Microbially Enhanced Oil Recovery

Vera Dmitrieva

Center for Ecological Research and BioResources Development

Pushchino

Russia

Members and Partners:

In Russia:

- Institute of Biochemistry and Physiology of Microorganisms, (*Pushchino)*
- State Research Center for Applied Microbiology and Biotechnology (*Obolensk)*
- All-Russian Research Institute of Phytopathology (*Golitsyno)*
- Research Center for Toxicology & Hygienic Regulation of Biopreparations (*Serpukhov)*
- All-Russian Research Institute of Biological Plant Protection (*Krasnodar)*
- State Research Center of Virology and Biotechnology, VECTOR (*Novosibirsk)*
- Institute of Volcanology and Seismology (*Kamchatka)*
- Institute of Biology, *Komi* Center
- Institute of Soil Science (*Pushchino)*
- Institute of Ecology of the North (*Apatity*)

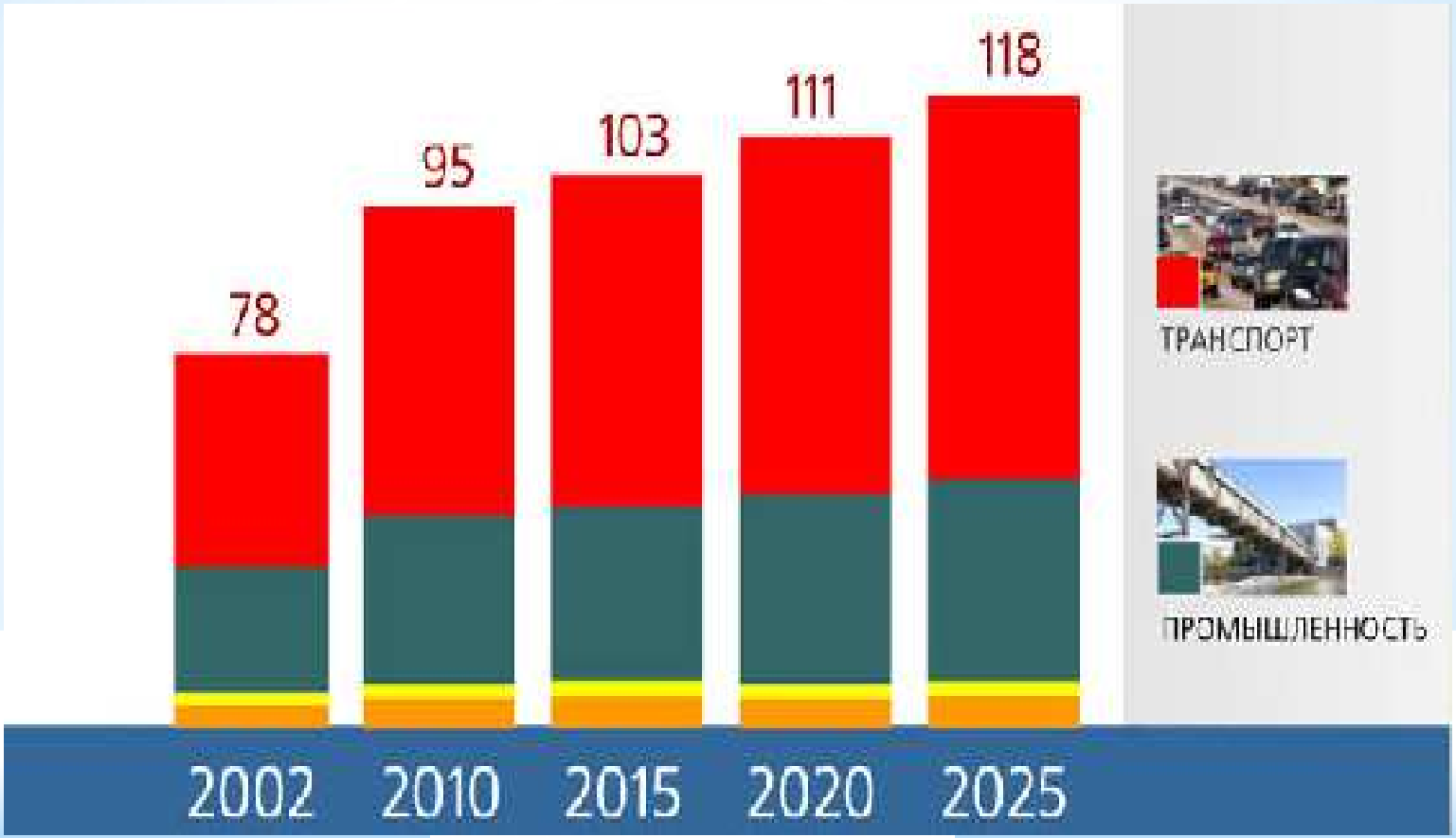
USA

- Department of Energy
- Department of States
- Environmental Protection Agency
- Argonne National Laboratory
- Lawrence Berkeley National Laboratory
- Idaho National Engineering and Laboratory
- Diversa Corporation, (Now Verenium)
- DuPont
- British Petroleum
- Chevron Texaco
- Novozymes

