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Associated Petroleum Gas Flaring: Environmental Issues

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Abstract—Environmental impact of associated petroleum gas flaring in oil fields of the Russian Federation was analyzed. The opportunities for state regulation aimed at more efficient utilization of associated petroleum gas in the Russian economy were analyzed.

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INTRODUCTION

Oil field development involves release from oil of gaseous components, associated petroleum gas (APG), which may be supplemented by gas breaking through the gas caps. The APG volume can range from 5 to 1000 m^3 per ton of oil, and when there are gas caps in oil fields, it may reach higher level, 700 m^3 and above per ton of oil (due to breakthrough) [1]. Along with hydrocarbons, there can be H_2S, N_2, CO, CO_2, Ar, H_2, He, and other components in the gas [2], as well as water and inorganic substances that occurred in oil and produced water.

The hydrocarbons in APG are dominated by C_1–C_5 alkanes, but there can also be hydrocarbons with significantly higher molecular weights (Table 1) [1–3]. In this case, the level and content of APG component is determined by specific technology solutions.

The actual volumes of the APG produced and flared in Russia are not known [4] because of imperfect techniques, lack of gas meters in the majority of oil companies, and use of calculations instead of direct measurements. However, comparison of the data available from different sources provides a more or less reliable estimate of the amounts of APG produced and utilized in Russia as a whole (Table 2).

In 2010, at the request of the Russian Branch of the World Wildlife Fund the leading Russian oil companies reported on production of APG and its use to good purpose in 2006–2009 (Table 3). The Fund will present its comments on these data in the "Utilization of Associated Petroleum Gas in Russia: Problems and Prospects" review expected to be available in late 2010.

Environmental Implications of Associated Gas Combustion

The World Bank's analytical report on the use of hydrocarbon raw material [5] states the following: "Gas flaring is associated with the release of a large number of pollutants. Improper combustion, as indicated by smoke from flare stack, contributes to increasing the hazardous chemicals released into the environment including volatile organic compounds.

Table 1. The APG composition, wt %, for various oil fields [3]

Field	CO_2	Nitrogen	Methane	Ethane	Propane	*i*-Butane	*n*-Butane	*i*-Pentane	*n*-Pentane
Samotlor	0.59	1.48	60.64	4.13	13.05	4.04	8.6	2.52	2.65
Var'eganskoe	0.69	1.51	59.33	8.31	13.51	4.05	6.65	2.2	1.8
Aganskoe	0.5	1.53	46.94	6.89	17.37	4.47	10.84	3.36	3.88
Sovetskoe	1.02	1.53	51.89	5.29	15.57	5.02	10.33	2.99	3.26
Tarasovskoe	0.48	1.47	54.16	12.5	16.44	4.2	6.39	1.98	1.58
Barsukovskoe	0.96	1.80	80.78	5.81	4.27	2.04	2.00	1.16	0.65

Table 2. Directions of APG usage in Russia [4]

APG usage direction	Volume, billion m^3
Processing at gas treatment plants	18–20
Heat and power generation at municipal utilities and energy facilities	10–12
Heat and power generation at oil production entities (either directly or via production of hydrocarbon fuel)	3–4
Flaring	15–25
Total for burning	28–39
Injection into reservoirs	0.1–0.2
Process loss	1.0–1.5
Grand total	47–64

Table 3. Amount of APG produced and used by Russian oil companies

Company	APG produced, billion m^3				APG burned, billion m^3				Utilization rate, %			
	2006	2007	2008	2009	2006	2007	2008	2009	2006	2007	2008	2009
Surgutneftegaz	14.62	14.13	14.096	14.035	1.012	0.861	0.684		93.5	94.3	95.37	96.89
Tatneft	0.785	0.739	0.762	0.757					98.0	94.0	95.0	94.0
TNK-BP	11.283	12.390	12.228	12.537	2.284	3.914	2.500	1.958	79.8	68.4	79.6	84.4
LUKOIL	6.7	7.6	7.4	8.196	1.7	2.3	2.2	2.369	75.0	70.0	71.0	71.0
Slavneft	0.92	0.93	0.899		0.55	0.44	0.40		62.5	68.1	69.5	71 .1
Rosneft	13.56	15.7	12.4	11.755				3.882	59.0	60.3	62.9	67.0
Russneft	1.634	1.546	1.488		0.466	0.452	0.571		71.0	70.3	61.0	
Gazprom Neft	4.532	4.886	4.569	4.282	2.491	3.140	2.431		45.0	35.7	46.8	48.1

