Environmental and Economic Rationale for the Use of Associated Petroleum Gas Using the Example of Fields in Eastern Siberia

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Abstract. The use of associated petroleum gas and the problem of its disposal and processing are being actively discussed, oil and gas companies are inventing new methods. The aim of our research is to consider the use of associated petroleum gas in fields in Eastern Siberia and to compare environmental and economic damage from the use of various methods for disposing of associated petroleum gas.

In this article, we reviewed some of the most promising in our opinion methods for processing and disposing of associated petroleum gas, such as deep conversion into gas, flaring, injection into the gas transmission system, reverse injection of associated petroleum gas, and the economic effect of their use. We estimated the environmental damage caused by enterprises and the economic effect of the application for several mining fields. The problem of rational utilization of APG remains acute in a number of regions and companies, especially among small independent producers.

1. Introduction

Associated petroleum gas (hereinafter APG) is one of the by-products of the oil production process. In the general case, the liquid obtained directly from the oil field well cannot be immediately sent to the main oil pipeline since it contains various substances (water, sulfur-containing compounds, metal salts, methane, linear and branched hydrocarbons) that must be separated and used/disposed of. Methane and other low molecular weight (volatile) alkanes are the main components of APG [1].

Until recently, associated petroleum gas has not been considered a priority for oil and gas companies. Moreover, the industrial fate of APG was predetermined - the associated gas was separated from the oil during its preparation for transportation and then burned in flares. Unproductive burning of APG is due to a number of technical and economic reasons, as well as the peculiarities of the legal regulation of the oil industry. As a result, more than 17,000 flares are burning at fields and oil refineries around the world, emitting about 350 million tons of CO₂ into the atmosphere each year, as well as a large number of various pollutants, including very hazardous ones [2-5].

An alternative to the burning of APG is its preservation by reverse injection into the subsoil for mining and processing in the future, use for generating electric and thermal energy, processing into fuel or raw materials for the chemical industry. This way, 147 billion m³ of associated petroleum gas burned in 2017 could turn into 750 billion kWh of electricity. For Russia, full utilization of APG
would mean annual production of 5-6 million tons of liquid hydrocarbons, 3-4 billion m$^3$ of ethane, 15-20 billion m$^3$ of dry gas or 60-70 thousand GWh of electricity [6-8].

The rational use of APG was triggered by both “stick” and “carrot”. These are fines with increasing coefficients for excessive APG burning combined with an option to include investments in the gas program for the implementation of projects for the beneficial use of associated gas into these payments. Quite recently, before the government decree “On the peculiarities of calculating payments for pollutant emissions” entered into force, Russia had been part of the global anti-rating of the countries that burn APG.

The aim of our research is to consider the use of associated petroleum gas in fields in Eastern Siberia and to compare environmental and economic damage from the use of various methods for disposing of associated petroleum gas.

2. Study objects and methods

Currently, the following methods of using APG are most common:

1) Rational (effective)
   - deep conversion into gas, fuel and raw materials for the petrochemical industry;
   - simple conversion into gas and fuel;
   - generation of electrical and thermal energy;
   - injection into the gas transmission system;
   - liquefaction of APG.

2) Allowable (unprofitable, APG losses up to 30-35% when re-extracting):
   - reverse injection of APG into the oil reservoir.

3) Disposal:
   - smokeless burning in flare units with high-intensity combustion chambers with a minimum amount of pollutant emissions into the atmospheric air.

4) Destruction:
   - flaring;
   - dispersion.

Let us consider the investments necessary for the implementation of projects for the processing and disposal of APG using the example of the Dulisma, Yarakta, and Iktekh fields [9-14].

In our work, we took financial investments into account in the form of:

- capital investments - the cost of building a flare unit and supply pipelines, organization of the collection and construction of a network of local gas pipelines before tapping into the main gas pipeline, a collection system and injection gas wells, capital costs of creating a set of infrastructure for the APG collection system, compressor stations and gas processing facilities, transportation of DSG and NGL, the cost of further redistribution.

- economic effect - provides for income in the form of full conversion of APG into market products: base polymers (polyethylene and polypropylene) and elastomers (polybutadiene) from monomers obtained by pyrolysis of fractions after APG fractionation; utilization of all APG; not incurred damage - the range between income from deliveries to GTN and income from the sale of petrochemical products; damage in the amount of the fine for burning.

- loss of profits - calculated as the range of differences in the economic effect of other directions of processing and the negative economic effect of burning (fine)

- environmental damage/effect - calculated on the basis of emissions to the atmosphere when burning APG [15-17].