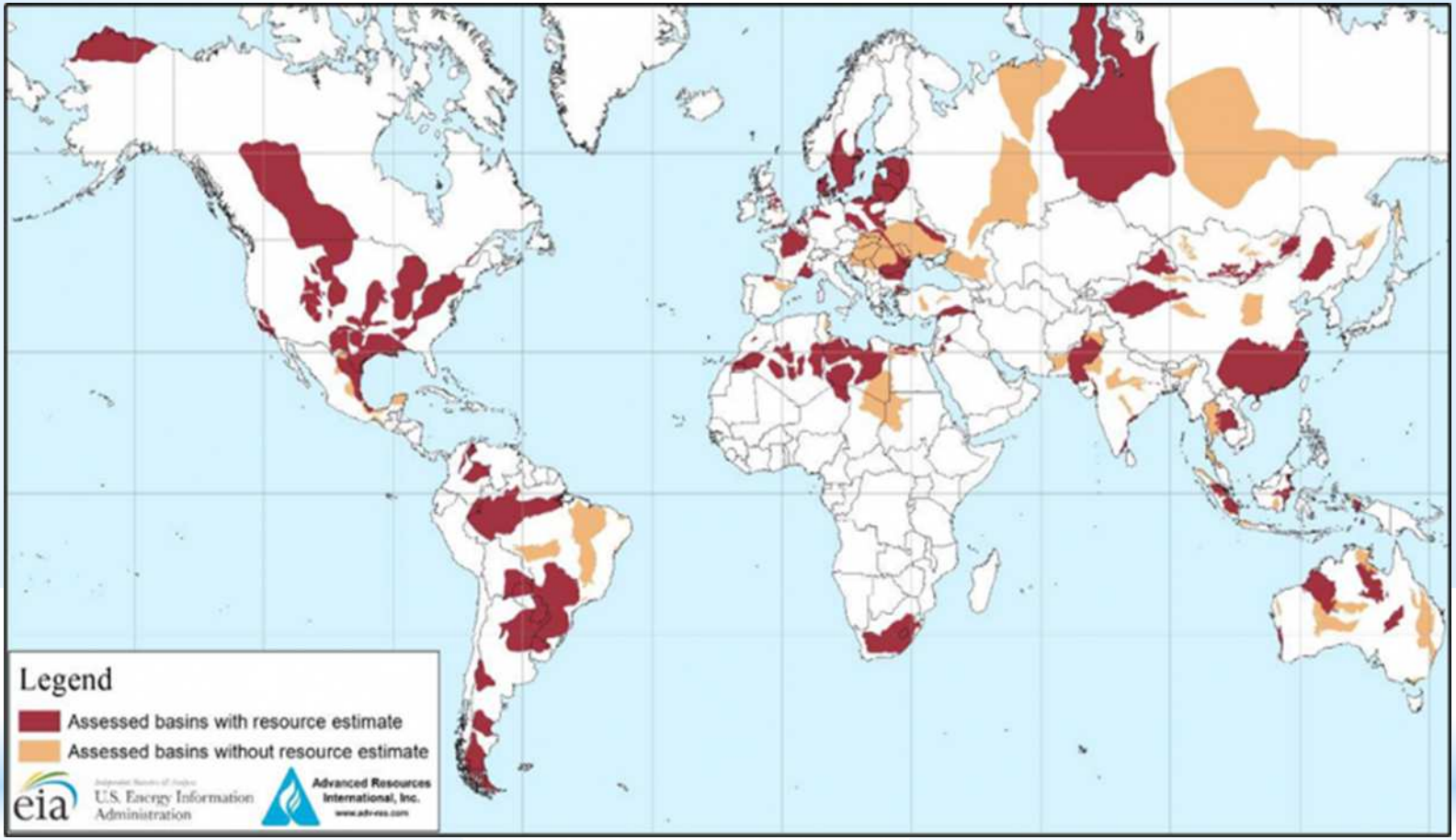
Abynskii site: Spring and summer of 2004

Summer of 2006

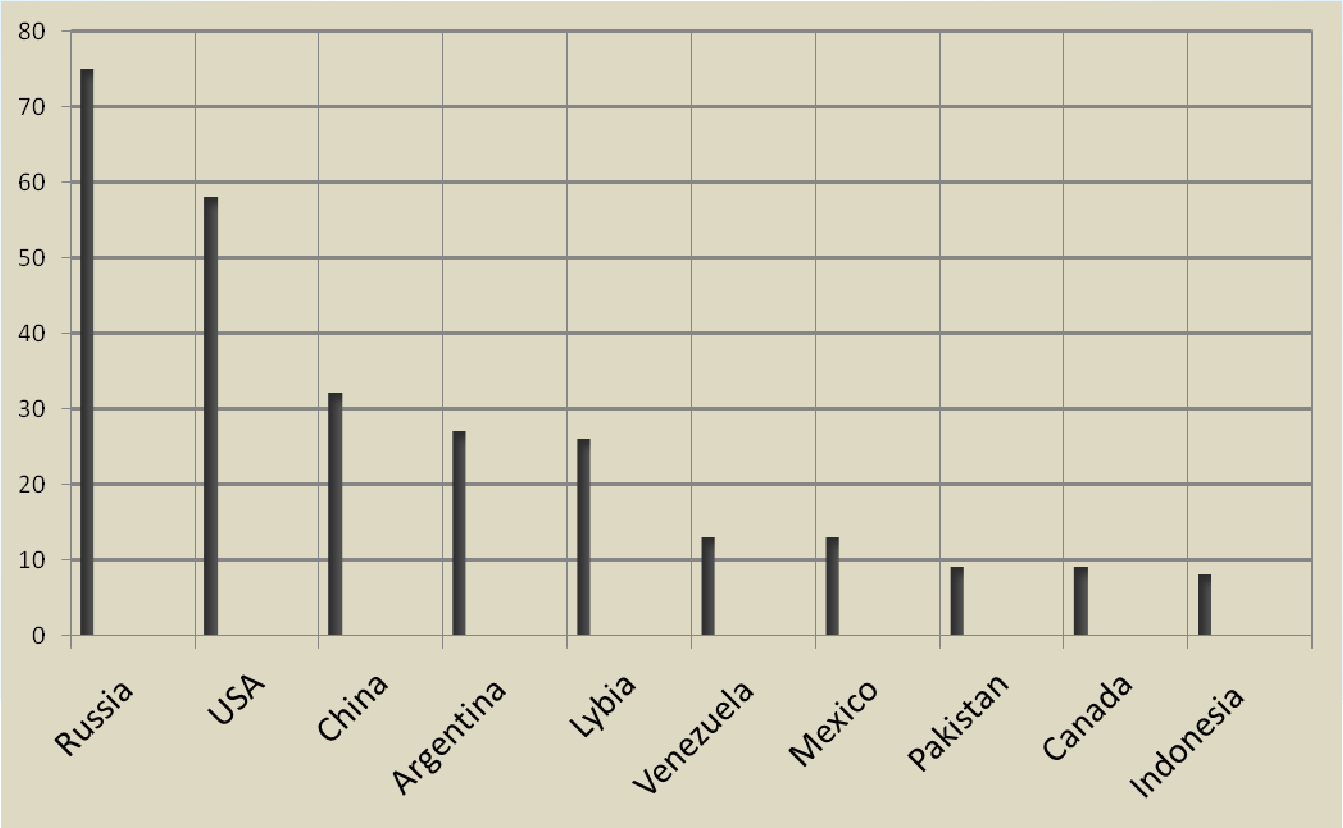
The world economy is totally dependent on oil