The substances include:

– more than 250 identified toxins, including carcinogens, benzopyrene, benzene, carbon disulfide (CS_2), carbonyl sulfide (COS), and toluene;

– metals such as mercury, arsenic, and chromium;

– nitrogen oxides; and

– sour gas with H_2S and SO_2."

The above-mentioned substances cause air, surface water, and soil pollution. Moreover, APG combustion may result in other adverse impacts on the natural environment and the population.

Atmospheric Air Quality Impact

Combustion of APG, like that of any organic substance, yields a mixture of products whose level and contents depend on the elemental composition and combustion conditions: concentration of reactants, efficiency of mixing, etc., and, ultimately, under normal conditions, on the design of the flare and combustion control (see, e.g., [6]). Emergencies and interruptions in the operation of the flare may lead to both "overburning" and "breakthrough" of a combustible material, i.e., to emissions of abundant toxic organic substances, as noted previously [5]. The amount of inorganic substances emitted (metals, metalloids, and their derivatives) depends on their content in APG solely and can be really determined only experimentally. At the same time, the amount of alkane combustion products emitted (carbon black, CO_2, CO, 3,4-benzopyrene, H_2O), as well as of unburned methane, nitrogen oxides, and sulfur dioxide, can be calculated in principle by the technique developed as early as 1997 [7] for specific APG composition, design and performance characteristics of the flare, combustion mode, and weather conditions.

Table 4. Atmospheric pollution emissions associated with burning of 225 million m^3 of APG in Nizhnevartovsk raion [6]

Substance	Emissions generated by indicated licensed blocks						Total, ton
	1	2	3	4	5	6	
Nitrogen dioxide	144.8	18.8	22.5	17.1	6.1	14.5	223.8
Nitrogen oxide	23.5	3.1	3.7	2.9	1.0	2.7	36.9
Sulfur dioxide	Traces	2.0	Traces	Traces	Traces	1.0	3.0
3,4-Benzopyrene	7.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	Traces	1.0×10^{-6}	1.1×10^{-5}
Methane (estimated amount per flare for APG containing 80% methane)							200000

Calculations are needed for assessing the environmental impact, preparing documents for environmental assessment, and getting environmental permits. For the actually functioning flares, the set of initial data required for calculations never proves to be complete, which necessitates occasional experimental determination of flare emission composition [6, 8–15].

Flare emissions typically contain a more or less invariant mixture of pollutants: carbon black, nitrogen oxides, carbon monoxide, 3,4-benzopyrene, sulfur dioxide, and other sulfur compounds (hydrogen sulfide, carbon disulfide, mercaptans). In six license blocks of Nizhnevartovsk raion [6], burning of ca. 225 million m^3 of APG throughout a year resulted in emissions of over 50 thousand tons of pollutants, including ca. 260 tons of nitrogen oxides (Table 4). In accordance with the Russian Federation Government Decree no. 410, the payment for emissions resulted from APG burning in amounts indicated in Table 3 is ~13 thousand rubles against 10 million rubles in the case of methane flaring emissions.

Along with the substances listed in Table 4, the flare emissions contained carbon monoxide, carbon black, hydrocarbons, mercaptans, and several tens of other substances. The mixture of pollutants in each specific case depended on the time and frequency of flare system operation, stack size (height and diameter), qualitative composition of APG, proportion of condensate therein, etc.

