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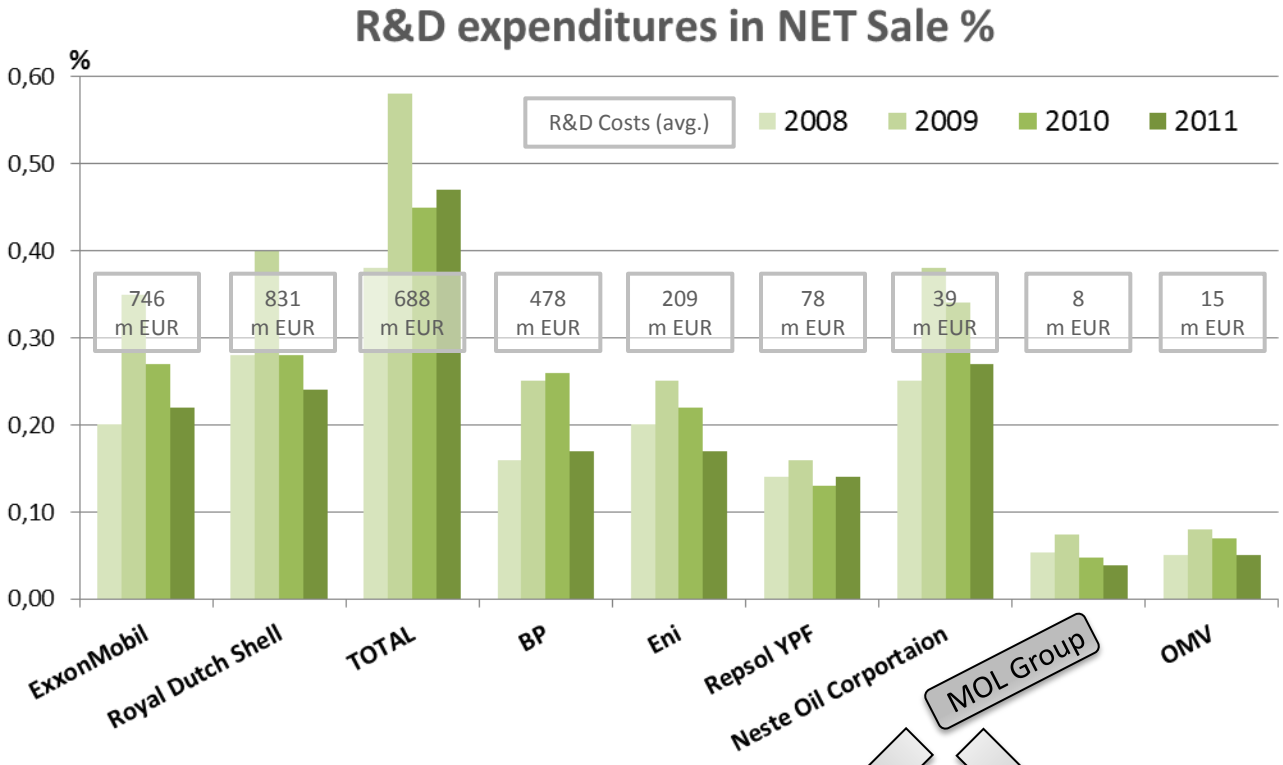
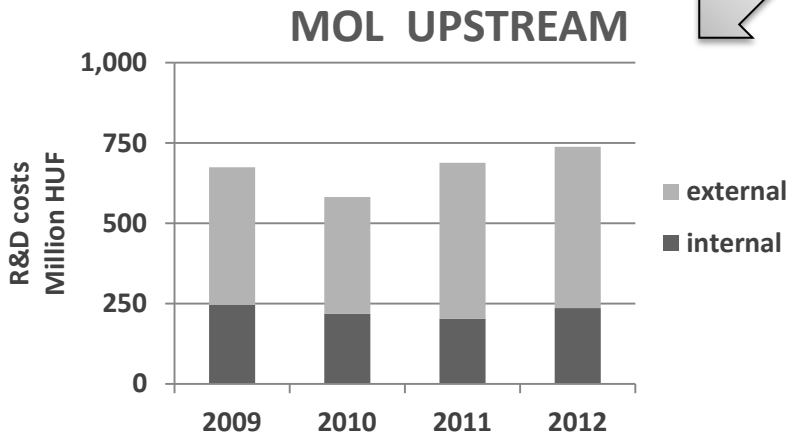
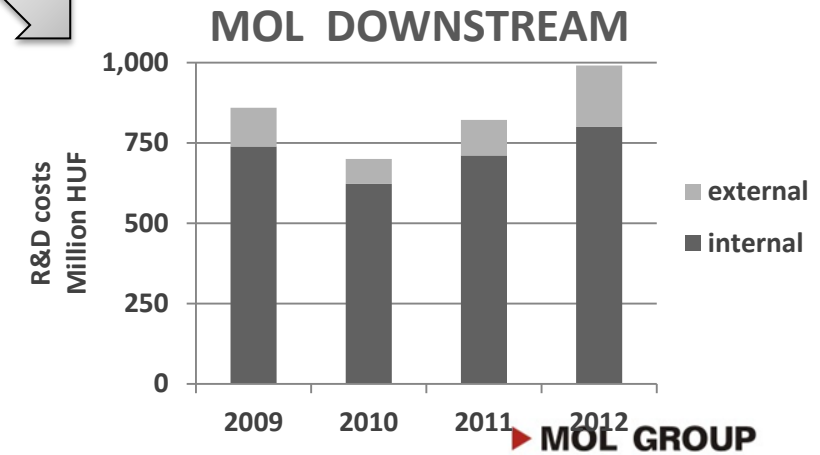
Agenda

- R&D definitions, categories
- R&D Strategy
- Summary of R&D project portfolio
- R&D cost sensitivity
- MOL R&D EOR related Case studies
- Conclusion

MOL R&D vs. Industry players R&D (integrated US&DS expenditures)







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Source: EU Industrial R&D Investment Scoreboard (2008- 2013); http://iri.jrc.ec.europa.eu/, OMV annual report, MOL Group annual report