The environmental-economic caused by the emission of pollution into the air for any source is determined by the aggregate account method according to the formula

$$D_{\text{atm}} = k \cdot t \cdot f \cdot M,$$

where $k$ is a constant, the numerical value of which may vary depending on the increase in prices, rub/toe;
t is the relative hazard coefficient, depending on the type of territory;
f is a dimensionless coefficient taking into account the dispersion of the impurity in the atmosphere. Its value depends on the sedimentation rate of particles, the height of their emissions from the ground; gas temperature;
M is the reduced mass of the gas pollution emission from the source, toe/year.
The magnitude of the reduced mass of pollution emissions into the atmosphere was determined by the formula

\[ M = \sum_{i=1}^{n} A_i \cdot m_i, \]  

where N is the total number of pollutants;
A_i is the dimensionless coefficient of the relative activity of the i-type impurity;
m is the mass of the annual i-type emission into the atmosphere, tons/year [18-21].
The obtained financial investments are presented in Table 1.

**Table 1. Capital investments for the implementation of APG projects.**

| Indicators                          | Dulisma field | Yarakta field | Iktekha field |
|------------------------------------|---------------|---------------|---------------|
| Production volume, million m³/year | 2250          | 2500          | 3000          |
| Capital investments by processing methods, million rubles | | | |
| Deep conversion                    | 3105          | 3450          | 4140          |
| Flaring                            | 2.25          | 2.5           | 3.00          |
| Injection into the gas transmission system | 112.5        | 125           | 150           |
| Reverse injection of APG           | 99            | 110           | 132           |
| Loss of profits, million rubles    |                |               |               |
| Deep conversion                    | 0             | 0             | 0             |
| Flaring                            | 2857          | 3175          | 3810          |
| Injection into the gas transmission system | 2137         | 2375          | 2850          |
| Reverse injection of APG           | 2565          | 2850          | 3420          |
| Economic effect, million rubles    |                |               |               |
| Deep conversion                    | 4455          | 4950          | 5940          |
| Flaring                            | -630          | -700          | -840          |
| Injection into the gas transmission system | 675          | 750           | 900           |
| Reverse injection of APG           | 0             | 0             | 0             |
| Environmental damage, million rubles | 159          | 177           | 213           |

3. Results and discussion
When assessing the environmental impact of the enterprises under study during APG flaring, we used the value of the environmental risk expressed in monetary terms. As a result, we revealed a significant environmental and economic damage to the atmosphere from emissions of APG combustion products, such as carbon monoxide, dioxide and nitrogen and sulfur oxides.
We calculated financial investments for APG processing projects taking into account environmental and economic damage, as well as capital investments. The results are presented in Table 2.
Table 2. Results of assessing the economic efficiency of APG processing projects, million rubles.

| Indicators                              | Dulisma field | Yarakta field | Iktekh field |
|-----------------------------------------|---------------|---------------|--------------|
| Deep conversion                         | 1350          | 1500          | 1800         |
| Flaring                                 | -3648.25      | -4054.5       | -4866        |
| Injection into the gas transmission system | -1574.5      | -1750         | -2100        |
| Reverse injection of APG                | -2664         | -2960         | -3552        |

After analyzing the results of the assessment, it is possible to confirm the significant economic costs of burning APG, compared with other processing methods, despite the insignificant capital costs from the construction of a flare unit. Environmental damage caused by the pollution of the atmosphere by APG flaring, fines and tax deductions from the use of this method and, most importantly, pollution of natural resources and the irrational use of natural resources level all the “illusory” benefits. Complete loss of APG during flaring is an example of irrational environmental management, a key negative factor in environmental pollution, which demonstrates the necessity to stop using this method of APG processing, since any other method considered in this paper does not cause loss of APG. Even with the reverse injection, which, according to the results, has the second negative economic efficiency, APG is used and is not wasted, which reduces damage to natural resources during mining operations.

4. Conclusion
The problem of rational utilization of APG remains acute in a number of regions and companies, especially among small independent producers. And, despite the increase in fines planned for 2020, it is already becoming clear that not everyone will be able to achieve the target value.

Today, Russia seeks, both at the level of corporations and at the state level, to set a high framework for the use of resources. The use of new technologies and technologies applicable in other countries makes it possible to achieve not only economic benefits but also rational environmental management. Contests held by oil and gas companies to attract new ideas and opinions, integration with scientists from different fields indicate the interest of new-generation enterprises. As recently as 20 years ago, almost no extractive enterprises were interested in the application of APG. Today, this issue is being urgently addressed and the solution to this problem is one of the priorities in the environmental and economic aspects of oil and gas production.

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