There are estimates that global energy demand will continue to grow over the next 25 years.



World map of shale gas and oil



The top 10 countries in terms of shale oil (billion barrels):

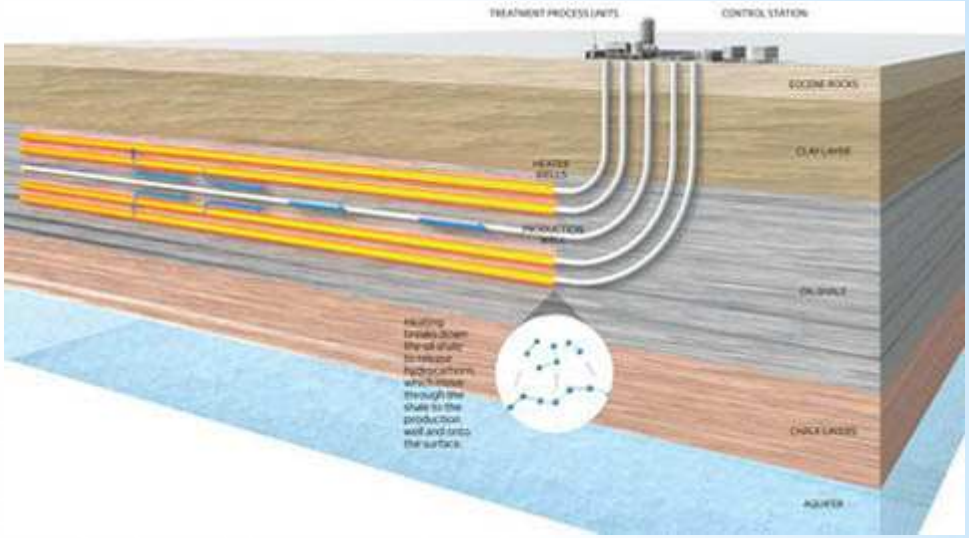
Russia, 75; United States 58; China 32; Argentina, 27; Libya 26; Venezuela 13; Mexico 13; Pakistan 9; Canada 9; Indonesia 8

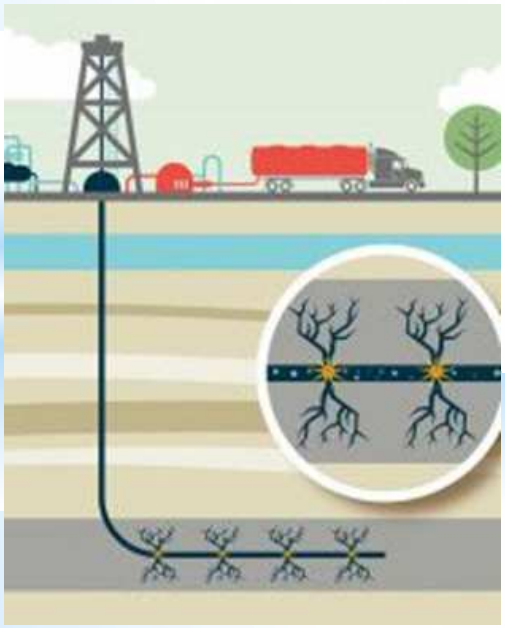
Large shale deposits in the Middle East region and in the Caspian Sea were not included in the review because of a lack of data.

Bazhenov formation

By comparison with the famous Bakken Shale gas play in the USA, the Bazhenov formation is about 80 times larger, covering 2.3 million square kilometers or 570 million acres, the equivalent of the Texas and Gulf of Mexico together.