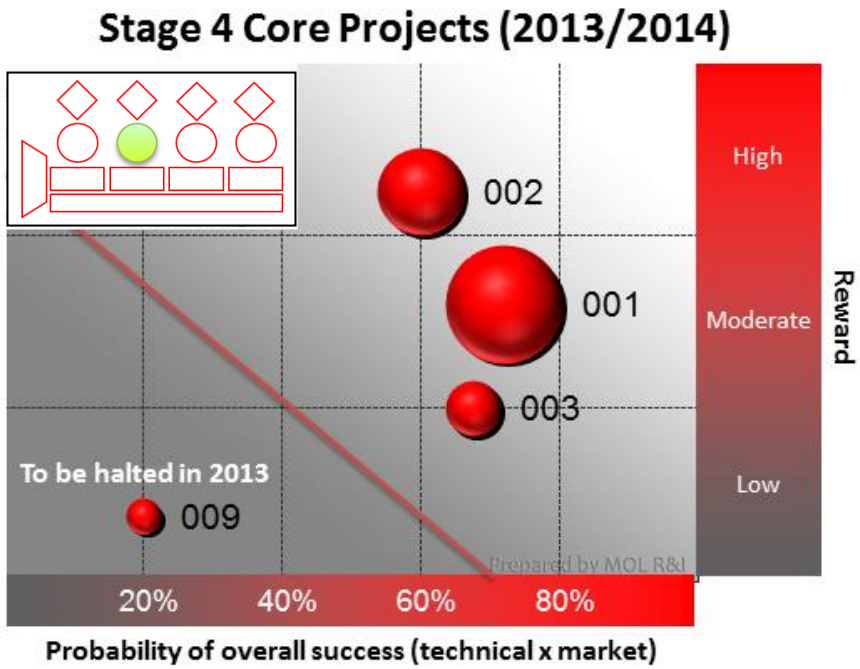
Advanced decision making tools

Scorecard

Title:
Created Date:
Last Modified:
Evaluator:
Identification number:
Idea owners:
Short description:
Driver (COMMERCIAL)
Driver (TECHNICAL)
Roadblocks (COMMERCIAL, TECHNICAL, LEGISLATIVE, etc.)
EVALUATION:
Reward *(driver)*
Business magnitude *(potential revenue)*
Time to commercial start-up *(Rough estimate)*
Payback period from commissioning *(Rough estimate)*
Probability of technical success
Technical gap vs. Current operation
Project technical complexity
Potential strategic importance
Fit with business strategy
Impact on business future and on competitive position
GO or FOLLOW or STOP
Impact on competitiveness
Competitive advantage and / or Intellectual Property protection
Probability of technical success
Technological competitive position of MOL *(Availability of competence, people & facilities to do the R&D internally)*
Feedstock availability at site
Probability of commercial success
Regulatory impact - Dependence on (volatile) EU/ Local regulatory framework
Marketing gap to product or technology commercialisation
Market competition
Sales of developed technology *(licence, IP, know-how, etc.)*
SCORE
Comments

- Main drivers (technical, commercial)
- Roadblocks (technical, commercial, legislative)
- Evaluation of main parameters
  - Reward
  - Possibility of technical success
  - Potential strategic importance

R&D Project Portfolio Analyzer



- Impact on competitiveness
- Probability of technical success
- Probability of commercial success
- Time-to-Completion
- Technological competitive position
- Maturity

External environment

- Global trend shows 100–200% rise in E&P R&D spending from oil companies and service companies alike in the last 10 years
- In a highly volatile and faster -than -ever changing environment, capabilities of product and technology development becomes more critical
- Altough EU and Government Grants and Funds decrease financial exposure of R&D projects, their complex administrative nature prolong project execution and unfeasible timeline with upstream R&D makes their application non attractive development cost needs.
- In some EU conties 20% extra tax savings on all R&D expenditures (mainly corporate tax deduction)

R&D & I Model

Basic research: experimental or theoretical work undertaken primarily to acquire new knowledge without any particular application or use in view.

Applied research: original investigation undertaken in order to acquire new knowledge but directed primarily towards a specific practical aim.

Experimental development: comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge.

Upstream R&D Strategy 2013-2018

- **Upstream R&D & Innovation is a key activity for value creation via successful project implementation worldwide**
  - **Increase recovery factors in mature fields**
  - **Decrease production cost (USD/boe)**
  - **Additional value available in the upstream business development processes**
  - **Boost-up New Technology (NT) applications next to Hungary in Croatia, Pakistan, Russia, Kurdistan**
- **Optimise commercialisation and deployment of R&D and NT projects**
- **Increase the international technology reputation of MOL Upstream**
- **All of the above mentioned based on the upstream country strategies as well**

Domestic / international standards for project phase classification

1

Basic research

Experimental or theoretical work undertaken primarily to acquire new knowledge without any particular application or use in view.

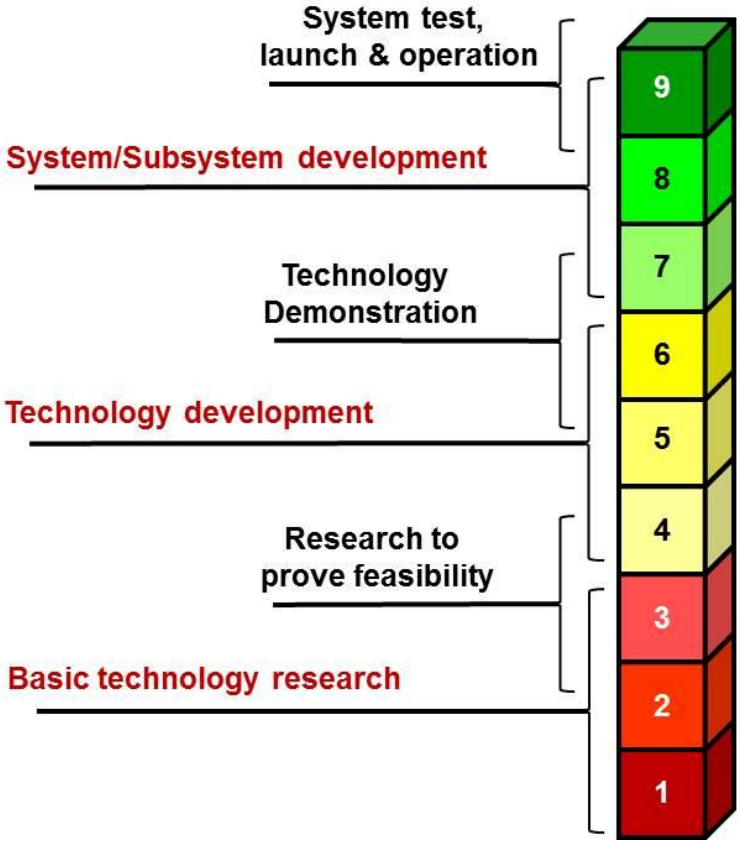
Applied research

Original investigation undertaken in order to acquire new knowledge, but directed primarily towards a specific practical aim.

Experimental development

Comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge.