The flare systems exploited in Pokachevskoe field emit not only significant amounts of carbon monoxide and nitrogen dioxide [8] but also abundant carbon black and saturated hydrocarbons, which are responsible for severe oil contamination of soils and degradation of adjacent ecosystems. All indications are that APG flaring in Pokachevskoe field is carried out either with imperfect flare systems or in a far from optimal mode.

The qualitative and quantitative composition of the pollution mixtures generated by APG combustion in the north of the Timan-Pechora province was assessed [10, 11]. It was found that fields with recoverable reserves of 15–20 million tons are responsible for emissions of CO, nitrogen oxides, sulfur dioxide, hydrogen sulfide, a hydrocarbon mixture, and benzopyrene totaling to up to 330 ton $year^{-1}$.

The APG flaring inVatinskoe field results in emission of suspended particulates and hydrocarbons, as well as of carbon, sulfur, and nitrogen oxides [12]. According to Aerokosmologiya Ural Regional Center data, the above-field background level of particulates in atmospheric air (with natural, anthropogenic, regional, and local background pollution levels taken into account) lies within double of the one-time MPCs. Zones with increased content of particulates [from 2 to 10 one-time maximum permissible concentrations (MPCs)] are formed near large industrial areas around town of Megion and Vysokii settlement.

The APG flaring in Samotlor field, like in the case of Vatinskoe field, significantly contributes to atmospheric pollution of a nearby settlement, town of Nizhnevartovsk [13, 14]. The flare plumes contain both diversified gaseous substances (ammonia, benzene, xylene, toluene, nitrogen oxides, sulfur dioxide, CO) and aerosol components (salts of various metals: mercury, iron, manganese, magnesium, zinc, lead, nickel, aluminum, titanium, etc.). As a result, in the cold weather period flare emissions contribute with ca. 25%, and in the warm weather period, with nearly 30% to air pollution.

Additional studies [14] showed that, in Samotlor field, the APG flaring products rise to a height of no lower than 600 m; the petroleum hydrocarbons and sulfur dioxide concentrations are at maxima specifically at this urban plume height. The maximum concentrations for the remaining seven pollutants indicated (like for other chemical components of aerosol) were revealed at a height of ~400 m.

Naturally, the area of the spread of pollution generated by APG flaring depends on the gas yield, qualitative composition, and relative density, as well as on the season and prevailing wind directions in the field area. Nevertheless, it is known [15] that, under relatively weak wind conditions, the largest spread distances (up to 15 km) are characteristic for the emitted hydrocarbons, ammonia, and CO Hydrogen sulfide migrates to a distance of 5–10 km; increased concentrations of nitrogen oxides are observed within a 1–3-km area around the pollution source. More accurate calculations can be performed with the use of appropriate guidance documents [16].

According to Michael Schulz, an HTAP expert (Michael.shulz@cea.fr), sulfates in the aerosol generated by APG flaring can be detected within approximately 40 days after the emission event. Among these sulfates, 40% is detected in the vicinity of the emission source, ~30%, at a distance of several hundred kilometers from the source, and the remaining 20%, over a distance of a few thousands to tens of thousands of kilometers.

The APG flaring leads not only to air pollution with various substances (the end-of-pipe concentrations of 2–3 hazard class substances reaches 300–1000 mg m^{-3}, the emission rate being 0.1–0.5 g s^{-1}), which spread over large distances but also to thermal pollution over a distance of 5 km from the flare device [17]. Both types of pollution affect the weather and climate conditions. The APG combustion causes formation of cumulus clouds in amount of 1–2 at the height of 200–300 m and attenuation of solar radiation by 5% [17].

Impact on Soil and Land

Adverse environmental impact is exerted starting from the prospecting activities and construction of oil production facilities, in particular, of flares [18]. The environmental implications of the construction of the central collection stations (CCSs) and pretreatment stations for oil, gas, and water, as well as of booster pumping stations (BPSs) and compressor stations and the subsequent operation in the allotted area include: clearcut timber stand, destroyed live ground cover, deep soil mixing or backfilling with imported soil, and contamination of 30–40% of the area with oil, saline water, and other substances.

