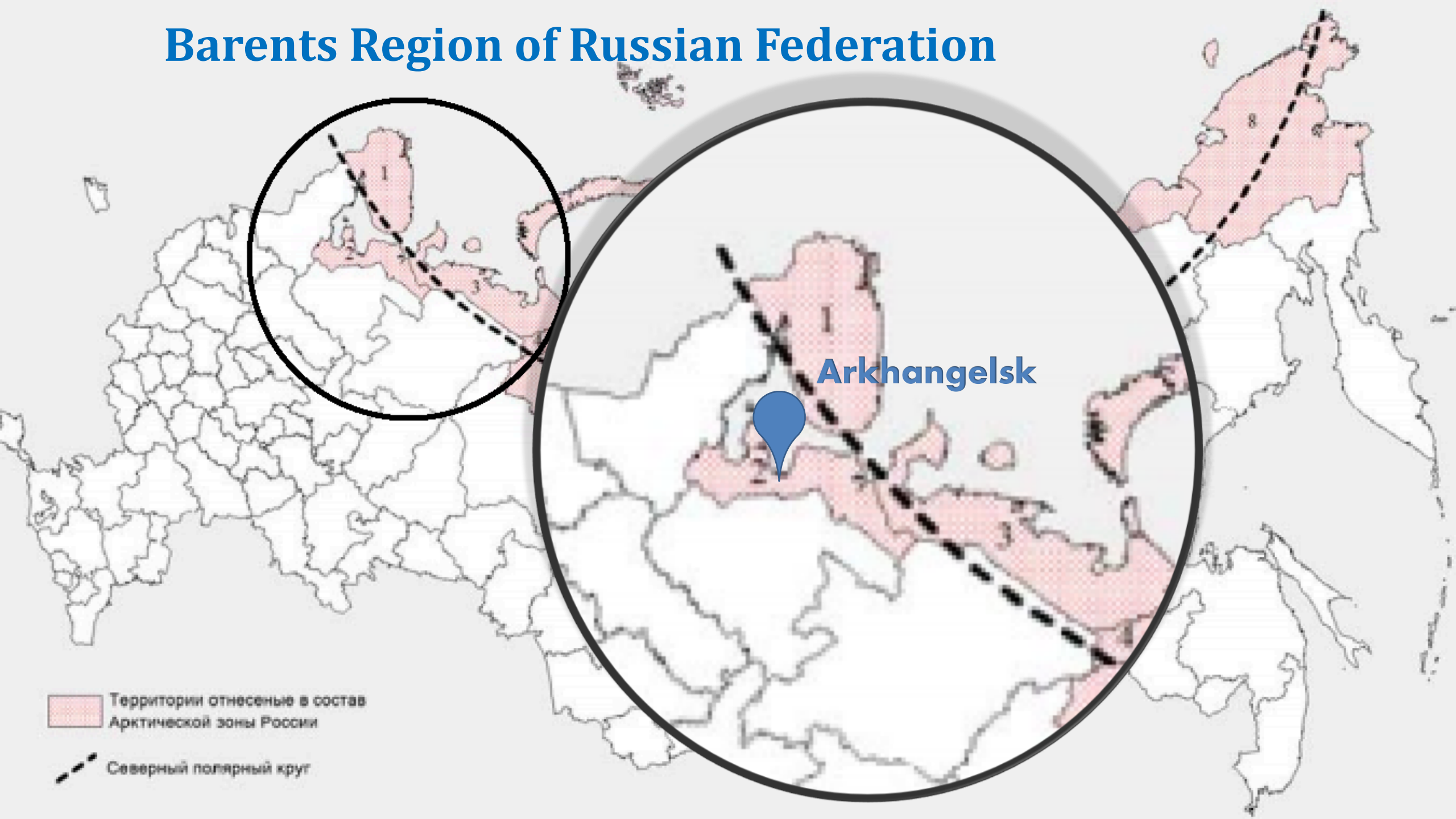
САФУ
СЕВЕРНЫЙ (АРКТИЧЕСКИЙ)
ФЕДЕРАЛЬНЫЙ УНИВЕРСИТЕТ
ИМЕНИ М.В. ЛОМОНОСОВА

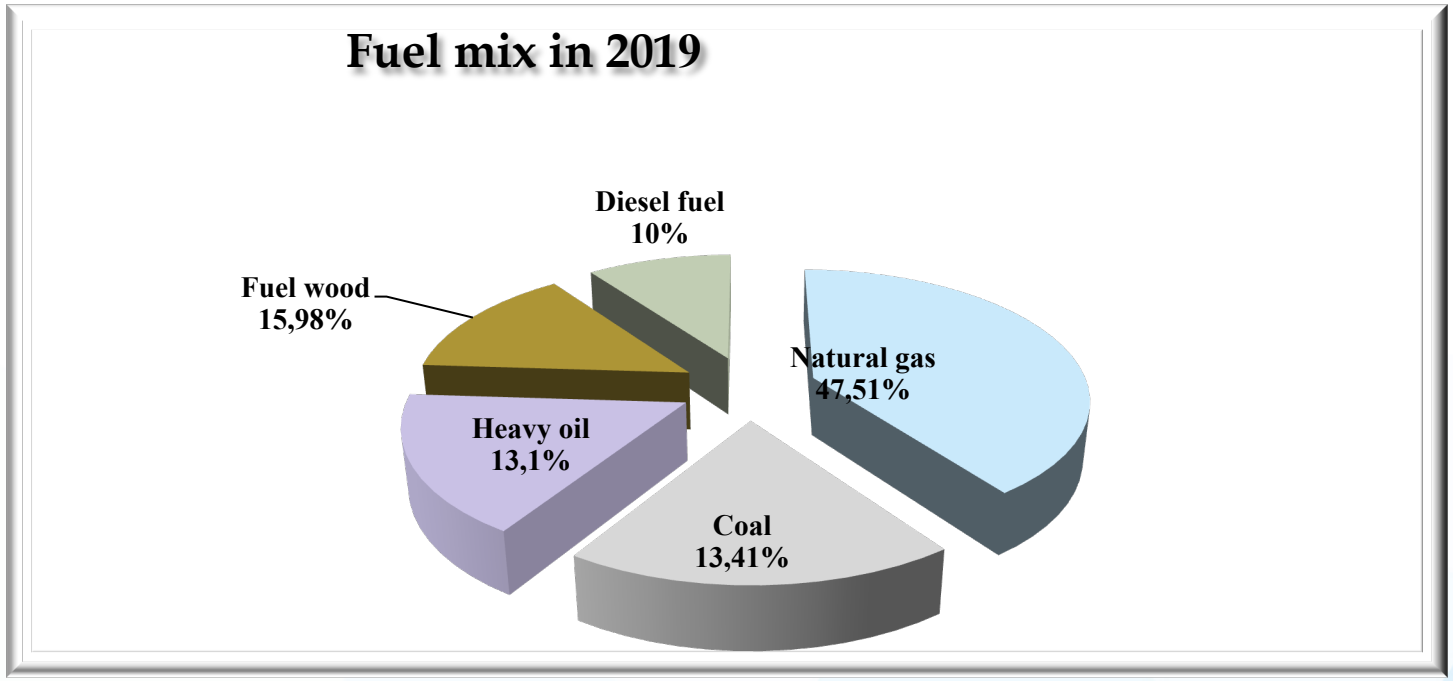
Emission of soot particles from the combustion of various fuels in boilers
(Выбросы сажи котлоагрегатами при сжигании различных видов топлива)

Lyubov V.K., Head of the Department of Power and Heat Engineering, Doctor of Technical Sciences, Professor
