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THE PROSPECTS OF EOR PROJECTS IN UKRAINE

Only for thirds of Ukrainian oil and gas fields the average value of oil density is 0.82 kg/m^3. Although density and specific gravity are used extensively in the oil industry, the API gravity is considered the preferred property. This value of 37.6 for Ukrainian oil is close to most famous ones all over the world (see table 1) [1]. A higher API gravity indicates a lighter crude or oil product, whereas a low API gravity implies a heavy crude or product [2]. But remaining 66 % of Ukrainian oil fields have the API Gravity of 17.5 close to SJV California. It has been reported that heavier crude oils may have high sulfur content and be highly viscous. This means the difficulties concerning recovery and treatment processes during production.

Table 1 - Properties of Some Reference Crude Oils [3,4]

Property	Arabian light	Arun Indonesia	Beryl N.S	Nigerian light	SJV Calif.
API (gravity)	33.9	54.1	36.5	37.6	15.2
Pour Point (°C)	- 42.3	- 48.3	- 6.75	-15	- 20.6
CCR (wt%)	3.6	0.01	1.3	1.1	7.0
Sulfur (wt%)	1.8	>0.1	0.42	0.13	1.05
Nitrogen (ppm)	60	50	880	0.06	6200
Nickel (ppm)	3	0.65	0.8	3.6	63
Vanadium (ppm)	19	0.15	3.7	0.3	60
Salt Content (kg per 1000 bbl)	4.536	1.367	3.357	2.268	6.35

Enhanced oil recovery refers to the process of producing liquid hydrocarbons by methods other than the conventional use of reservoir energy and reservoir repressurizing schemes with gas or water. On the average, conventional production methods will produce from a reservoir about 30% of the initial oil in place. The remaining oil, nearly 70% of the initial resource, is a large and attractive target for enhanced oil recovery methods.

The initial production of hydrocarbons from an underground reservoir is accomplished by the use of natural reservoir energy. This type of production is termed primary production. Sources of natural reservoir energy that lead to primary production include the swelling of reservoir fluids, the release of solution gas as the reservoir pressure declines, nearby communicating aquifers, and gravity drainage.

When the natural reservoir energy has been depleted, it becomes necessary to augment the natural energy with an external source. This is usually accomplished by the injection of fluids, either a natural gas or water. The use of this injection scheme is called a secondary recovery operation. When water injection is the secondary recovery process, the process is referred to as water flooding. The main purpose of either a natural gas or a water injection process is to repressurize the reservoir and then to maintain the reservoir at a high pressure. Hence, the term *pressure maintenance* is sometimes used to describe a secondary recovery process.

When gas is used as the pressure maintenance agent, it is usually injected into a zone of free gas (i.e., a gas cap) to maximize recovery by gravity drainage. The injected gas is usually natural gas produced from the reservoir in question. This, of course, defers the sale of that gas until the secondary operation is completed and the gas can be recovered by depletion. Other gases, such as N2, can be injected to maintain reservoir pressure. This allows the natural gas to be sold as it is produced.

Waterflooding recovers oil by the water's moving through the reservoir as a bank of fluid and "pushing" oil ahead of it. The recovery efficiency of a waterflood is largely a function of the sweep efficiency of the flood and the ratio of the oil and water viscosities.

Sweep efficiency is a measure of how well the water has come in contact with the available pore space in the oil bearing zone. Gross heterogeneities in the rock matrix lead to low sweep efficiencies. Fractures, high-permeability streaks, and faults are examples of gross heterogeneities. Homogeneous rock formations provide the optimum setting for high sweep efficiencies.

When injected water is much less viscous than the oil it is meant to displace, the water could begin to finger, or channel, through the reservoir. This is referred to as viscous fingering and leads to significant bypassing of residual oil and lower flooding efficiencies. This bypassing of residual oil is an important issue in applying enhanced oil recovery techniques as well as in waterflooding.

Tertiary recovery processes were developed for application in situations in which secondary processes had become ineffective. However, the same tertiary processes were also considered for reservoir applications for which secondary recovery techniques were not used because of low recovery potential. In the latter case, the name *tertiary* is a misnomer. For most reservoirs, it is advantageous to begin a secondary or a tertiary process concurrent with primary production. For these applications, the term *enhanced oil recovery (EOR)* was introduced and has become popular in referring to, in general, any recovery process that enhances the recovery of oil beyond what primary and secondary production would normally be expected to yield [5].