The impact exerted by APG flaring spreads over an area that exceeds at least 3–4 times the allotted area [18]. This is associated with atmospheric oxygen consumption, high temperature exposure; air, vegetation, and soil contamination with products of incomplete combustion of hydrocarbons in flare stacks, including dispersed oil, carbon and nitrogen oxides, sulfur dioxide, carcinogenic substances, and some other toxic substances.

High temperature exposure, depending on the flare system capacity, causes burnout of soil organic matter and, correspondingly, of soil flora and fauna, over a distance of 50 to 150 m. This phenomenon is observed within a radius of up to 20 m, depending on the flare capacity [6, 19]. This causes soil calcination into a dusty structureless sand or sintered clay loam, which is occasionally cracked and has metallic luster. With increasing distance from the flare stack the degree of soil degradation caused by high temperature exposure decreases, especially as the soil is protected by the plant cover, but adverse changes in soil are observed 150–200 m away from the flare stack [19].

The chemical impact on soil results from deposition of combustion or transformation products of APG components: carbon black, benzopyrene, polycyclic aromatic hydrocarbons, dioxins and their analogs, inorganic salts, and unburned (or burning) dispersed oil [6, 9, 17, 18]. The soils occurring near the flares are characterized by consistently high, >450 ng g^{-1}, levels of polycyclic aromatic hydrocarbons [20, 21], and 3,4-benzopyrene may occur in concentrations of up to 10–20 MPCs.

The interaction of nitrogen and sulfur oxides with atmospheric moisture causes formation of acids whose deposition is responsible for soil acidification [6, 17]. Also, the under-flare soil is almost always contaminated with sulfates and nitrates. For example, in the vicinity of one of the flares in the Tyumen oblast field [22] the sulfate and nitrate concentrations exceeded several times their corresponding background levels even at a distance of 800 m. The amount of sulfates and nitrates deposited under the flare was estimated at 310 and ~570 kg per annum, respectively.

A special problem is presented by emissions of burning or unburned (dispersed) oil, generated by APG flaring [9, 17, 18, 20]. Dispersed oil is responsible for not only burnout of vegetation but also for severe oil contamination of soil in addition to other processes accompanying oil production and pretreatment, in which petroleum hydrocarbons are released.

Table 5. Characterization of the environmental impact from APG flaring [19]

Location	Exposure period, year	Adversely affected area, ha		
		soil and land contamination with fuel oil	soil cover disturbance	timber stand loss
Pokachevskoe field, CCS	10	23.7	29.2	19.7
Aganskoe field, CCS	2	11.0	11.0	11.0
Vatinskoe field, oil and gas production department	4	–	11.9	11.9
Vakhskoe field, BPS	5	2.7	1.1	1.1

Petroleum hydrocarbons are emitted not only from ground-based flares but also from facilities arranged on offshore oil production platforms. Flaring emissions associated with putting into operation and fitting to regime of oil wells in Beaufort Sea caused formation of a thick oil hydrocarbons film over the sea surface around the platform [23]. The amount of emitted petroleum hydrocarbons that, moreover, contain polycyclic aromatic compounds, was estimated at 350 tons per day.

Impact on Wildlife

As noted above, the operating flare systems generate fire hazard, especially in view of the fact that the mass of dead and dry vegetation in their vicinity is constantly increasing. The injury to vegetation from direct thermal effects produced by low-capacity flare stacks spreads over up to 50-m distances, and that for higher-capacity flare stacks, up to 150-m distances [19]. The burning oil fractions ejected beyond the mineralized zone systematically cause forest fires over an area of tens of hectares, which are responsible for demise of animals, birds, and insects. On the whole, indications of vegetation suppression due to thermal radiation exposure solely spread over up to 4-km distances [15].

The purely thermal effects of flares and exposure of wildlife to high temperatures are supplemented by the chemical impact exerted by various components of flaring emission. The combined environmental effect of these two factors may spread to distances ranging from several hundreds of meters to several kilometers, according to different sources [18, 19]. Depending on the flare height and operation mode, as well as on the amount and composition of the APG, flaring may result both in complete destruction and partial degradation of vegetation, for which there exists a probability for recovery after the chemical and thermal loads will be alleviated. In some instances, APG flaring resulted in complete destruction of timber stand at a distance of 180 m from the flare point along the direction of prevailing winds [24].