Popov A.N., Associate Professor of the Department of Power and Heat Engineering, Ph.D.
Popova E.I., Associate Professor of the Department of Power and Heat Engineering, Ph.D.
SEWAN
2021

Barents Region of Russian Federation



Characteristics of the fuel and energy balance in the Arkhangelsk Region



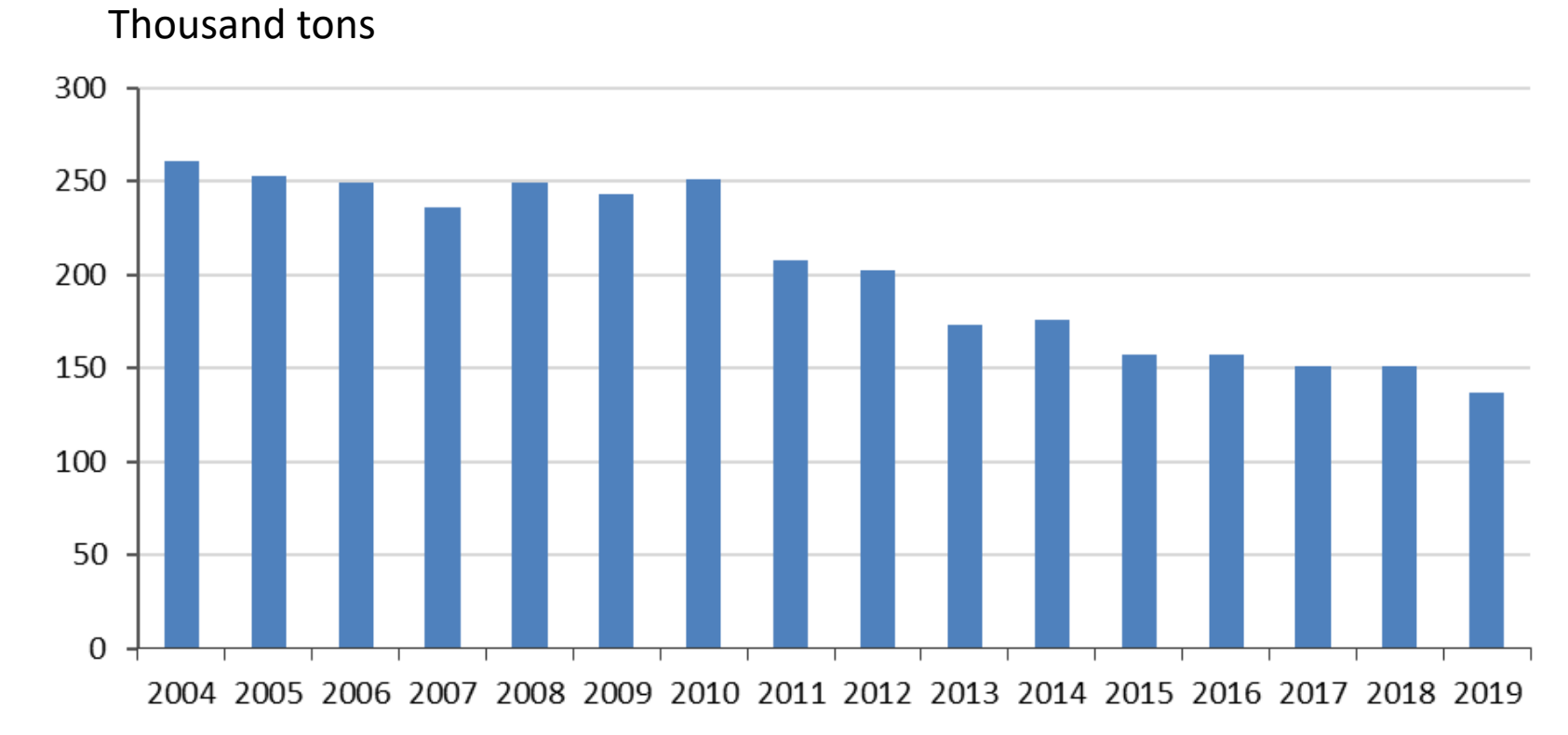
By 2020, **101** boiler houses have converted to biofuel use
And **15** new boiler houses have built