Enhanced oil recovery processes can be classified into four categories (figure 1):

1. Miscible (gaseous) flooding processes
2. Chemical flooding processes
3. Thermal flooding processes
4. Other (such as microbial) flooding processes

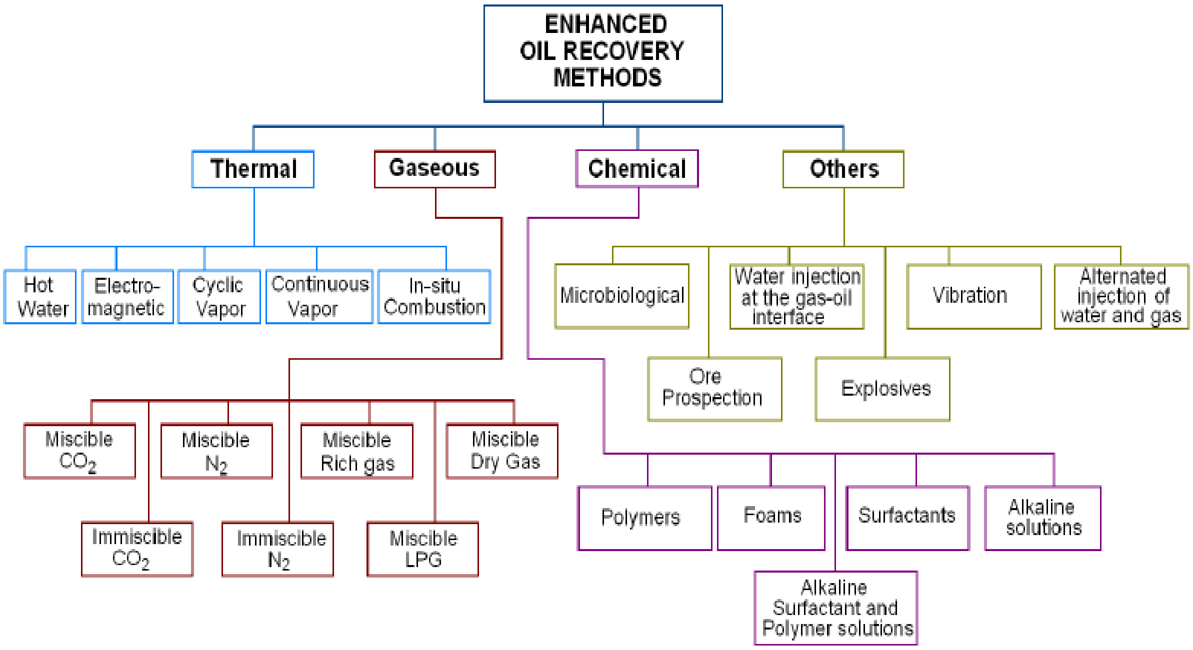

Fig. 1. Some enhanced oil recovery methods (LPG = liquefied petroleum gas)

The category of miscible displacement includes single-contact and multiple-contact miscible processes. Chemical processes are polymer, micellar–polymer, and alkaline flooding. Thermal processes include hot water, steam cycling, steam drive, and *in situ* combustion. In general, thermal processes are applicable in reservoirs containing heavy crude oils, whereas chemical and miscible displacement processes are used in reservoirs containing light crude oils. Microbial processes use microorganisms to assist in oil recovery.

In the United States, the remaining producible reserve is estimated to be 21 billion barrels. Of this 21 billion, currently implemented EOR projects are expected to recover 3 billion barrels. A 1998 report in the *Oil and Gas Journal* listed a production of 759,653 barrels of oil per day (b/d) from EOR projects in the United States. This amount represented about 12% of the total U.S. oil production.

A somewhat dated but highly informative study conducted by the U.S. National Petroleum Council (NPC) and published in 1984 determined that, with current EOR technology, an estimated 14.5 billion barrels of oil could be produced in the United States over a 30-yr period. This amount includes the 3 billion barrels that are expected to be produced from current EOR projects. The 14.5-billion-barrel figure was derived from a series of assumptions and subsequent model predictions. Included in the assumptions was an oil base price of $30 per barrel in constant 1983 U.S. dollars. The ultimate oil recovery was projected to be very sensitive to oil price, as shown in Table 2 [6].