Nitrogen and sulfur oxides head the list of pollutants that most strongly affect the vegetation, especially under conditions of increased humidity existing in the contaminated area which it owes the flares as well [18]. On the whole, the closer the vegetation to the flare point, the more pronounced its defoliation [8]. Also observed is a pronounced trend toward increase in defoliation degree and a shift to higher defoliation classes with increasing time of operation of the flare (although some researchers [19] believe that the flare impact zone is formed already within the first two years of the flare operation).

In Pokachevskoe field [8], the timber stand separated from the flare stack by a distance of 100 m is absolutely dominated (60%) by III and IV defoliation category trees (the timber stand is greatly weakened.) The closed canopy is estimated at 0.36 against ≥ 0.47 in the control areas. Another indicator is the timber biomass increment: For DPS-4 flare the timber biomass increment (timber stock change) over a 9-year period was estimated at 1 m^3 ha^{-1} at a distance of 250 m from the flare stack against 7 m^3 ha^{-1} at a distance of 440 m [8].

Termination of APG flaring causes the amount of undergrowth to sharply increase. During APG flaring the undergrowth was characterized by intense litter, and the proportion of well-established saplings of pine did not exceed 25.6%; after 8 years elapsed since APG flaring was terminated the number of seedlings and saplings increased by a factor of 1.9. The proportion of well-established pine saplings increased to 50.0–56.8% [8].

Flare impact on vegetation is manifested, along with defoliation, in deterioration of the quality of green mass, especially in coniferous trees [6, 24]. In Nizhnevartovsk raion, on experimental plots separated from the flare point by 150–950 m, the extent of damage to the needles reached 70% against 31–34% in the control areas at 3.5–6.0-km distances. The damage appeared not only as necroses but also as chloroses, which resulted from direct exposure to the flaring products of APG comprising chlorides which clearly passed to APG from produced water.

Typically, the higher the nitrogen oxide emission level, the more profound the damage inflicted to conifers. The permissible daily average concentration of nitrogen dioxide is 0.03 and 0.05 mg m^{-3} for coniferous and deciduous plants, respectively [25], and the MPC of nitrogen dioxide for plants is even lower, 0.02 mg m^{-3}. In the case of APG flaring the end-of-pipe nitrogen oxides concentration may reach 300–1000 mg m^{-3} [17], which value is sufficient for the permissible chemical impact levels on vegetation to be exceeded many times. It should be noted that the adverse impacts produced on vegetation by nitrogen oxides and SO_2 are mutually reinforced [6].

The impact exerted by flares on the lower vegetation layers appears as depletion of the species composition of saplings and live ground cover, as well as in reduction of the proportion of well-established saplings [9, 24]. Above all, this causes reduction in phytomass of cranberries, blackberries, blueberries, ground lichens, and mosses [24]. The total phytomass of the live ground cover in absolutely dry state at a distance of 100 m from the flare is as low as 1400 against 4209 kg ha^{-1} at a distance of 250 m.

Flare emissions and thermal effects also suppress the vital activity of soil biota via slowing down the mineralization of dead plant residues [24]. With decreasing separation from the flare point, the litter tends to accumulate: At 100-m separation the absolutely dry phytomass of litter is 46767 against 33552 kg ha^{-1} at a distance of 240 m.

The removal of anthropogenic load, i.e., termination of APG flaring, causes the total mass of live ground cover and timber stand to actively increase [6, 9]. The APG flaring termination affects most beneficially the saplings. Overall, similar trends were observed at all the APG flaring sites examined: West Siberia and Middle Volga region, as well as Tyumen, Tomsk, and Samara oblasts [20].

Table 5 summarizes selected data characterizing the environmental impact of APG flaring in some of the fields.