The average physical wear of fixed assets of the energy sector is more than **60 %.**

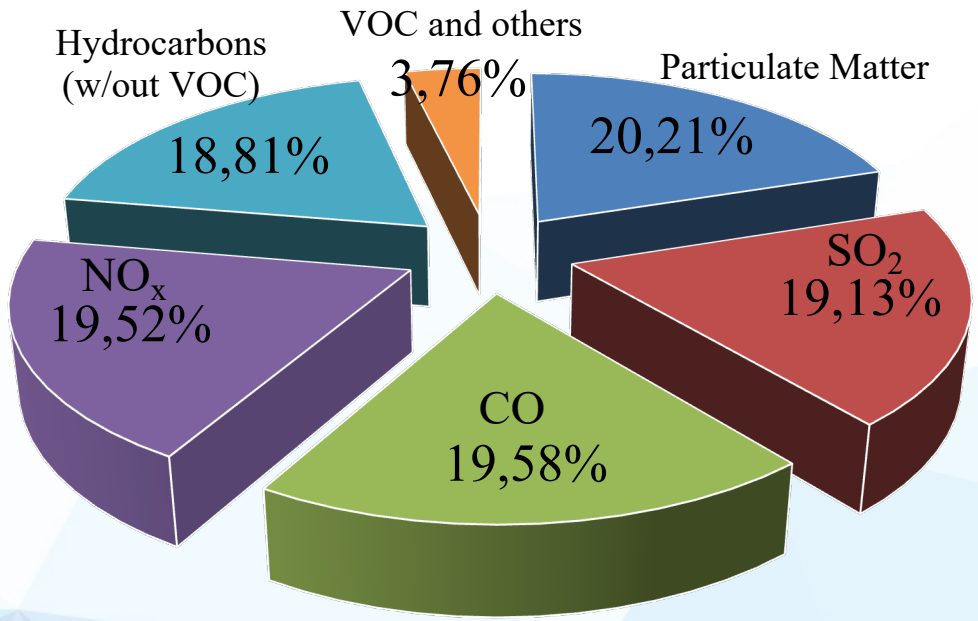
Electricity consumption in the region drops by **2-3 %** per year