2



TRL – TECHNOLOGY READINESS LEVEL

9 Actual system proven in operational environment

8 System complete and qualified

7 System prototype demonstration in operational environment

6 Technology demonstrated in relevant environment

5 Technology validated in relevant environment

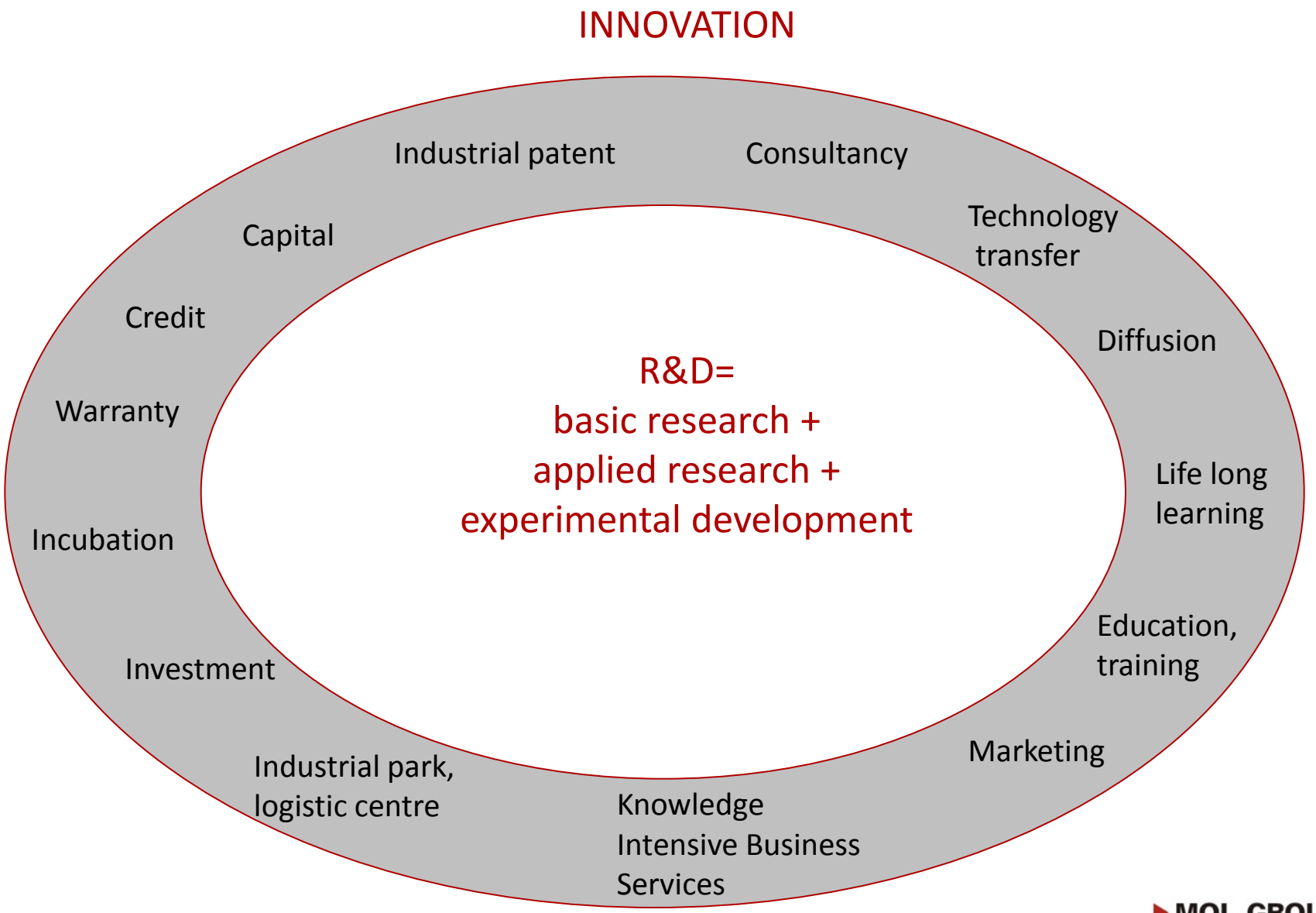
4 Technology validated in lab

3 Experimental proof of concept

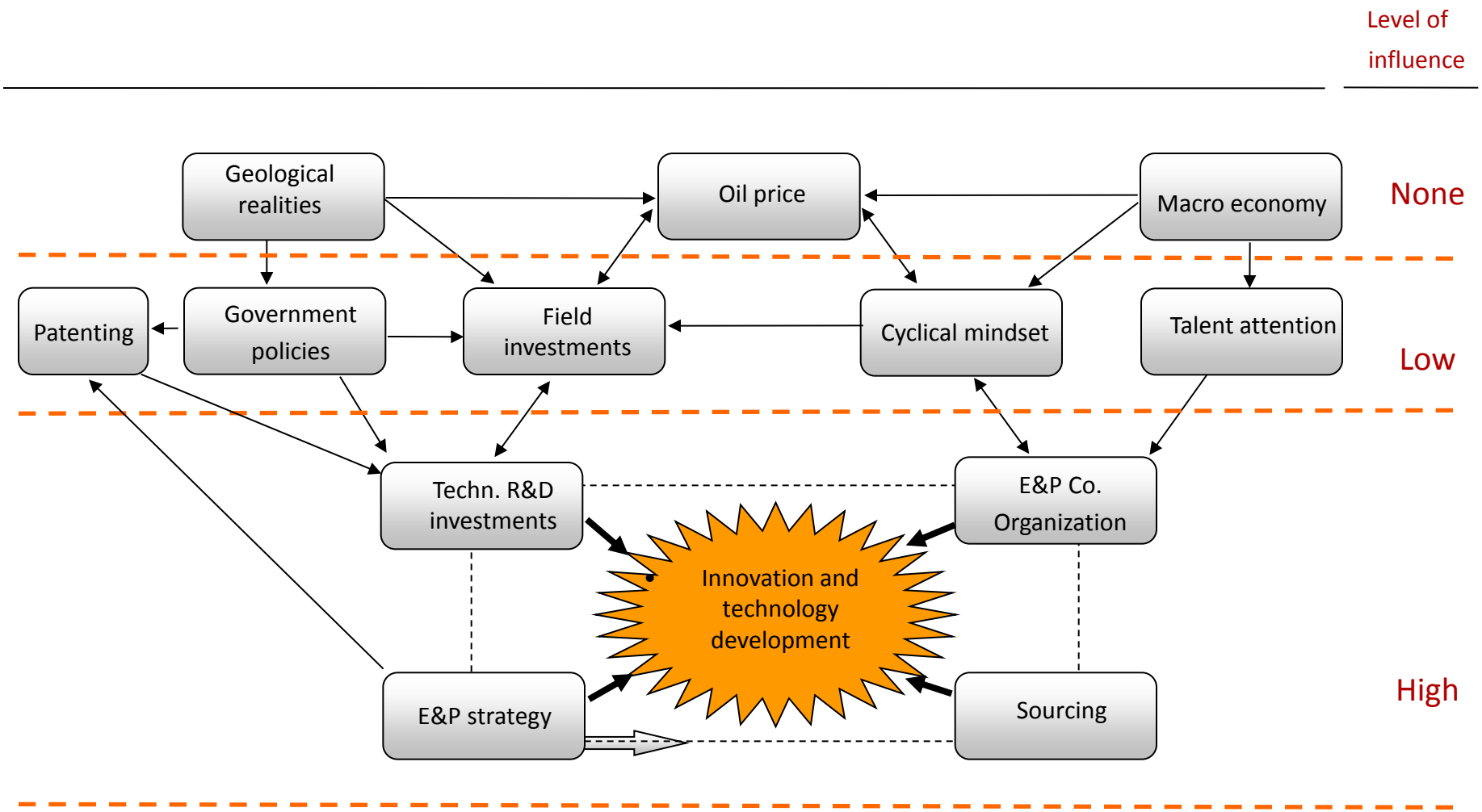
2 Technology concept formulated

1 Basic principles observed

Relation between R&D and Innovation



Factors influencing E&P innovation and technology



Improved Hydrocarbon Recovery R&D challenges

R&D experimental: can range from simple (phase behaviour), to complex (core flooding) and very complex (ISC testing).

Back to basics : better understanding of mechanisms, but how to predict field performance, under laboratory conditions?

Continuing challenges in EOR: higher T, higher salinity and difficult HC (sour fields). Still some R&D to be done (e.g. new chemistries)

Staff competence: requires multidisciplinary mentality, difficult to find technical specialists in individual areas.

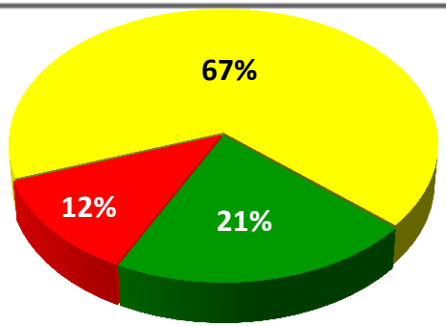
Links between different disciplines in EOR: geo-mechanics, water treatment, facilities to establish R&D needs (link with operational needs).