Also, the constant noise produced by APG flares exerts an adverse, repelling, effect on wild animals, birds, and insects [10, 18, 19], which leads to reductions in their population size and species composition. The repelling effect on animals is exerted not only by audible sound but also by infrasound. Studies undertaken at IS31-Aktyubinsk station showed that, in Zhanazhol field, an infrasound signal is detected even at a distance of 235 km from the APG flaring point [26].

The available data concerning the direct impact exerted by APG flaring on the animal health are scarce. However, they are indicative of adverse changes induced in the myocardium, liver, and kidneys of lemming inhabitants of the vicinity of flares of a production facility, which are similar to those observed in lemmings in the vicinity of lubricant bases [27].

It is also known that malignant tumors in mouse-like rodent inhabitants of the vicinity of flare points are more common than in animals whose habitats are far from oil production facilities [28]. In this case, a direct analogy may be drawn to the fact that, in the Middle Ob Region residents, the cancer incidence rate exceeds nearly thrice that in Russia on the average [19].

APG Treatment Regulation

The current situation in the Russian Federation with treatment of APG, a valuable hydrocarbon raw material and a power resource simultaneously, is unique in the worst sense of the word. The majority of license blocks lack APG meters, and the exact volumes of the APG produced and utilized are unknown [4]. The damages inflicted to Russia's economy by APG flaring (via loss of a raw material and environmental impact exerted by APG combustion products) may reach several hundred billion rubles per annum [4].

The legal framework regulating the APG treatment is very far from perfection. Above all, the existing regulations do not treat APG as a mineral resource to be rationally used. For example, Article 23 of Federal Law no. 126-FZ "On Mineral Resources" of August 8, 2001, states that the basic, together with co-occurring, mineral resources and their associated components are to be recovered to the largest possible extent without mentioning APG among these components. This law is also lacking in the concepts of the normal and above the normal loss of gas dissolved in oil. Moreover, subparagraph 2 of paragraph 1 in Article 342 of the Tax Code of the Russian Federation stipulates a zero tax rate on APG production.

Until 2001, the APG utilization levels (norms of extraction losses) were approved annually by the Russian Federation Ministry of Energy (in its sector-specific documents) in consultation with Gosgortekhnadzor (Federal Committee for Mining and Industrial Supervision). Currently, the APG utilization levels can be set forth by a license agreement solely, which opportunity is taken advantage of by no means always. For example, in the Khanty-Mansiisk Autonomous District-Yugra, which produces nearly 60% Russian oil, a half of the license agreements are lacking in any APG utilization requirements [4].

It should also be mentioned that oil and gas field development projects typically do not specify the amount and usages of the APG produced. For example, the “Standard Procedure for Drawing up the Engineering Design Documentation on the Development of Oil and Gas Fields” (RD 153-39-007-96) does not contain the “associated petroleum gas” term or its equivalent at all.

The situation with APG utilization was analyzed by Russian Gas Society (RGS) experts with the participation of representatives from companies engaged in hydrocarbon production and processing. It was shown that APG utilization in Russia cannot be improved by the simple prescriptive (restrictive) methods. This analysis revealed the need in development and implementation of a package of measures to generate in oil companies a serious interest in careful handling of APG, considering the diversified conditions of oil production, insufficient development of gas pipeline system needed to supply APG to enterprises engaged in its processing, and some other factors. Also, the need in special regulations was naturally identified, especially in those at the legislative level, in which administrative measures would be reasonably combined with economic incentives. As a result, a draft Federal Law “On Amendments to Some Legislative Acts of the Russian Federation on Efficient Use of Petroleum (Associated) Gas” was developed in early 2009.