Table 2 – Ultimate Oil Recovery from Enhanced Oil Recovery Methods as a Function of Oil Price*

Oil price per bbl (1985 US $)	Ultimate recovery (billions of bbl)
20	7,4
30	14,5
40	17,5
50	19,0
*) bbl – barrel(s)	

So, EOR projects have been strongly influenced by economics and crude oil prices. The initiation of EOR projects depends on the preparedness and willingness of investors to manage EOR risk and economic exposure and the availability of more attractive investment options. In the U.S., chemical and thermal EOR projects have been in constant decline from mid 1980's to 2005 (Figure 2) [7].

EOR gas injection project statistics remained constant since mid 1908's and exhibited a growing trend since year 2000, especially with the increase of CO2 projects. Indeed, since 2002 EOR gas injection projects outnumber thermal projects for the first time in the last three decades. However, thermal projects have shown a slightly increase since 2004 due to the increase of High Pressure Air Injection (HPAI) projects in light oil reservoirs. Chemical EOR methods still have not captured the interest of oil companies with only some projects.. However, there is an increase in EOR chemical projects in the U.S. and abroad that have not been documented in the literature for different reasons.

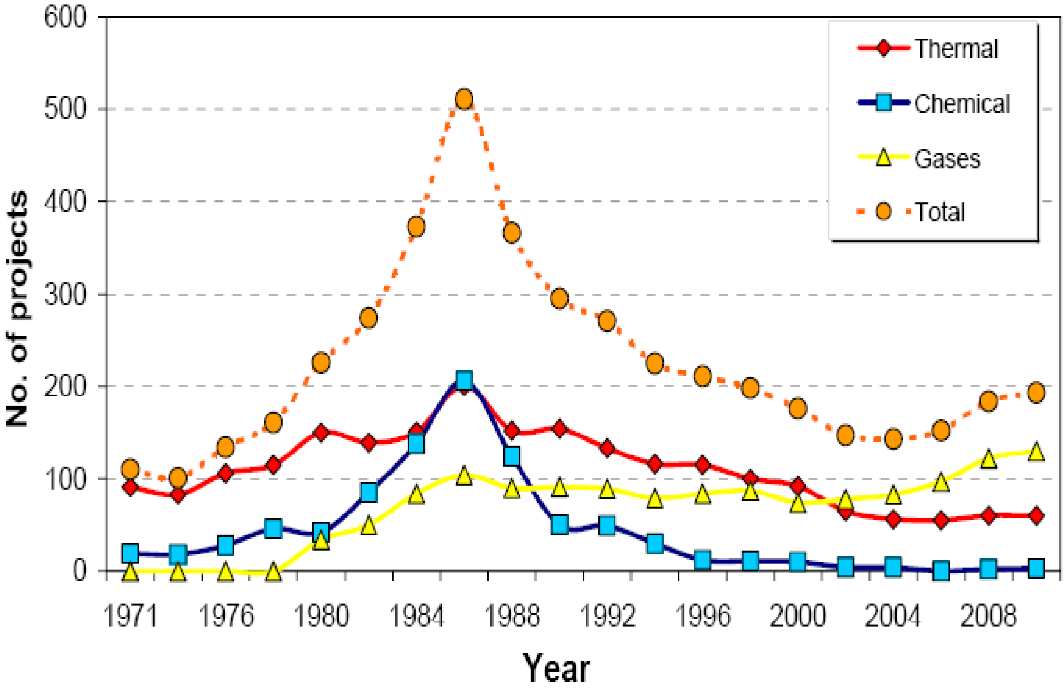

Fig. 2. Evolution of EOR projects in the United States (From Oil & Gas Journal EOR Surveys 1976–2010)

One of the reasons to explain the increase in U.S. EOR gas injection methods is due to vast sources of cheap sources of CO2 from natural sources ($US 1–2/Mscf) and a readily available CO2 pipeline system making CO2 EOR projects economically attractive at oil prices even around $US 20 per barrel.

However, it is important to remark that the CO2 pipeline system in the U.S. was built in a 30 years (1975–2005) time span when oil prices and tax incentives were sufficiently attractive to ensure security of supply as main drivers as recently reported. On the other hand, the existing pipelines are privately own and this can be interpreted as a competitive advantage, but we cannot estimate the potential benefits or impact of privately *vs.* publicly owned CO2 pipelines on future CO2-EOR and/or storage markets. Figure 3 shows evolution of CO2 projects in the U.S. and average crude oil prices for the last 28 years. Oil price used are the refiner average domestic crude oil acquisition cost reported by the Energy Information Administration [7].