Oil Shale


TREATMENT PROCESS UNITS
CONTROL STATION
EOCENE ROCKS
CLAY LAYER
OIL SHALE
CHALK LAYERS
AQUIFER

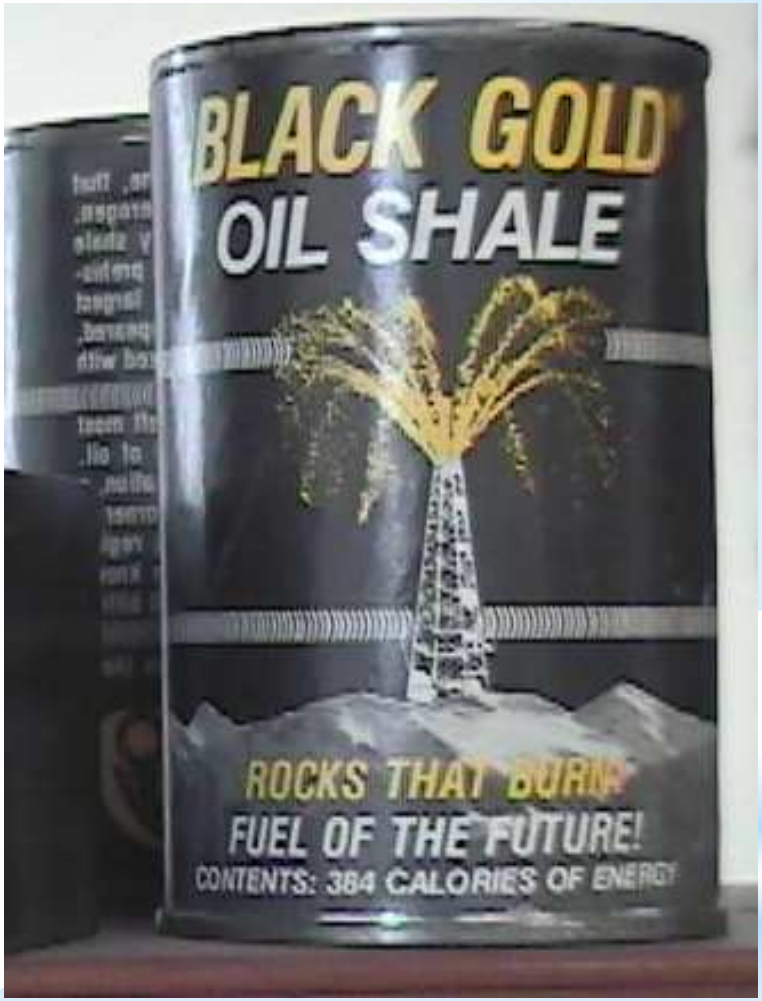



NO
FRACKING
POLICE

Shale oil extraction technologies are still in the early stages of development.

The cost of raw materials, though it has tended to decline, is considerably higher than traditional oil production costs.

Shale oil is still rather promising reserve for the future and is unlikely to have a significant impact on the present oil market.



More than a hundred trillion dollars (one hundred million million dollars) has been invested into infrastructure, production, transportation and refining of oil in the world

В инфраструктуру добычи, транспортировки и переработки нефти в мире было вложено более ста триллионов долларов (сто миллионов миллионов долларов).

World Oil Reserve as for **01.01.2013 (milliard barrels)**

Source BP Statistical Review of World Energy 2013

Country	Oil reserve	% of World Reserve
Venezuela	297,6	17,8
Saudi Arabia	265,9	15,9
Canada	173,9	10,4
Iran	157,0	9,4
Iraq	150,0	9,0
Kuwait	101,5	6,1
United Arabian Emirates	97,8	5,9
Russia	87,2	5,2
Libya	48,0	2,9
Nigeria	37,2	2,2
USA	35,0	2,1
Kazakhstan	30,0	1,8
Qatar	23,9	1,4
China	17,3	1,0
Brazil	15,3	0,9
The rest of the world	131,3	7,9

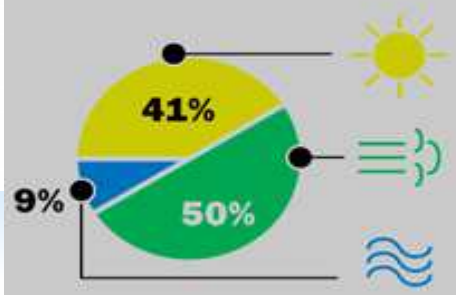
ЧТО НАС ЖДЕТ

когда закончится нефть

Oil: Years remained

Whole world	Весь мир	50
Great Britain	Англия	5
Canada	Канада	6
USA	США	10
Australia	Австралия	11
Argentina	Аргентина	11
Germany	Германия	17
Brasilia	Бразилия	19
China	Китай	20
India	Индия	20
Libya	Ливия	57
Russia	Россия	59
Iran	Иран	68
Saudi Arabia	Саудовская Аравия	88
UAE	ОАЭ	112
Iraqi	Ирак	115
Kuwait	Кувейт	145