The draft law included amendments to a number of existing laws on which basis the underlying principles of the state policy in the sphere of APG treatment could be formulated, in particular:

– resolve the problem of determining the levels and permissible usages of APG, depending on its production conditions and composition and establish the compliance assessment mechanisms for relevant requirements;

– determine the conditions of state participation in financing and implementing federal, regional, sectoral, and corporate programs aimed to achieve higher APG utilization levels;

– identify the financial incentives to motivate the reduction of pollutant and greenhouse gas emissions associated with APG flaring;

– identify the benefits (tax, customs, etc.) for companies that undertake construction and operation of plants engaged in APG processing and manufacturing further APG processing products;

– identify the financial incentives to motivate APG utilization by oil and gas companies to meet the household needs in heat energy and electricity of residents in settlements in Far North regions and other remote places, as well as to supply electricity to the Unified Power System of Russia;

– to delineate the responsibilities between the federal and regional state administrations in solving the problem of efficient use of APG, etc.

In early 2009 this draft law was introduced in the State Duma of Federal Assembly of the Russian Federation by the Energy Committee but was withdrawn in the fall of 2009 because of the revocation by the subject of the right of legislative initiative. This draft law will be reintroduced in the State Duma by the Federation Council Commission on Natural Monopolies.

With a law that could radically solve the APG treatment problem lacking so far, the Russian Federation Government is seeking to encourage oil companies to reduce APG flaring. For example, on January 8, 2009, the RF Government issued Decree no. 7 “On Measures to Stimulate the Reduction of Air Pollution Products from Burning Associated Gas in Flares” which prescribes the reduction of the proportion of APG flared to 5% of its total amount produced since January 1, 2012. Also, the decree introduces much higher payment rates for emissions of harmful (polluting) substances generated by APG flaring.

On March 9, 2010, the Federal Law “On Amendments to Article 32 of the Federal Law “On Electric Power Industry”” was adopted. It provides for the priority access to the Unified Power System of Russia for facilities that use APG and its processing products for power generation.

Table 6. JIP applications on APG utilization, accepted for competitive selection by the Savings Bank of Russia

Run no.	Project title	Emission reduction, tons of CO_2 equivalent
1	APG utilization at Samotlor field	846 246
2	APG utilization at Ety-Purovskoe field	3 109 867
3	APG utilization at Komsomol'skoe field	4 000 000
4	APG utilization at East-Pereval'noe oil field	311 610
5	APG utilization at Middle-Khulym oil field	526 114
6	Efficient use of APG at Tatneft Open Joint-Stock Company facilities	115 925
7	Utilization of APG from the Kharampur group of fields of NK Rosneft Open Joint-Stock Company	5 000 000
8	APG flaring reduction and electricity production at Khasyreiskoe oil field	711 277
9	APG processing at South-Balyk Gas Processing Complex	9 640 842
10	APG utilization at Serginskoe oil field	107 876

Finally, pursuant to Decree no. VP-P9-51pr issued by Prime Minister V.V. Putin on November 10, 2009, a working group was established at the Russian Ministry of Energy, whose activities are aimed, in particular, at improvement of the regulatory framework promoting the rational use of APG.

Associated Petroleum Gas and the Kyoto Protocol

The Kyoto Protocol (KP) to the UN Framework Convention on Climate Change (Article 7) [29] stipulates the greenhouse gas (GHG) emission reduction by all the Country Parties to the KP, including Russia. Along with carbon dioxide, GHG include methane, nitrous oxide, and some other substances. For convenience, all GHG are converted to the carbon dioxide equivalent (CO_2 equivalent) using global warming potentials GWPs [29, 30]; carbon dioxide has a GWP of 1, and methane, of 21. The Kyoto Protocol provides several mechanisms for transfer of GHG emission reduction units among the Parties to the Kyoto Protocol, including the joint implementation mechanism. The latter allows any Party to the KP to invest in emission reduction projects in any other party to KP, in particular, in Russia, as an alternative to reducing emissions (Article 6).

By the end of 2008, about one hundred Joint Implementation Projects (JIPs) were developed in Russia, whose implementation would result in a total GHG emission reduction by ca. 180 million tons of CO_2 equivalent.