Not covered in presentations: surveillance : is there R&D needed for particular EOR applications (meters for produced fluids).

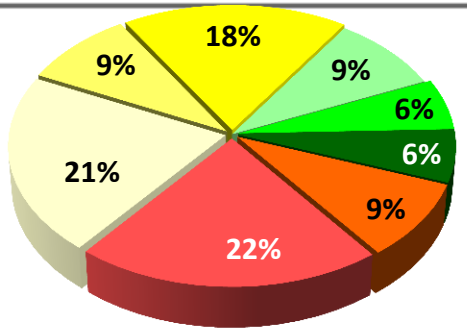
Many challenges in reservoir modeling in EOR applications.

Materials: many new developments – but these need to be considered within the brownfield context (e.g. integrity).

SUMMARY OF ALL R&D PROJECTS (33) 2014



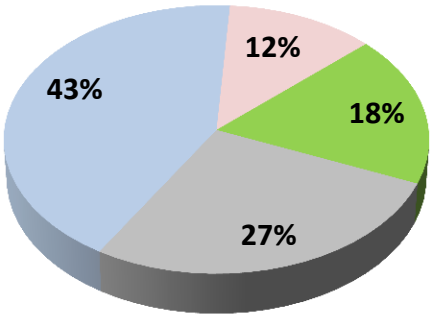
- Basic research (4)
- Applied research (22)
- Experimental development (7)



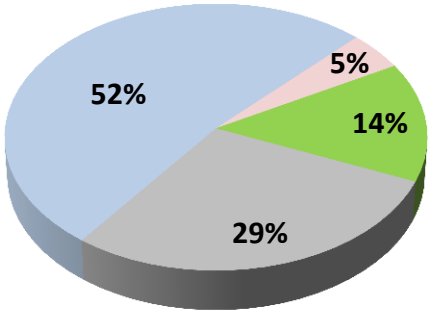
- TRL 2 (3)
- TRL 3 (7)
- TRL 4 (7)
- TRL 5 (3)
- TRL 6 (6)
- TRL 7 (3)
- TRL 8 (2)
- TRL 9 (2)

Current phase | TRL grade

Project type | Budget 2014*



- Production technology (9)
- Reservoir technology (14)
- HSE related (4)
- Exploration & field development (6)



- Production technology
- Reservoir technology
- HSE related
- Exploration & field development

Cost of different EOR applications

Process	Additional recovery % OOIP	Additional cost (USD/bbl)
CO_2 flood	5-20	12-20
Polymer flood	5-15	2-7
Surfactant + polymer flood	15-30	22-37
Alkali + surfactant + polymer flood	15-35	41-56

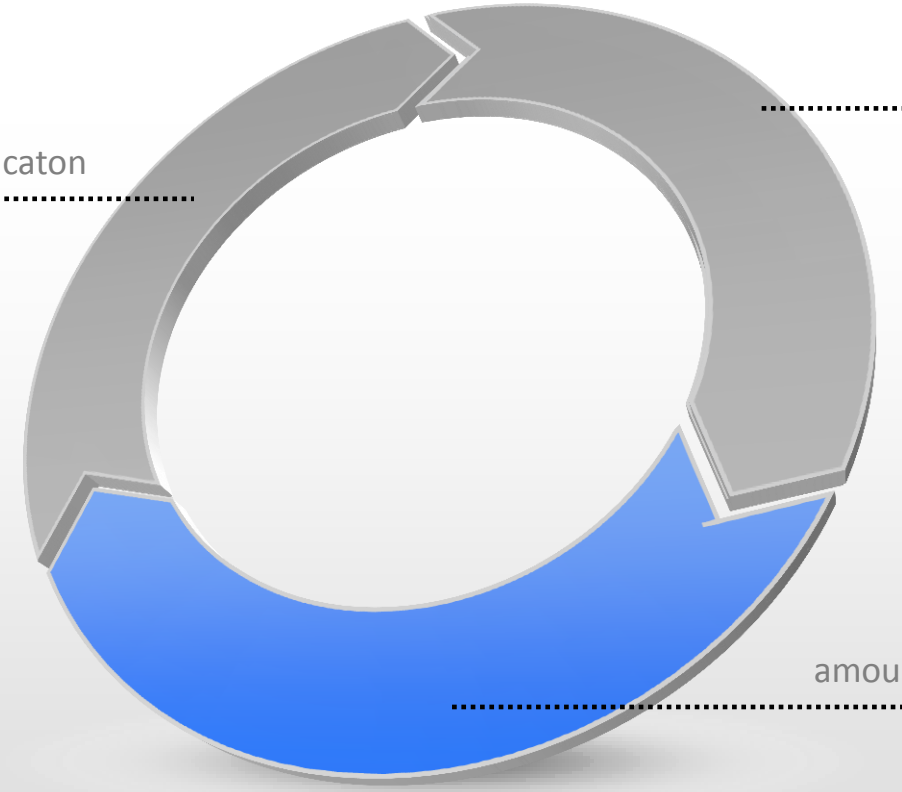
- Pilot Phase costs are higher compare to the full scale implementation
- Water-shut-off technology cost depends on the lenghts of the treatments effect and the good design the amount of injection
- MEOR additional RF is around 5-10% and costs about 2-10 USD/bbl

Data from University of Texas at Austin by Mojseh Delshad

Project information circuit

1. Project main data
type, classification, applicaton

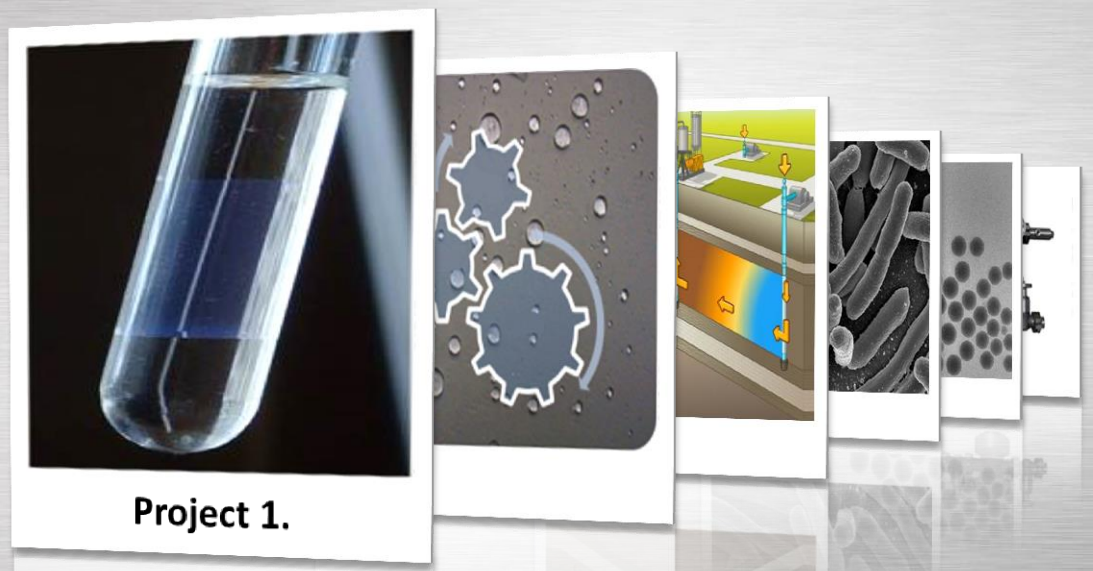
2. Project main goals
target, milestones, plan



3. Project CAPEX need
amount, calculation, breakdown

Highlighted 4 Hungarian R&D projects

Injection of metastable micro emulsion for reducing hydrocarbon wells water influx



Project 1.