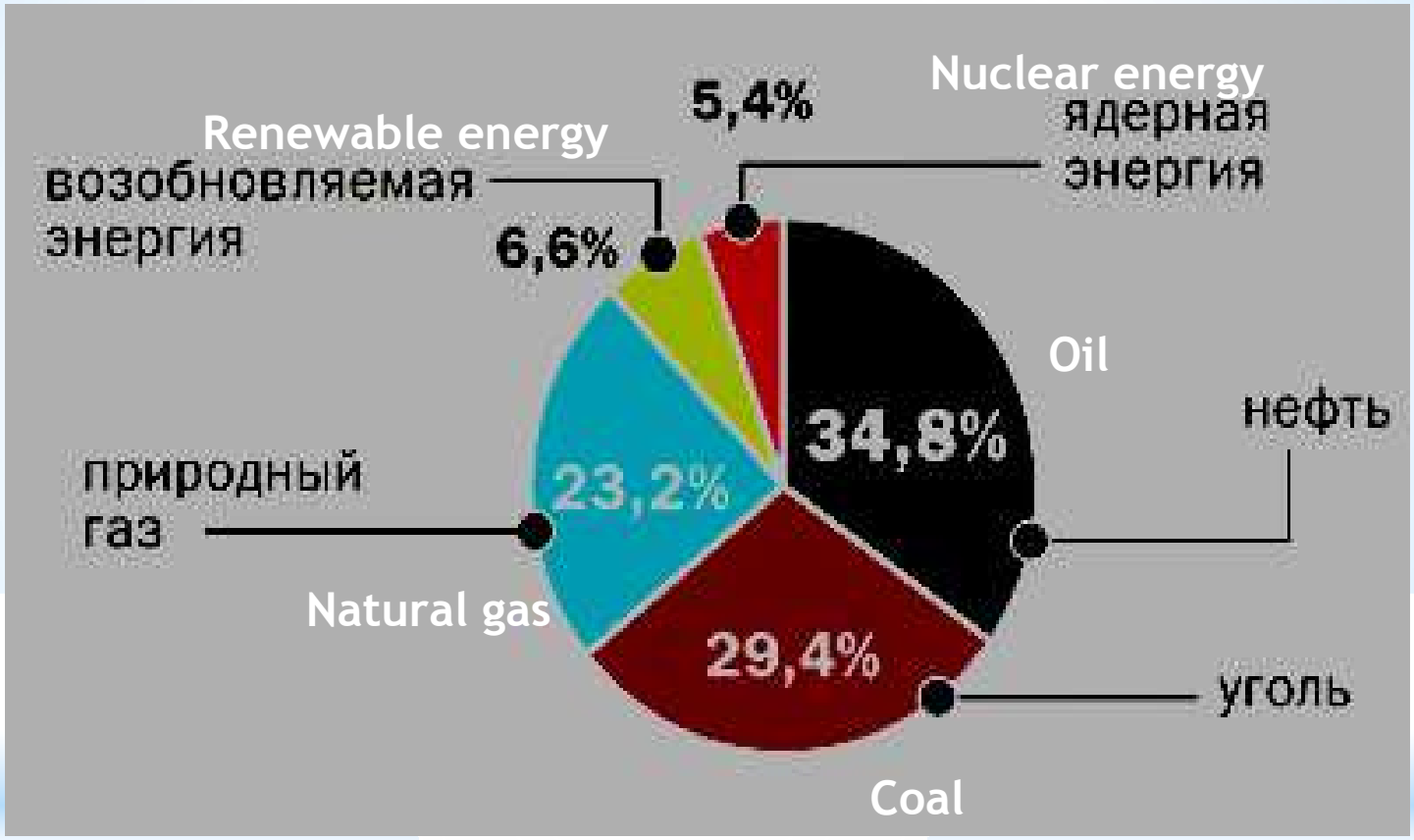
Распределение источников чистой энергии в 2030 году



