25th Annual CO_2 Conference

Theme Session III:
Case History of Tertiary CO_2 injection at Ivanić and Žutica Oil Fields, Croatia

Presented at the 25th Annual CO_2 Conference

Friday Dec 13th, 2019

Silvan Mikulić
Karlo Petrović

Bush Convention Center

Midland, Texas

SUMMARY

1 EOR in Croatia

- Introduction
- Reasons for CO_2 WAG flooding

2 EOR PROJECT – Ivanić and Žutica oil fields

- Basic info
- EOR project scheme
- EOR project overview

3 EOR PROJECT – Monitoring

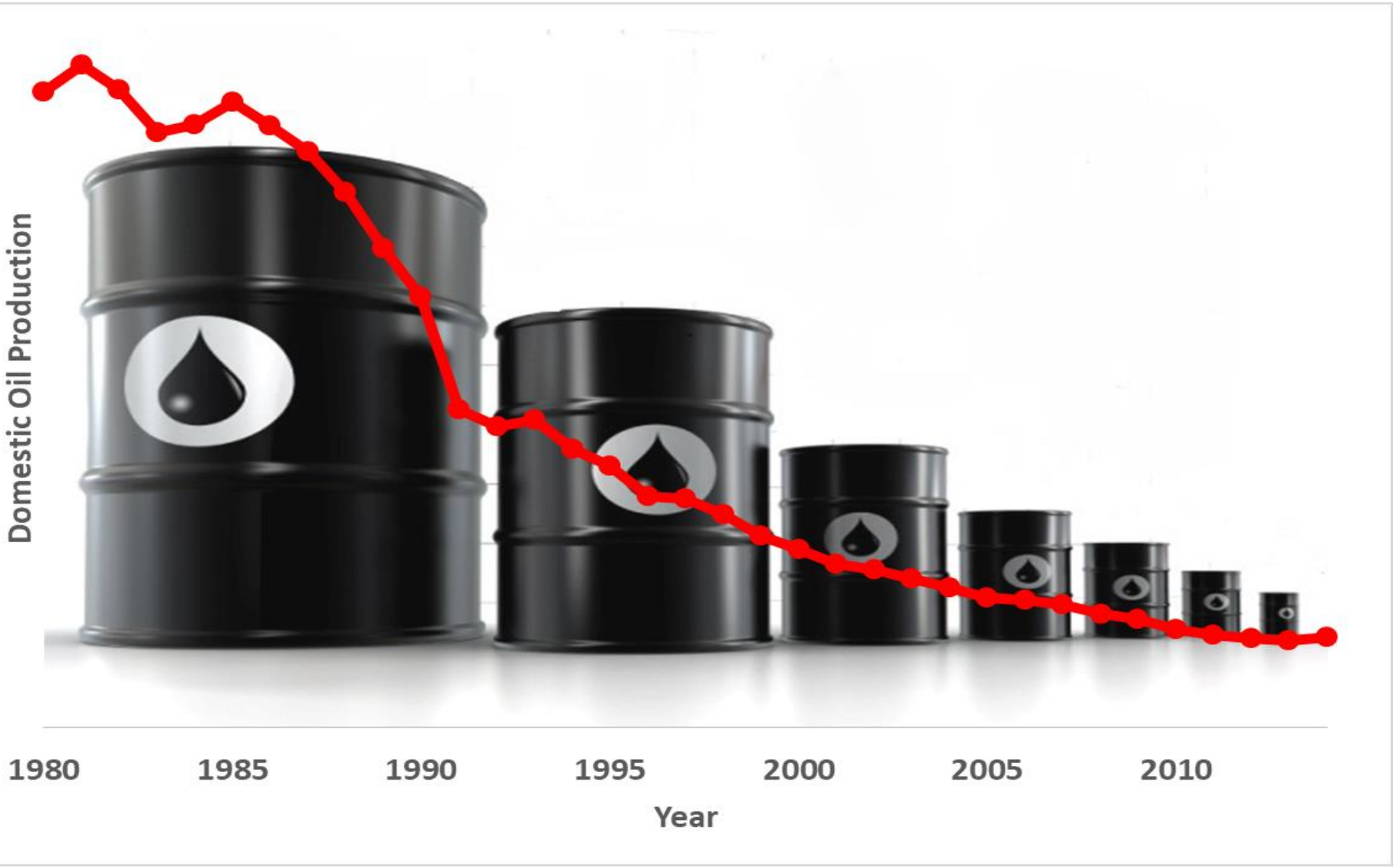
- Monitoring of CO_2 WAG process
- EOR project results
- Production engineering challenges