References: Data of the Arkhangelsk region Administration

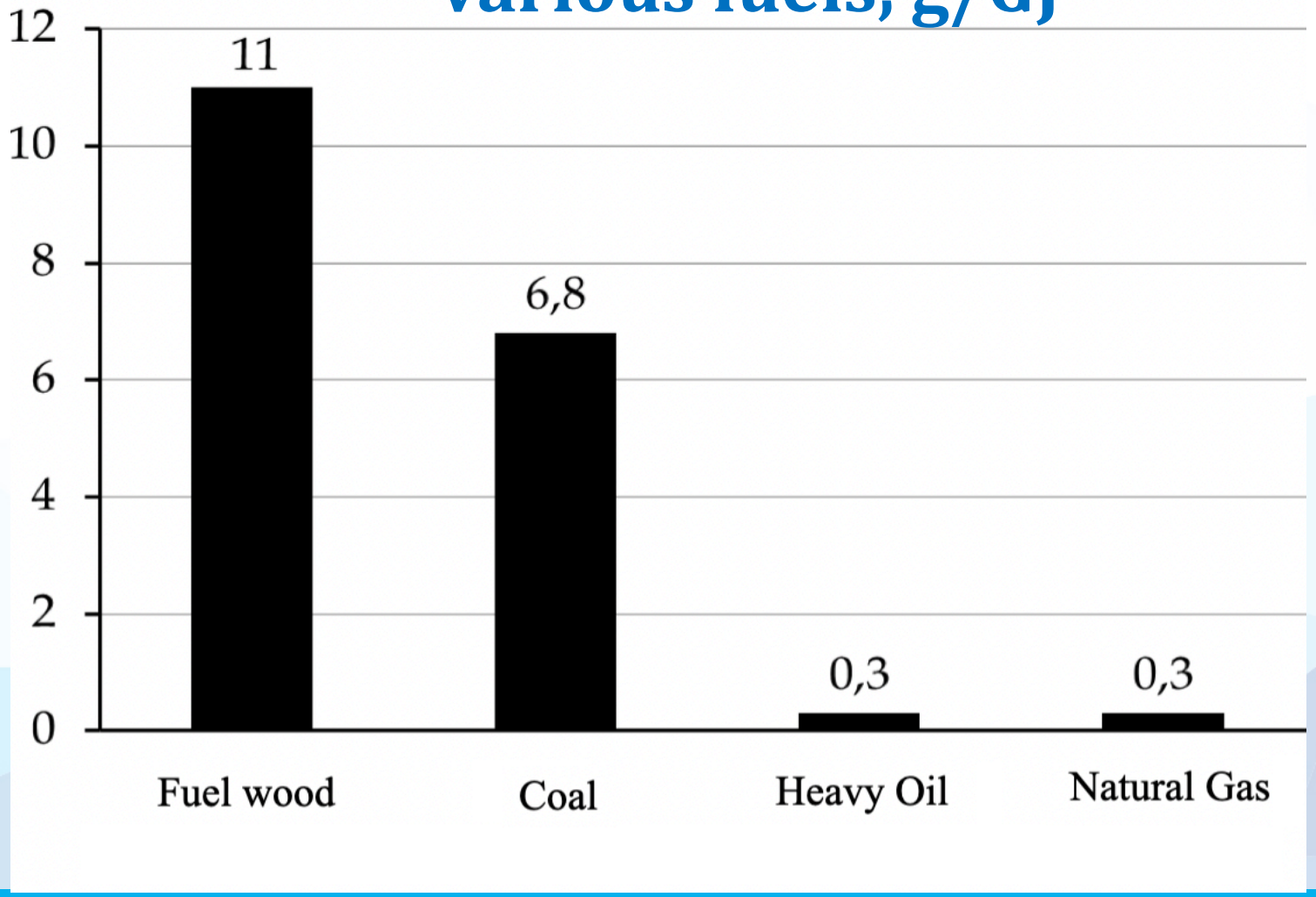
Dynamics of pollutant emissions from stationary sources



Composition of pollutant emissions from stationary sources of Arkangelsk region (w/out Nenets autonomous region) in 2019, %



The values of specific emissions of soot particles PM 2.5 recommended by American scientists for combustion of various fuels, g/GJ



Conversion coefficients on PM2.5 soot particles

Type of fuel, burning method	Value
Wood:	
primary	0,06
wastes	0,14
heavy oil	0,1
waste oil	0,1
natural gas	0,38
Grate firing of coal:	
bituminous	0,02
subbituminous	0,04
Flame combustion of coal:	
subbituminous	0,1

Data from the US EPA report on soot, March 2012.

Results of generalization of experimental studies on the emission of PM2.5 soot, g/GJ

Biofuel:

- raw firewood when burning in sectional cast iron hot water boilers with manual operation («Universal», «Tula», «Energiya» etc.) 18,0;
- a mixture of chips with sawdust during combustion in mechanized boilers with a capacity of up to 2 MW, equipped with inertial ash collectors 5,7;
- a mixture of chips with sawdust during combustion in mechanized boilers with a capacity of up to 6 MW, equipped with inertial ash collectors and in operation for up to 15 years 2,5;
- a mixture of chips with sawdust during combustion in boilers of the DKVr and KE brands, equipped with high-speed combustion pre-furnaces and snail ash catchers 4,6;
- boiler units with a capacity of up to 4 MW, operating on wood pellets, equipped with inertial ash collectors 0,4;
- boiler units operating on bark and wood waste, equipped with an adiabatic furnace with three-way gas movement in the furnace volume, equipped with a pneumatic system for cleaning heating surfaces and inertial ash collectors 1,4;
- boiler units operating on waste plywood production, equipped with an adiabatic furnace with a two-way movement of gases in the furnace volume, equipped with a pneumatic system for cleaning heating surfaces and inertial ash collectors 1,8.