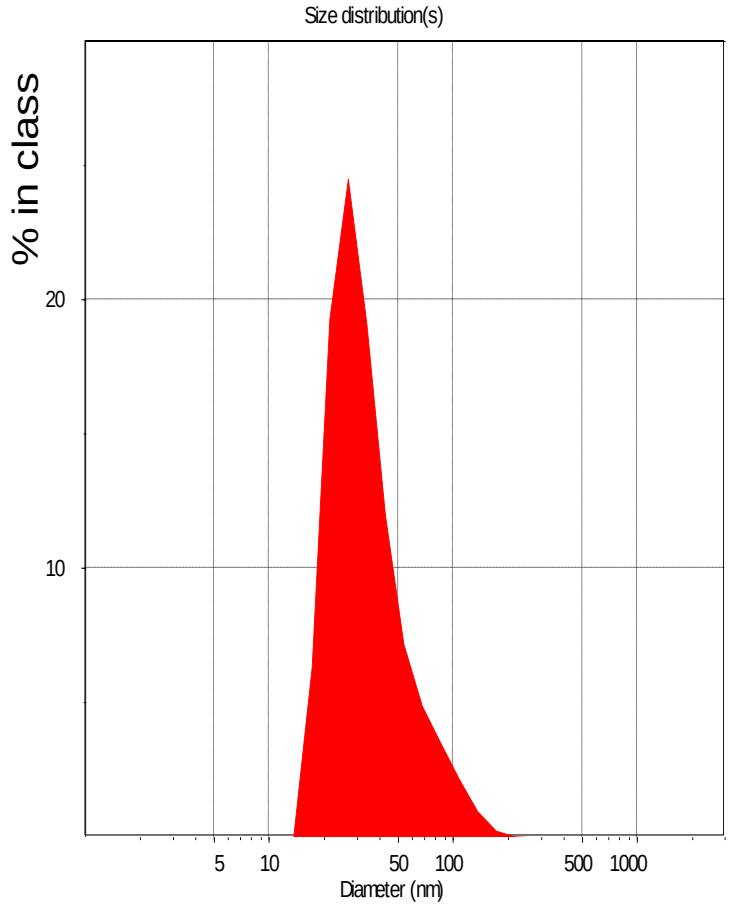
Theoretical aspects of water shutoff

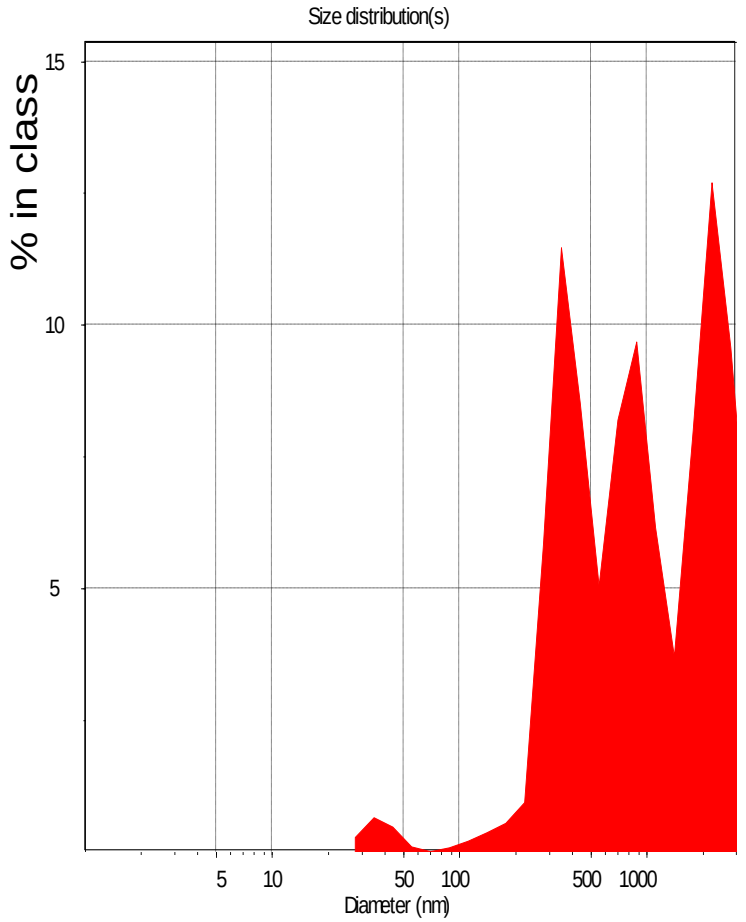
The conventional well treatment techniques are based on in-situ formation of a low mobility or immobile blocking phase. The chemical reactions are triggered by mixing of solutions, ionic and covalent bonding, pH alteration, precipitation and encapsulation of solid particles and gel domains, etc. Since the beneficial and selective permeability modification is invariant to the nature of saturating fluid, the flow resistance against water often develop not in the right time and pore space, and hence the results of the treatments

- **In oil/water systems the phase (water or gas) having higher mobility should be influenced (restricted or blocking);**
- **In gas/water systems the phase (water) having lower mobility should be influenced (restricted or blocking).**

Selective control of flow phenomena in oil/water and gas/water systems needs adverse theoretical approach, chemical systems, technologies and surface facilities!

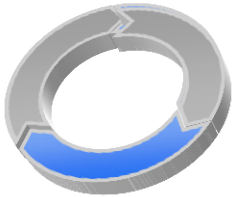
Diffference between micro and macro





Project 1.

Injection of metastable micro emulsion for reducing hydrocarbon wells water influx



1.

Aim of project	work out a simple, economical and routinely applicable well service method based on new mechanism that is suitable for limiting water production both in gas reservoirs and in underground gas storages systems		
Type of project	reservoir technology	Domestic classification	Experimental dev.
Strategic objective	increase recovery factor	TRL classification	8
Possible application	Hungary, and worldwide		

2.

Target of project	average 30-40% less formation water and hereby more HC production 503,200 boe (80 Mm^3) gas for Y2015
Milestones in 2014	3 wells were treated. In case of well 1. the produced water is on same level referred to initial water production level with tripled gas production. In case of well 2. and 3. 30% more gas production, 30% less water and an additional oil production was obtained
Activity for 2015	well treatments in further gas wells

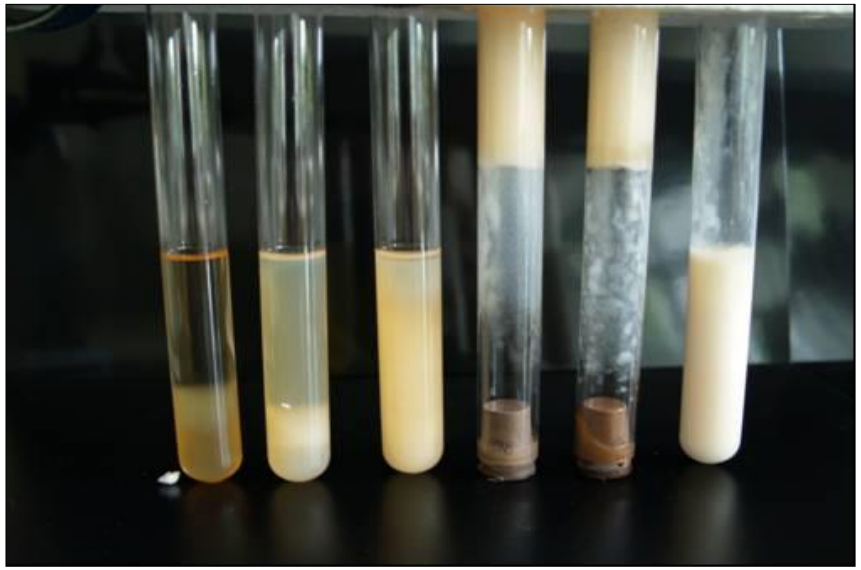
3.