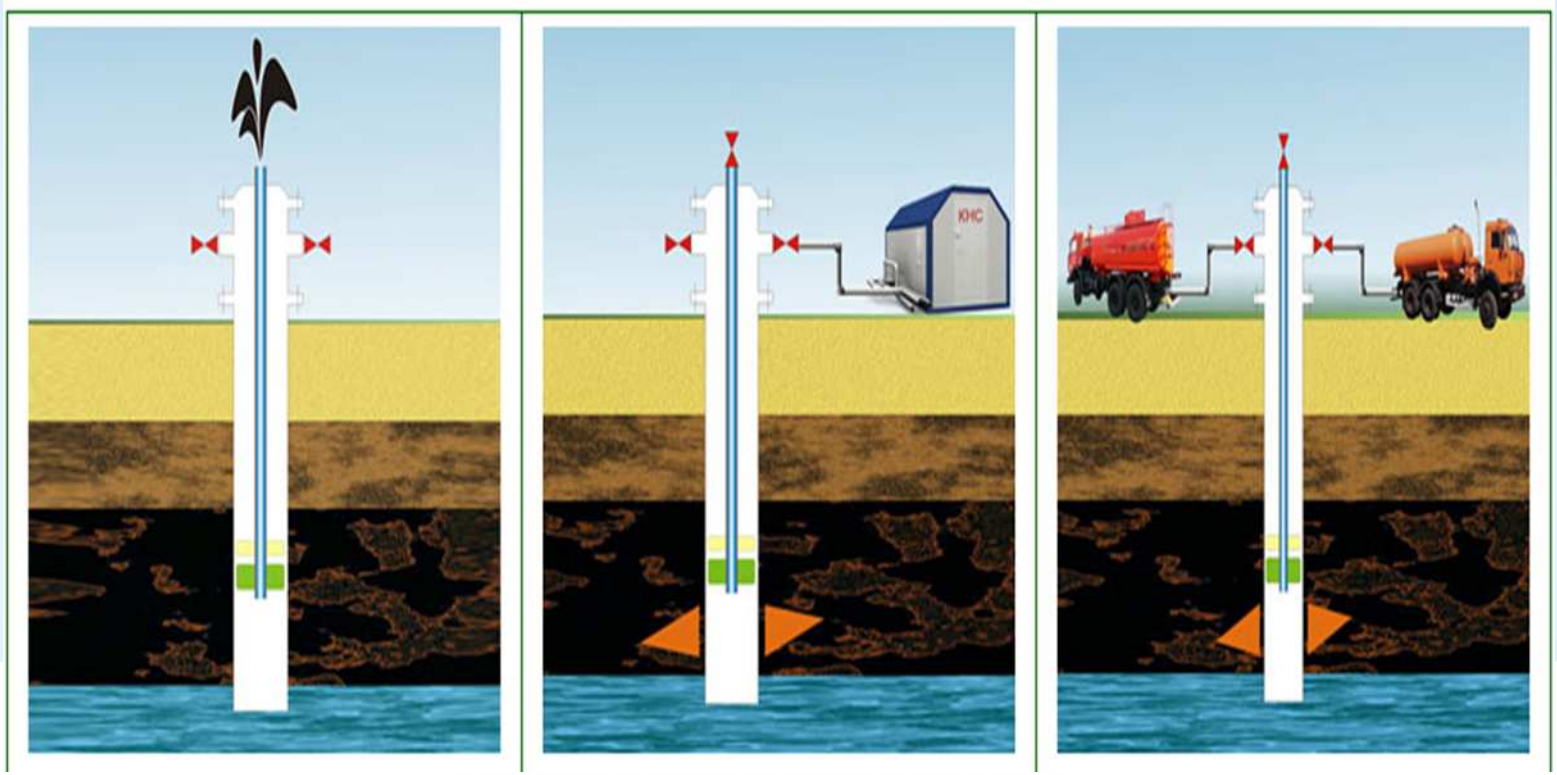
солнечная энергетика
4,715 ТВт

ветроэнергетика
5,750 ТВт

гидроэнергетика
1,035 ТВт



Basic sources of energy on the Earth



Primary recovery	Secondary recovery	Tertiary recovery
Natural energy of oil bed	Injection of water/gas	Application of EOR

The world's first oil well was drilled in 1847, in the District of Baku on the Caspian Sea

August 27, 1859, is considered the starting date of the world oil industry. In this day the United States first oil well drilled by Colonel Edwin Drake yielded the oil flow with a fixed output.

1928, Huntington Beach (Surf City, USA).
Such a landscape was quite usual until the 1960 's.

.

Традиционные технологии первичной и вторичной добычи нефти позволяют извлечь только около 1/3 первоначальных геологических запасов, что означает оставление 2/3 сырой нефти в недрах

Современные геологические запасы нефти во всех известных месторождениях мира достигают более 500 млрд.т.

Из них более 300 млрд.т. относятся к категории неизвлекаемых современными промышленно освоенными методами.

Secondary recovery
Methods of the enhanced oil recovery (EOR)

According to different estimates, the worldmarket of technologies of enhanced oil recovery will make up $ 1,3 trillion by 2015

These technologies are employed in Iran, Canada, Saudi Arabia, Russia, USA, Angola, the United Arab Emirates, Venezuela, Kuwait, and many other countries.

Methods of the enhanced oil recovery (EOR)

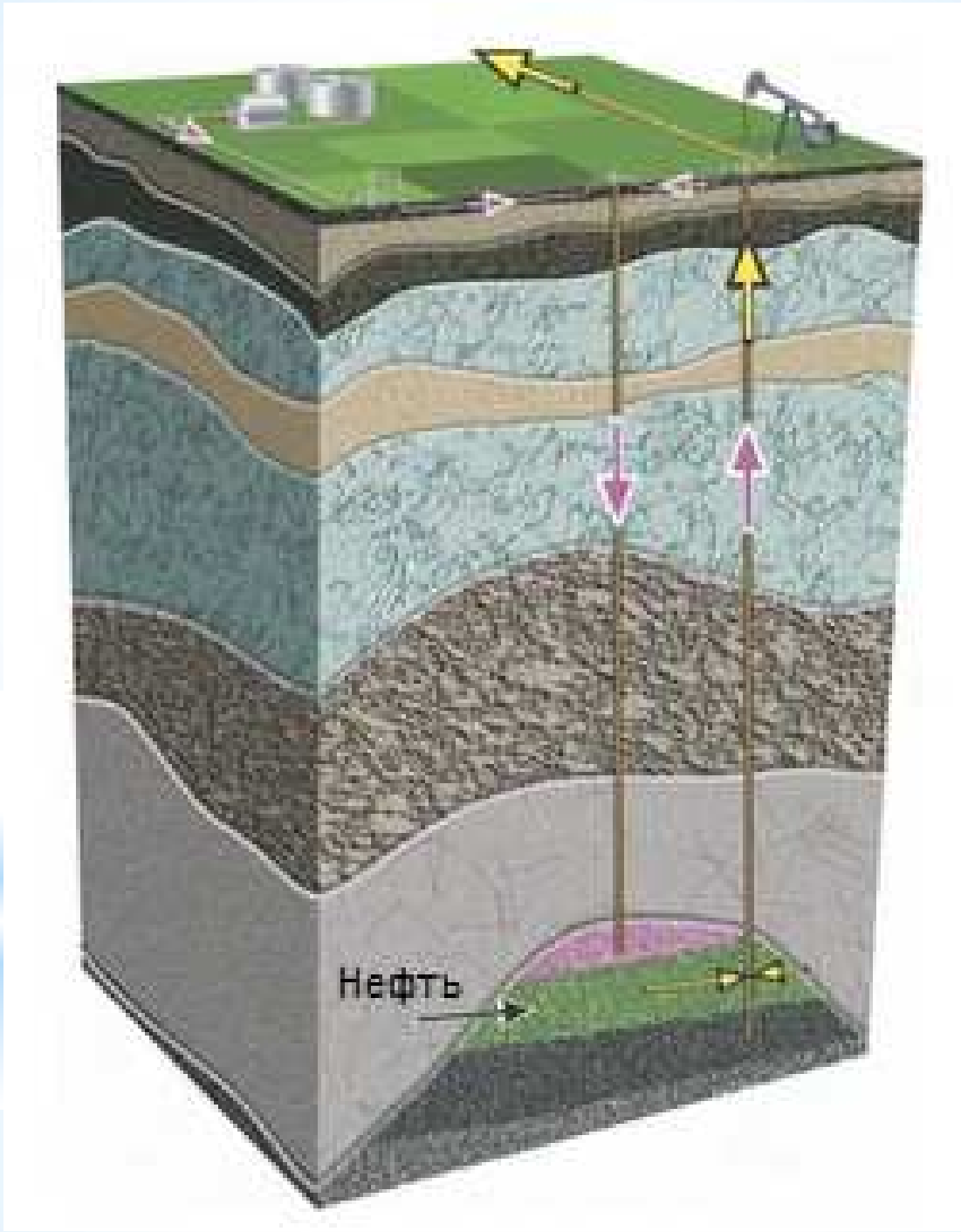
Методы увеличения нефтеотдачи (МУН)