Although it can be concluded that CO2-EOR («**from natural sources**») is a proven technology with oil prices > $20/bbl, this EOR method represents a specific opportunity in the U.S. and not necessarily can be extrapolated to all producing basins in the world. Therefore, the present paper gives the opportunity to estimate the application of EOR methods in Ukraine.

If we change the table 2 taking into the account the proven reserves of crude oil in Ukraine (3,1 billion barrels) and its market price (53,22 $ per barrel as of 2015.09.16 in table 3), one can see that Ukraine has perfect condition for implementation EOR methods.

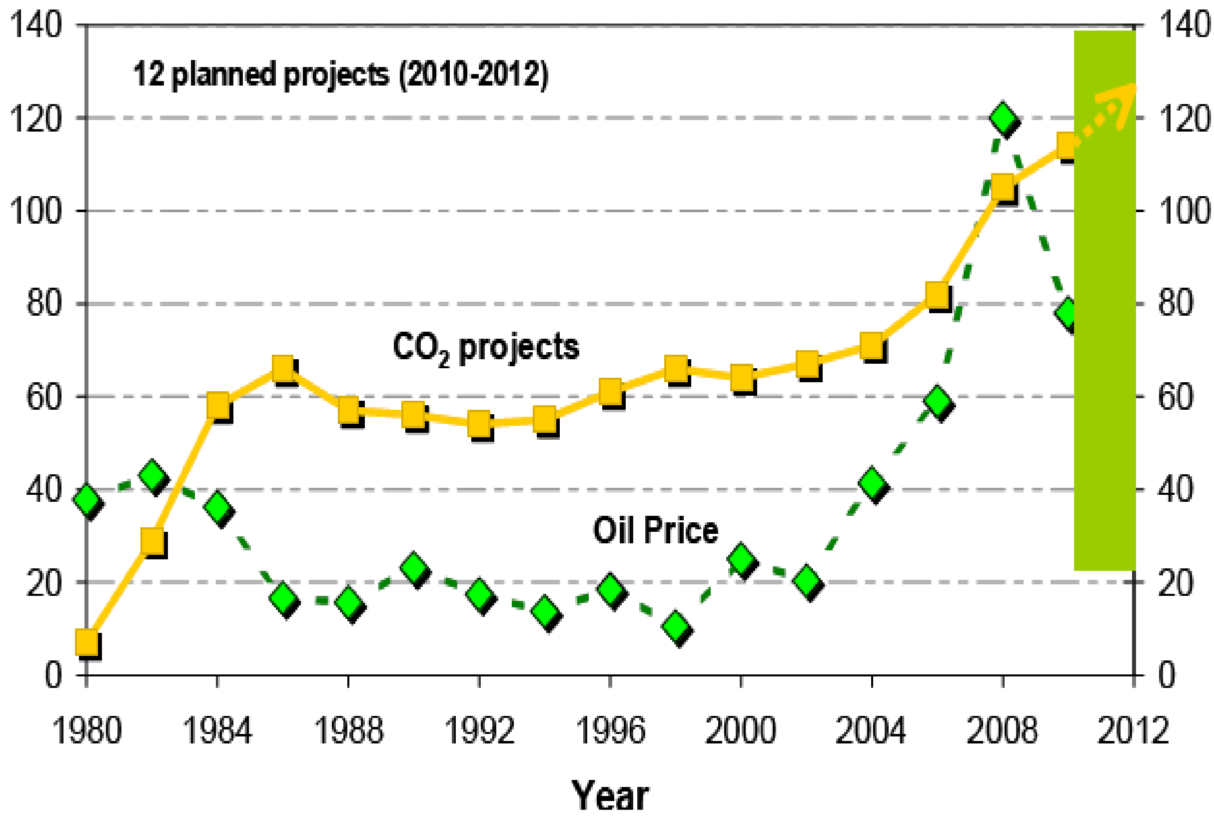

Fig. 3. Evolution of CO2 projects and oil prices in the U.S. (From Oil & Gas Journal EOR Surveys 1980–2010 and U.S. EIA 2010)

Table 3 - Ultimate Oil Recovery from Enhanced Oil Recovery Methods as a Function of Oil Price*

Oil price per bbl	Ultimate recovery (billions of bbl)
20	1,1
30	2,1
40	2,6
50	2,8
*) bbl – barrel(s)	

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