CAPEX breakdown	40-60% chemicals, 40-30% service cost, 20-10% well workover, road etc.

Physical appearance of test fluids and treated wells data examples

Well 1.:

Average porosity	%	30
Average permeability	mD	600
Average water saturation	%	26
Effective thickness	m	3,5
Average clay content	%	7



Well 2.:

P_{wst}	Mpa	15,986
Effective thickness	m	8,5
Temperature	^{o}C	92
Average permeability	mD	300
Porosity		0,26-0,3
Average water saturation	%	45
Average clay content, VSH	%	12

Well selection criterias

- Production history and water production trend analysis: Fast growth of water production is very good indication
- Direction of watering: water coning is contra indication but edge watering is good indication.
- Open perforation can not be in the water phase, perforation must be above G/W surface
- Active gas cap can cause problems, GWR>700 contra indication
- If it is no lower water body , can be advantageous
- Advantageous water cut must be between 75-95%, above 98% is hopeless.
- Average permeability must be above 50 mD
- It is better if the reservoir is more heterogeneous : permeability contrast must be more than 10 (Bull-Head type treatment)
- It must be determined the reason of water in-flow (fracks??)
- Reservoir temperature must be less than 100 ^{0}C.
- Total salt content of water must be less than 5-6 g/liter
- Gas production minimum 8 - 10 000 m^{3}/day

Treatment sequence and sensitivity test

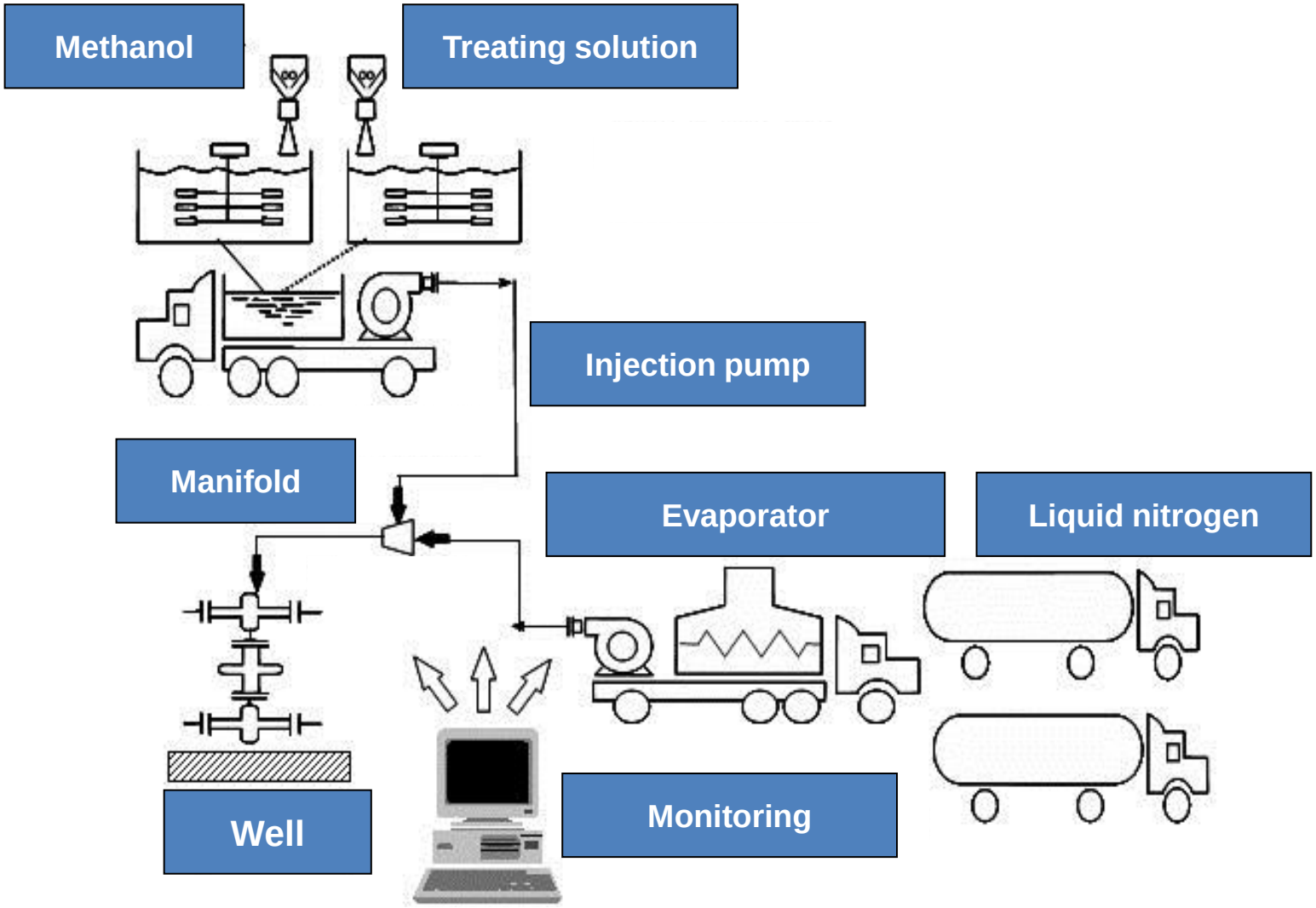
Treatment sequence

- Shut-in
- Bottomhole clean-up
- Mind acidization
- Methanol injection
- Nitrogen injection
- Injection of treating solution
- Nitrogen injection
- Shut-in
- Production

Sensitivity test

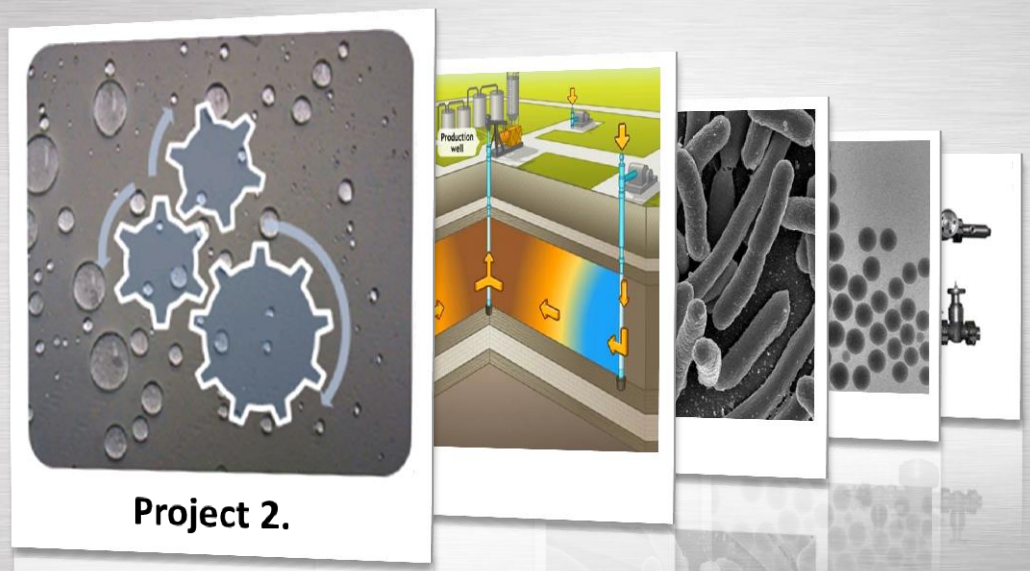
- Hydrochloric acid
- Methanol
- Oil-soluble anionic surfactant
- Temperature (up to 120 ^{o}C)
- Permeability (20 – 500 mD)
- Dissolved salts:
- TDS = 0 g/l
- TDS = 3 g/l (formation water)
- TDS = 5 g/l (formation water)
- TDS = 25 g/l (formation water)