(1) **Тепловые** - вытеснение нефти теплоносителями, воздействие с помощью внутрипластовых экзотермических окислительных реакций);

(2) **Газовые** - закачка углеводородных газов, жидких растворителей, углекислого газа, азота, дымовых газов);

(3) **Химические** - заводнение с применением поверхностно-активных веществ (ПАВ), полимерное, мицелярное заводнение и др.);.

(4) **Микробиологические** - введение в пласт продуктов микробной жизнедеятельности или их производство микроорганизмами в самом пласте


Нефть

MEOR outcomes

So far, the outcomes of MEOR are explained based on two predominant rationales:

(1) Increment in oil production.

This is done by modifying the interfacial properties of the system oil-water-minerals, with the aim of facilitating oil movement through porous media.

In such a system, microbial activity affects fluidity (viscosity reduction, miscible flooding); displacement efficiency (decrease of interfacial tension, increase of permeability); sweep efficiency (mobility control, selective plugging) and driving force (reservoir pressure).

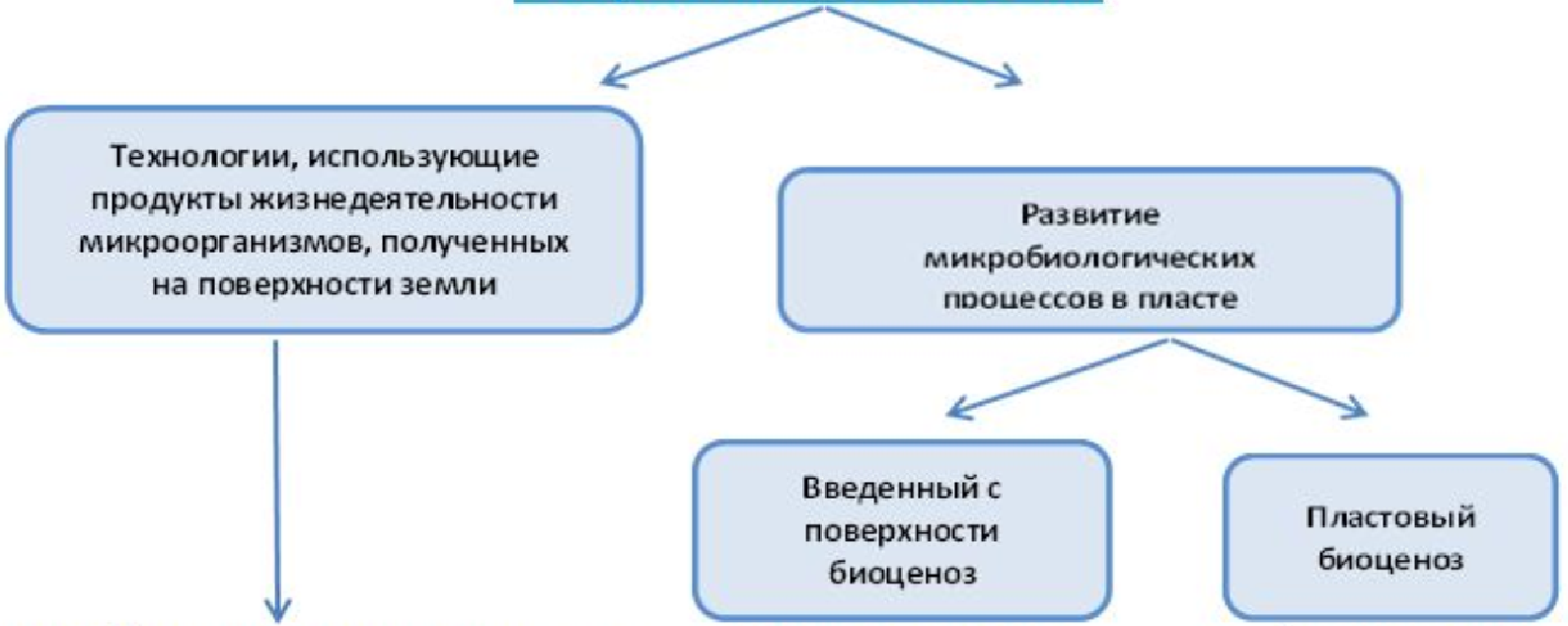
(2) Upgrading. In this case, microbial activity acts may promote the degradation of heavy oils into lighter ones. Alternatively, it can promote desulphurization due to denitrification as well as the removal of heavy metals.