Results of generalization of experimental studies on the emission of PM2.5 soot, g/GJ

Peat briquettes:

- steel hot water boilers KVr-0.4K with manual fuel loading, equipped with inertial ash collectors 0,8;
- steel hot water mechanized boilers KVm-2.0,

equipped with fireboxes with a rustling bar and inertial ash collectors 1,6.

Reactive coal:

- fire-tube boilers (two-furnace and single-furnace) with manual operation with a capacity of up to 2 MW. 25,0;
- raw firewood when burning in sectional cast iron hot water boilers with manual operation («Universal», «Tula», «Energiya» etc.) 15,0;
- steel hot water mechanized and steam boilers with a capacity of up to 2 MW with manual fuel loading

equipped with inertial ash 6,6;

- mechanized boilers of the DKVr and KE brands, equipped with inertial ash collectors 5,1;
- coal dust flare boiler units with a nominal capacity of 128–160 MW, equipped with angular slot burners with a tangential arrangement, and equipped with wet-type ash collectors 0,7.

Results of generalization of experimental studies on the emission of PM2.5 soot, g/GJ

Liquid fuels:

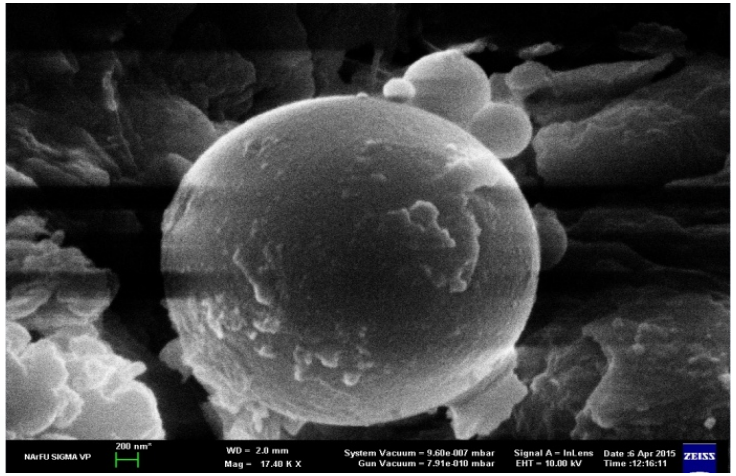
- boilers of the DKVr, KE and DE brands when operating on heavy oil of the brand 100 3,4;
- modern waste oil boilers with a capacity of up to 5 MW 0,3;
- high-pressure steam boilers operating on heavy fuel oil,

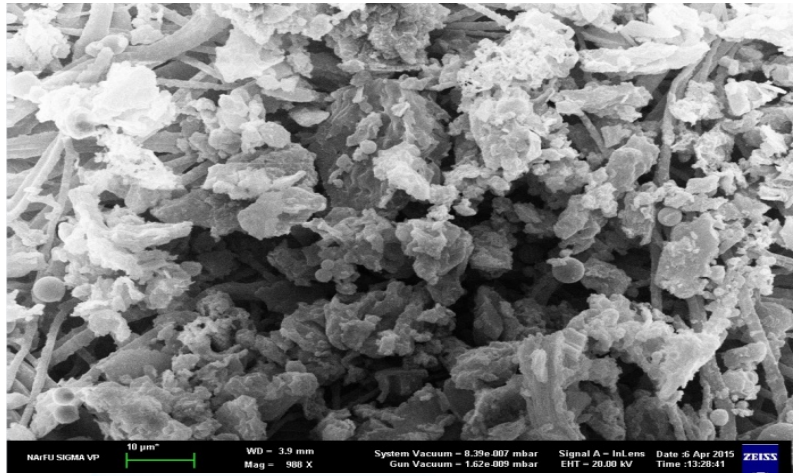
with a capacity of 320-380 MW 0,11.

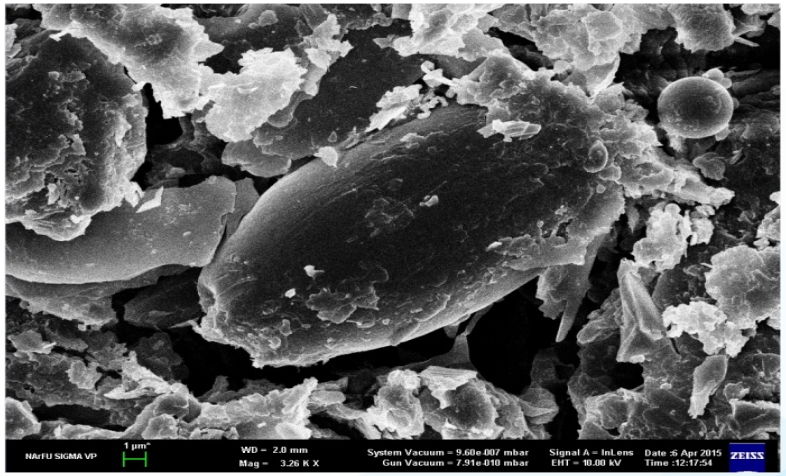
Natural gas:

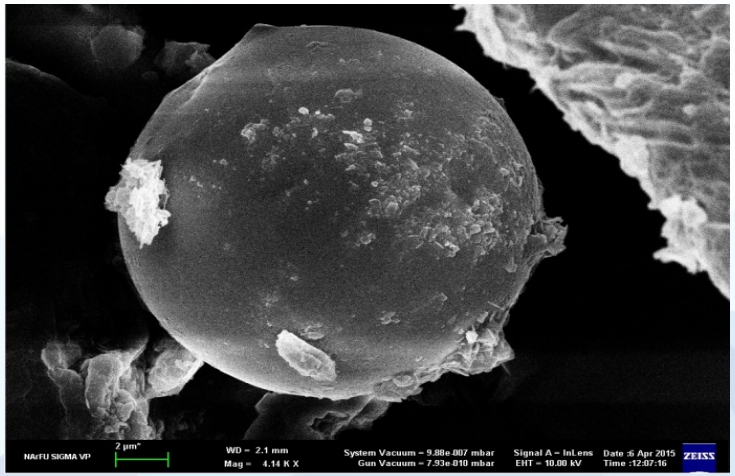
- high pressure steam boilers with a capacity of 128 MW and more 0,01;
- low-capacity boilers 0,05.

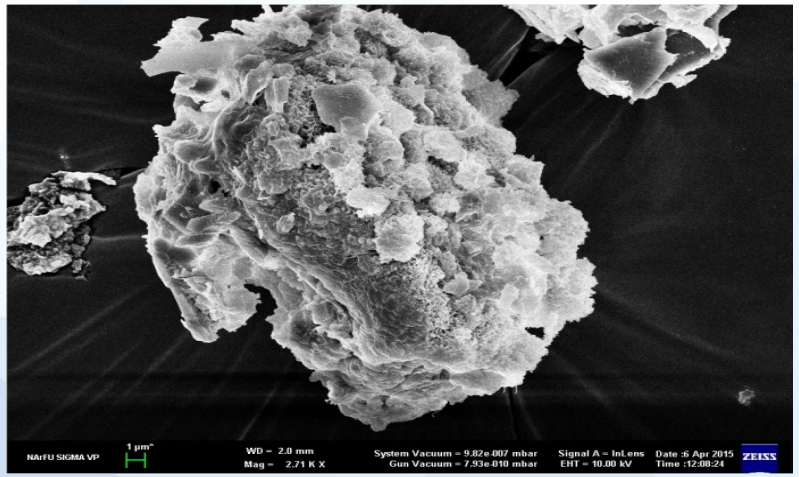
The structure of the solid particles produced by burning sod peat: a – spherical; b –amorphous; c – crystalline