Surface facilities for treatment



Highlighted 4 Hungarian R&D projects

Application test of micro and macro heterogenous gels for fluid flow improvement



Project 2.

Application test of micro and macro heterogenous gels for fluid flow improvement

1.

Aim of project	improve efficiency gels for correcting conditions of fluid flow in porous and fractured reservoirs		
Type of project	reservoir technology	Domestic classification	applied research
Strategic objective	increase recovery factor	TRL classification	4
Possible application	Hungary, worldwide		

2.

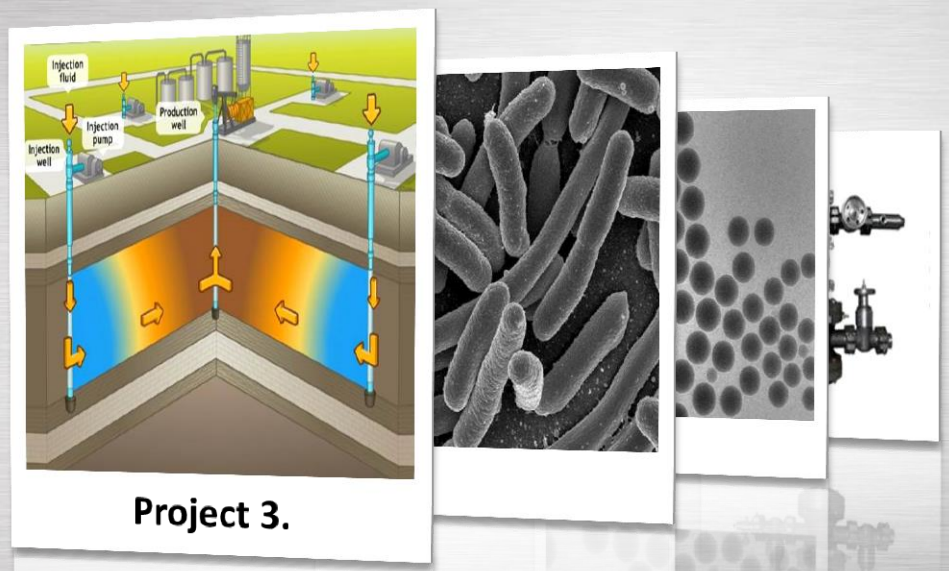
Target of project	less formation water production, stop the decreasing oil production rate and sustain the production at the estimated yearly level 144,000 bbl (20,000 ton) oil for Y2015
Milestones in 2014	Well 1. was tested and water cut decreased by 58% and oil production increased by 7%
Activity for 2015	well injection tests in further 6 oil wells

3.

CAPEX breakdown	40-60% chemicals, 40-30% service cost, 20-10% well workover, road etc.

Highlighted 4 Hungarian R&D projects

Polymer-surfactant flooding pilot in Algyő field



Project 3.
Polymer-surfactant flooding pilot in Algyő field

1.

Aim of project	economical applicable tertiary flooding method which uses new, more effective Gemini surfactant and their mixture with polymers for EOR and hereby significantly contributes to the enlargement of recoverable reserves. A main effort of the development is to expand and realize the chemical EOR method for high temperature reservoirs.
Type of project	reservoir technology
Domestic classification	applied research
Strategic objective	increase recovery factor
TRL classification	6
Possible application	Hungary

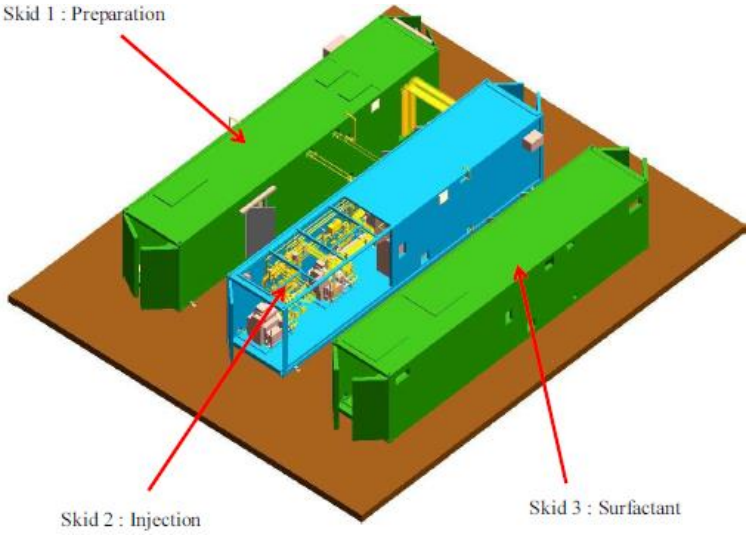
2.

Target of project	successful two injection / five production wells pilot 108,000 bbl (15,000 ton) oil from Y2019
Milestones in 2014	polymer-surfactant backflow test in well 1.was completed, analyse backflow test results and prepare for a multi-well pilot
Activity for 2015	elaborate a multi-well pilot, prepare wells for treatment

3.

CAPEX breakdown	23% chemicals, 14% service cost, 39% well workover, 24% surface technology

Pilot - heart of applied system (SNF Standard Polymer Injection Unit 100)



- 2 injection wells
- 5 production wells
- Water-supply system
- Water-treatment system
- Electrical supply system
- Surface technology related containers and tanks

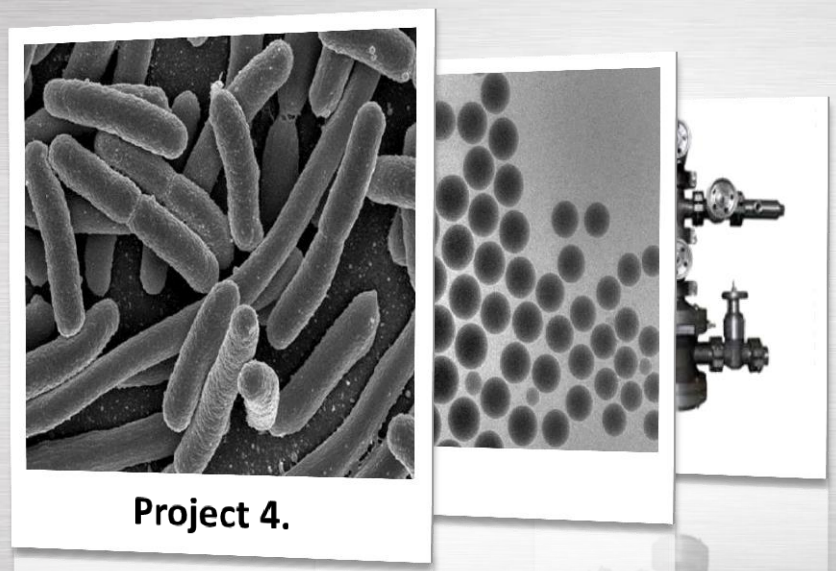
Pilot - technical details of expenditures