In 2009, active preparation of JIPs was undertaken by the leading Russian oil and gas companies: Gazprom, Rosneft, Lukoil, TNK-BP, Surgutneftegaz, Nizhnekamskneftekhim, SUEK, and RUSAL Open Joint-Stock Companies, as well as by Ilim Group. The leading international financial institutions, the World Bank and the European Bank, Deutsche Bank, Dresdner Bank, and Sumitomo, as well as European and Japanese industrial and energy companies and a variety of public and private carbon funds monitored the situation with new large Russian projects and offered the emission reduction technologies to be purchased under conditions that they deemed appropriate.

The number of the joint implementation projects prepared in the first half of 2009 was as large as 125 with the carbon potential of 240 million tons of CO_2 equivalent. Based on the current market prices, the expected emission reductions would be no less than 3.5 billion US dollars.

However, despite the obvious interest expressed by business, a real benefit expected by the economy, and the appropriate regulatory framework existing since 2008, neither of the JIPs was approved by the Russian Federation Government. In 2009, the Government revised the procedure for consideration and approval of JIPs, that was not implemented by that time and issued Decree no. 884-r of June 27, 2009, and Decree no. 843 "On Measures to Implement Article 6 of the

Kyoto Protocol to the UN Framework Convention on Climate Change" dated October 28, 2009. Those documents assigned the functions of "carbon units operator" to Sberbank of Russia (Joint-Stock Commercial Savings Bank of the Russian Federation) which was commissioned with assessment of JIP applications with a view to select those to be further approved by the Russian Federation Government. Among the first 39 JIPs that were submitted in April 2010, ten projects were aimed to solve the APG utilization problem for oil and gas fields (Table 6). Based on the results of the assessment, project nos. 1–5 out of the projects listed in Table 6 were approved by Order no. 326 of the Russian Federation Ministry of Economic Development, dated July 23, 2010. Upon implementation and verification of those projects, their investors would possess the reduced GHG emissions to be traded at international carbon markets.

CONCLUSIONS

Topical for all oil-producing countries, the problem of utilization of associated petroleum gas has long been especially pressing for Russia. This is due to Russia's world leadership in terms of the amount of APG flared and to a number of historical factors (lacking infrastructure and access to markets, biased price estimates for APG, etc.), which make simple, one-sided, and quick algorithms unsuitable for solving this problem in Russia.

In the present-day situation, the consequences of APG flaring are manifested in direct loss of valuable hydrocarbon resources and in profits lost by the state, which are associated with the shortfall in gas and chemical products. Flaring of associated petroleum gas leads to environmental degradation and deterioration of the living conditions in oil production areas. Also, APG combustion products contribute to the development of planetary processes that exert adverse impacts on climate.

The core of the solution of the problem lies in the priority role played by the state as the main subject in regulation of economic relations to the national economic interests. Today, the APG utilization problem is largely approached on the basis of a number of new investment projects whose implementation entails high capital costs and requires stable market. In this context, it is essential that economically viable options for APG utilization be found which take into account the new emerging opportunities, e.g., application of international practice principles, in particular, the financial mechanisms prescribed by the Kyoto Protocol, the priority access to the Unified Power System of Russia in accordance with amendments to Federal Law "On Electric Power Industry," etc.

Today, there are quite a number of joint implementation projects developed in Russia that seek an efficient use of APG. The long-awaited progress was achieved in approval of the first JIPs of which many are aimed at APG utilization. Russian companies undertake implementation of new business solutions aimed at efficient use of APG, in particular, via joint ventures, public-private partnerships, etc. The volumes of APG produced and utilized by companies exhibit favorable dynamics which, however, is insufficient for most of the companies to arrive at the 95% level of APG utilization by 2012.

Efficient use of APG can be achieved through taking an integrated approach based on a mutually beneficial and productive cooperation of all stakeholders: government, business, and the public. Certain progress in addressing the APG flaring problem was achieved through the activity displayed by the RF Government in implementation of the JI mechanism under the Kyoto Protocol, namely, approval of some of the investment projects on APG utilization, as well as of amendments to the Federal Law "On Electric Power Industry," encouraging the production of electricity from APG. High activity of all the stakeholders, including the public, as well as improvement of the relevant regulatory framework, would allow achievement of the prescribed level of 95% for associated gas utilization by 2012.

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