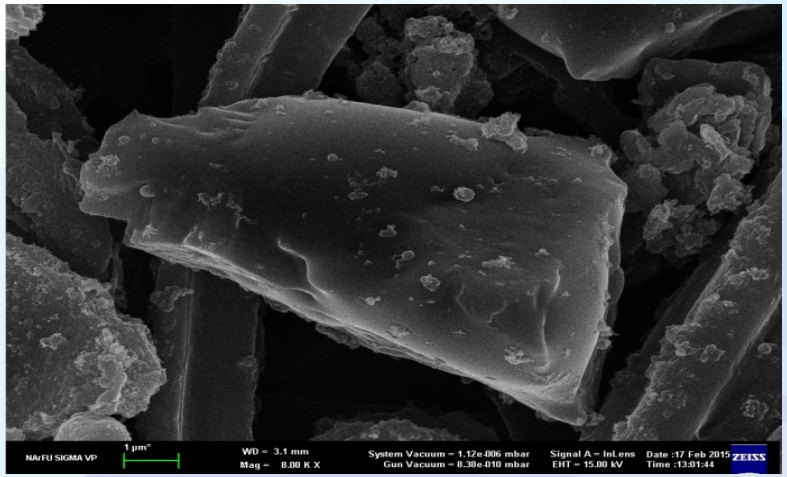






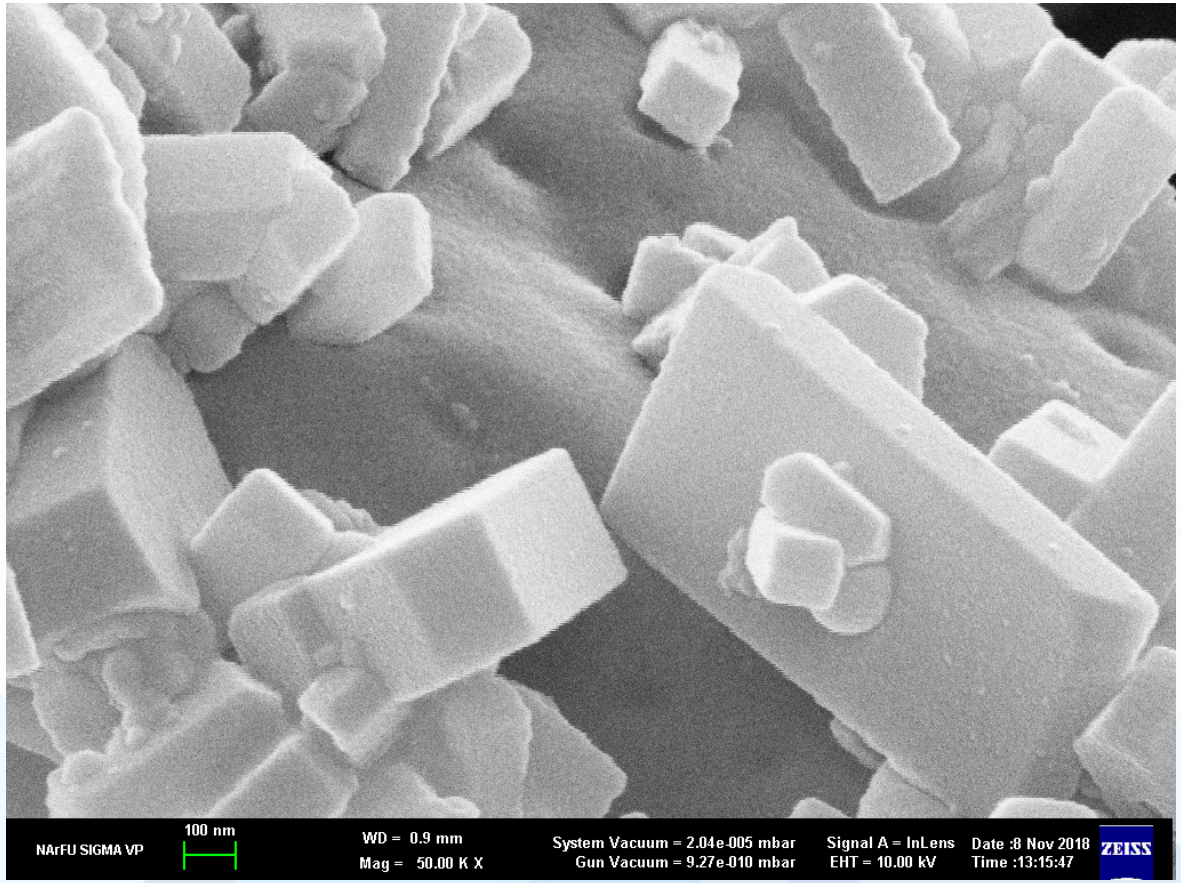


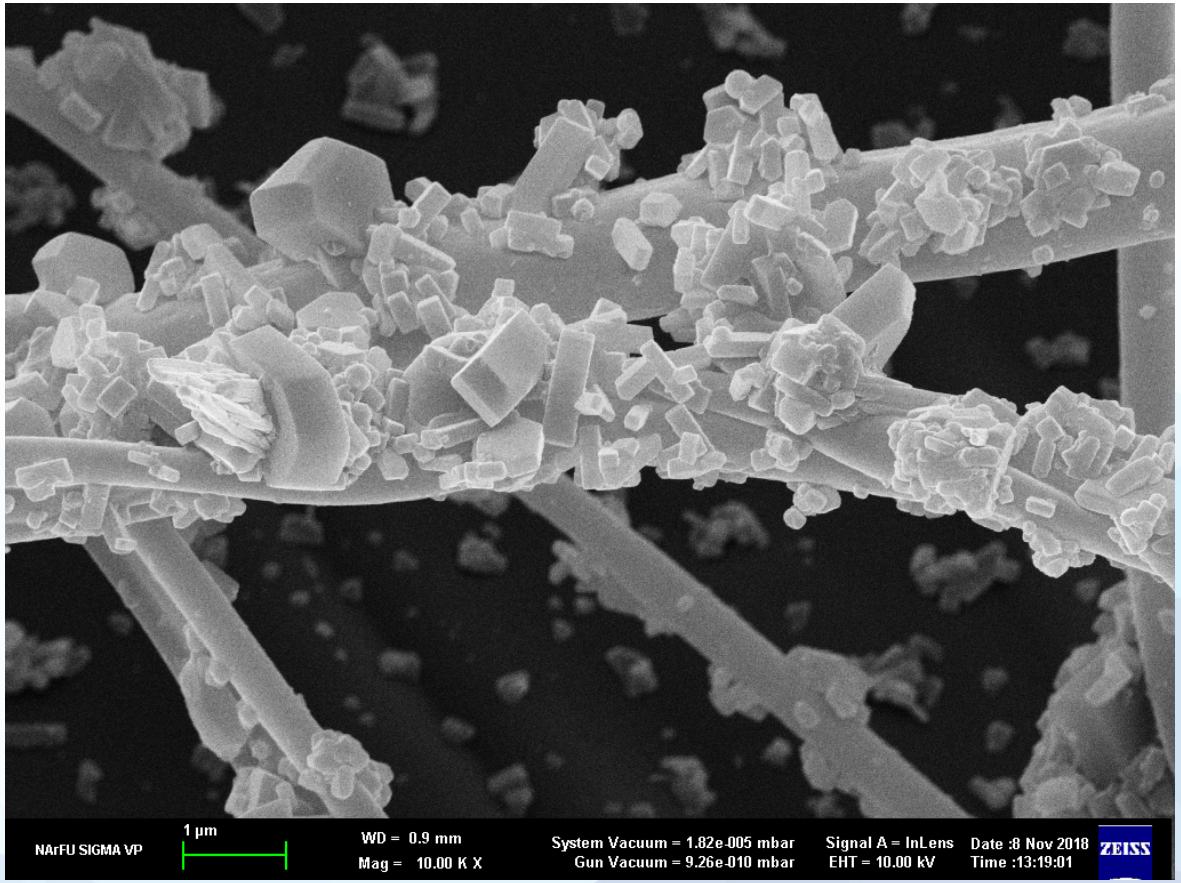




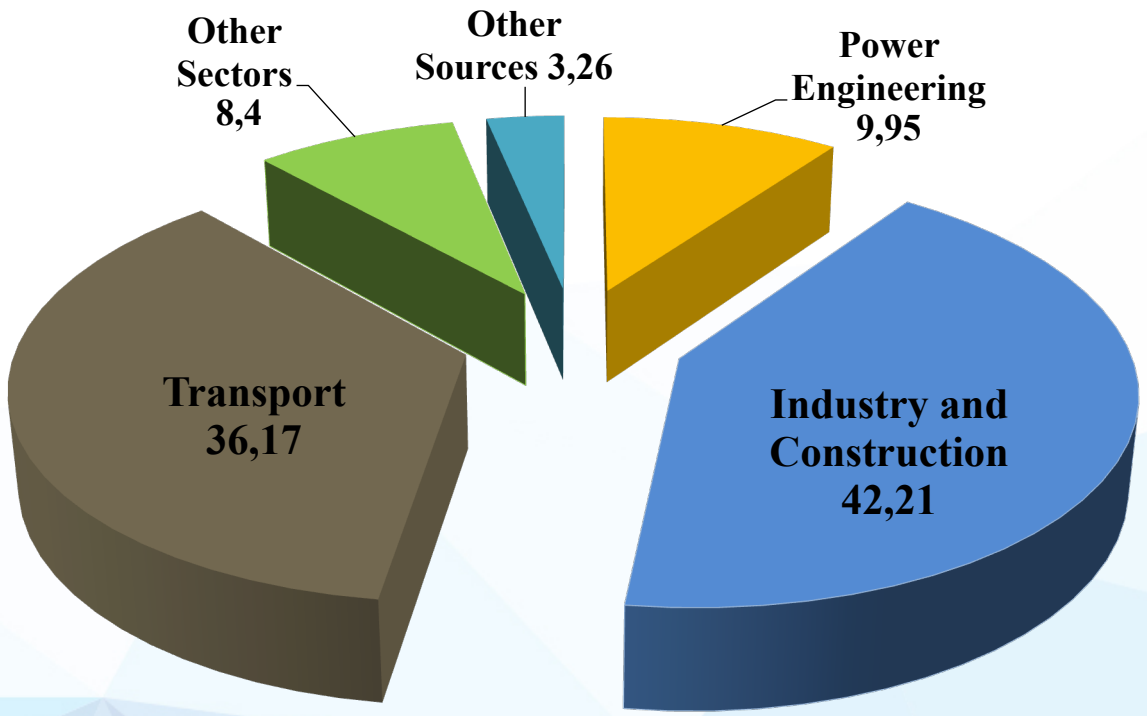
a b c

The structure of entrainment particles formed during the combustion of linden bark





The share of various sectors of the economy of the Arkhangelsk region in the total emissions of soot particles, %



Conclusion

- The level of emissions of soot particles is determined by the quality of the fuel, the design of furnace and burner devices, the combustion method, the degree of perfection and level of adjustment of the automation system, the presence and type of gas cleaning devices, as well as the technical condition and quality of service of heat generating plants.
- To determine the composition and size of soot particles, as well as the quantitative and weight content in them of particles with a size of 2.5 microns and less, the method of electron microscopy should be used.
- The total emissions of black carbon (RM 2.5) in the Arkhangelsk region amounted to 539 213 kg. The highest soot emissions are from industry and construction, as well as transport. The energy industries are in third place due to the dominant share of natural gas in their fuel mix. At the same time, the largest black carbon emissions in the energy industry are associated with the operation of boiler houses, which account for 6.29% of the total black carbon emissions.

Conclusion

- The relevance of the task of a comprehensive study of all aspects related to emissions of black carbon, its distribution in the atmospheric air and the impact on human health and environmental components is increasing every day. The first step towards its solution should be an inventory of soot emissions. To carry out the inventory, the values of the specific emissions of soot particles PM2.5 should be used when various fuels are burned in heat generating plants of various capacities and designs.

Thank you
for your attention!

v.lubov@narfu.ru