- **Well workover**: completions of 2 injection (Algyő-151 / 349) and 5 production wells (Algyő-2 / 152 / 475 / 973; Tápé-1) and furthermore execution of injectivity tests **(55.5 % of total CAPEX)** — CAPEX
- **Water-supply system:** construction of 0.43 mile pipeline and configuration of well areas — CAPEX
- **Water-treatment system:** special 4 way filtering system with 2 separate storage tanks for slop and purified water storage. Technology built in a container with engineering and controlling units. — CAPEX
- **Injection technology:** SNF Standard Polymer Injection Unit 100 (PIU 100) and additional 3 containers (2 for storage, 1 for staff) and 2 tanks (1 for surfactant, 1 for slop) — CAPEX
- **Electrical supply system:** construction of electrical wireline and a transformation station on site — CAPEX

- **Chemicals:** - own developed surfactant type KOMAD 6201 by MOL-LUB
  - polymer type FLOPAAM AN 125 SH by SNF **(77.2 % of total OPEX)** — OPEX
- **Operating cost and administration fees :** - production unit cost / energy cost / cost of water injection / HR cost / maintenance cost
  - authority administration / decommissioning / planning / patenting — OPEX

Highlighted 4 Hungarian R&D projects

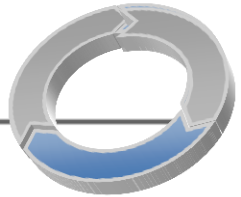
Profile control and EOR applying bio-technology methods



Project 4.

Project 4.

Profile control and EOR applying bio-technology methods



1.

Aim of project	work out and improve microbiological enhanced oil recovery (MEOR) that is applicable with water injection. Develop bio-tenside, bio-polymers and bio-surfactant / bio-polymer complex mixtures that can be used in MEOR, reservoir treatment, well service and adapt to the selected oil fields.
Type of project	reservoir technology
Domestic classification	applied research
Strategic objective	increase recovery factor
TRL classification	6
Possible application	Hungary, Croatia

2.

Target of project	average 20-30 % overall production increase and oil quality improvement (especially viscosity) after treatment 3,600 bbl (500 ton) oil for Y2015
Milestones in 2014	bacteria-bio-surfactant-biopolymer mixture injectivity test in Demjén-W field was completed. Based on treatments the oil production increased by 5-7 %. Prepare injection wells and the connecting surface technology.
Activity for 2015	microbiological analyse of produced fluids from monitoring wells

3.

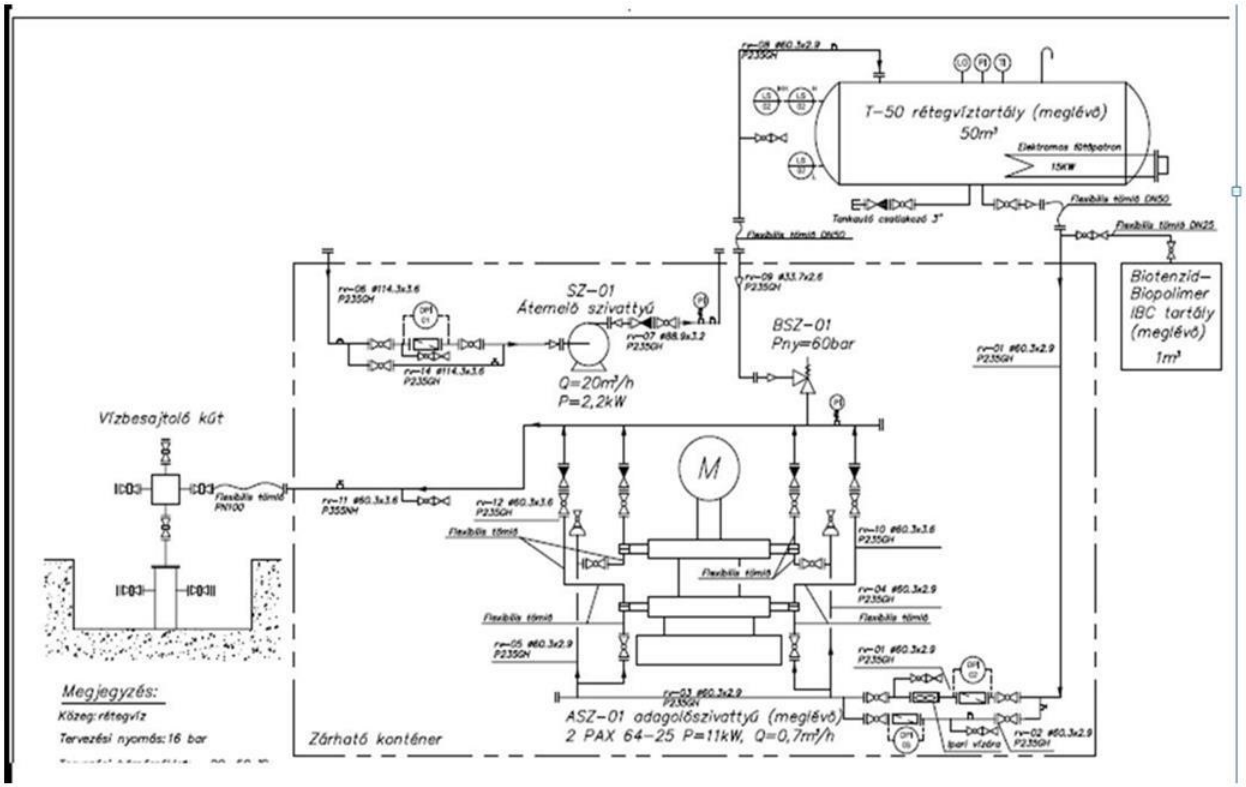
CAPEX breakdown	40% chemicals, 20% service cost, 40% well workover

Activity for 2014-2015

- **Development of continous injection surface facility with one injection well (De-23) and monitoring wells and treatment of this area in Demjén field (De-11,-18,-19,20,-21,-22,-33,-35,-54,-55,-56,-60,-61)**

Plan:

- **20 m3/day injection rate**
- **Total 2000 m3 injection with 16 banches of bio treatment plug**



Activity for 2014-2015

Injection unit in pictures

- Water storage tank

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Conclusion based on our experinces

- Oil price would not have to lead the future of EOR projects
- So many EOR technology are financially attractive in the present price environment
- Technologies are developing with the result of less cost and better efficiency compare to previous years
- Risk managment has to be take into account in green field exploratory drilling versus EOR pilot/project
- OGP's must be utilize the less service costs by starting at least new pilots
- So many chemical additive's price went down just because of oil price, time for re-evaluate the ‚frozen' projects
- In case of mature field, the technical condition of wells have to be on accepted level to get chance for EOR before abandonment.
- Chemistry and microbiology understanding must be increased at the OGP's
- Laboratory intensive tests are important before going to the fields

Thank you for your Attention!

„Innovativeness requires a climate of trust”

(Arthur D. Little, Prism, 2013)

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