History

It was in 1926 when Beckam proposed the utilization of microorganisms as agents for recovering the remnant oil entrapped in porous media.

In 1947, ZoBell and colleagues set the basis of petroleum microbiology applied to oil recovery, whose contribution would be useful for the first MEOR patent

Микробиологические МУН



- Методы близки к химическим;
- Создание на поверхности биоПАВов, биополимеров, эмульгаторов;

- вводятся культуры микроорганизмов с питательными веществами

- Активируется естественная микрофлора путем подачи в пласт питательных веществ с поверхности

Дорого, экологически небезопасно!

- **Комплексное воздействие на пласт**
- **Дешево**
- **Экологически безопасно**

Injecting selected microbes into the oil well

Mixing nutrients with microbes

Preparing nutrients for injection into the oil well

MEOR Site

MEOR advantages

- Injected microbes and nutrients are cheap; easy to handle in the field and independent of oil prices.
- Economically attractive for mature oil fields before abandonment.
- Increases oil production.
- Existing facilities require slight modifications.
- Easy application.
- Less expensive set up.
- Low energy input requirement for microbes to produce MEOR agents.
- More efficient than other EOR methods when applied to carbonate oil reservoirs.
- Microbial activity increases with microbial growth. This is opposite to the case of other EOR additives in time and distance.
- Cellular products are biodegradable and therefore can be considered environmentally friendly.

MEOR disadvantages

- The oxygen deployed in aerobic MEOR can act as corrosive agent on non-resistant topside equipment and down-hole piping

- Anaerobic MEOR requires large amounts of sugar limiting its applicability in offshore platforms due to logistical problems

- Exogenous microbes require facilities for their cultivation.

- Indigenous microbes need a standardized framework for evaluating microbial activity, e.g. specialized coring and sampling techniques.

- Microbial growth is favored when: reservoir temperature is inferior to 80 0C, salinity is below 150 g/L and reservoir depth is less than 2400m.

Конечная цель проекта - разработка эффективного подхода для повышения нефтеотдачи пластов, где имеется высокая степень солености и высокая температура.

Найдены микроорганизмы, способные хорошо расти при солености (> 10%) и температуре> 50°C с образованием биопленок и биополимеров, важных для закупоривания нефтяного месторождения, а также биосурфактантов, способствующих нефтеотдаче с твердых поверхностей в нефтяном пласте.

Полученные результаты служат основанием для разработки биотехнологии, основанной на внесении мелассы и нитратов в пласт. Осуществляется активация бактерий рода *Clostridium* (образующих нефтевытесняющие метаболиты из мелассы), гетеротрофных нитратредуцирующих бактерий (образующих биосурфактанты и конкурирующих с сульфидогенами за органические субстраты) и автотрофных нитратредуцирующих бактерий, снижающих содержание сульфидов в пластовых флюидах.

One of the main purposes of this research was to provide biological solutions to enhanced oil recovery, to screen microorganisms for the ability to grow at salinities (total dissolved solids) of >10% and temperatures >50oC with production of biofilms and biopolymers useful for the plugging oil reservoir, and biosurfactants promoting oil release from solid surfaces in the oil reservoir.

The novel cultivation approaches were developed to isolate microorganisms which utilize geologic hydrocarbons as their sole source of energy and can be used to improve petroleum extraction, transformation and bioremediation processes.

The results obtained can be used for the development of biotechnology, based on the introduction of molasses and nitrates in the oil bearing formations. This biotechnological effect combines the activation of fermentation bacteria of the genus *Clostridium (*forming different oil-displacing metabolites from molasses), heterotrophic nitrate reducing bacteria (forming biosurfactants and competing with sulfidogenes for organic substrates) and autotrophic nitrate reducing bacteria that decrease sulfides in the formation fluids.

MEOR Trends

- **Wellbore microbial plugging and consequent lost of injectivity (clogging).**
- Dispersion of components necessary to the target.
- Control of indigenous microbial activity.
- Mitigation of unwanted secondary activity due to competitive redox processes such as sulphate reduction, i.e. control of souring.
- Microbial paraffin removal.
- Microbial skin damage removal.
- Water floods, where continuous water phase enables the introduction of MEOR.
- Single-well stimulation, here the low cost makes MEOR the best choice.
- Selective plugging strategies.
- **MEOR with ultramicrobes.**
- **Genetically engineered MEOR microorganisms able to survive, grow and produce metabolites at the expense of cheap nutrients and substrates.**
- **Application of extremophiles: halophiles, barophiles, and thermophiles.**
- Artificial neural network modeling for describing in situ MEOR processes.
- Competition of exogenous microbes with indigenous micro flora, no understanding of microbial activity.

WWW.CERBRD.RU

Исследовательский центр
«БиоРесурсы и Экология»

Center for Ecological Research and BioResources Development

Prospect Nauki 5, Pushchino, 142290, Russia,
vdmitrieva@ibpm.pushchino.ru

Thank you for attention!