4 EOR PROJECT – Next steps

- EOR project next steps
- Potential EOR targets

CONFERENCE CO2 25TH ANNIVERSARY

INTRODUCTION



- Stop the natural production decline
- Recover additional oil/Improve Recovery Factor
- Extend production life of the fields

CONFERENCE CO2 25TH ANNIVERSARY

REASONS FOR WAG CO_2 FLOODING

- Quantity of available CO_2
  - High % of CO_2: gas fields in Northern Croatia
  - Pure CO_2: Šandrovac oil and gas field
- Laboratory data
  - 20 years of experiments with crudes from various Croatian oilfields
- Practical experience with CO_2 injection
  - Pilot project on Ivanić field 2003-2006 (WAG process)
- Significant remained oil in place in discovered reservoirs
- CO_2 sequestration

EOR PROJECT SCHEME

GTP MOLVE

LO-CAT

640 000 m³/d CO_2

COMP.

30 bar

DEH.

88 km

GTP ETHANE

COMP.

100 bar

LIQUEFACTION

PUMP 200 bar

CO_2

ETHANE PLANT

MEMBRANE SEPARATOR

FOLLOWING PROJECT-CCS

DEH.

COMP. ST. ŽUTICA

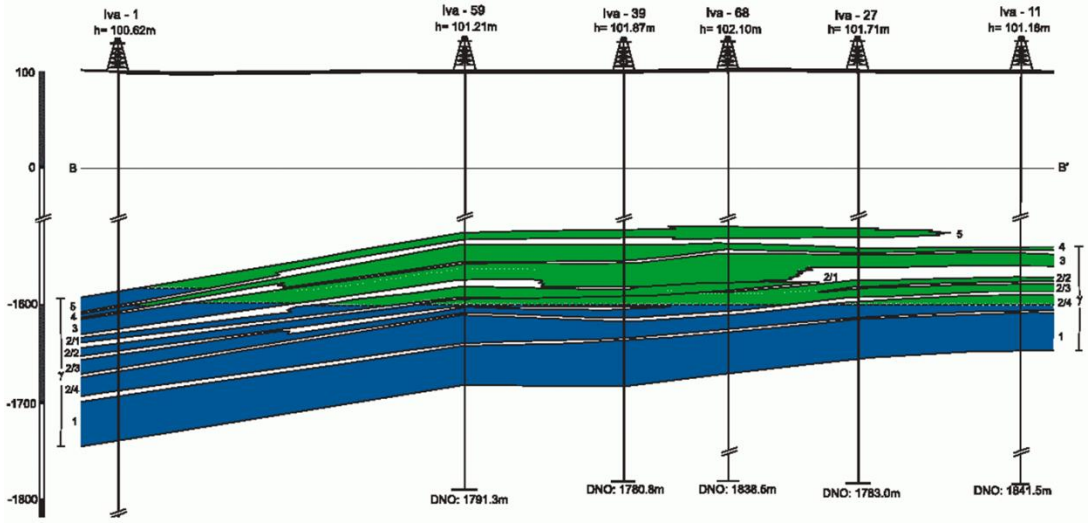
IVANIĆ

ŽUTICA

Refinery

IVANIĆ AND ŽUTICA OIL FIELDS – BASIC INFO

Ivanić



Primary recovery: 1963 - 1972

Secondary recovery (WF) : 1972 -2014

Tertiary recovery (EOR) : 10/2014

Miocene sandstones

f = 21.5 – 23.6 %

k = 15 - 80 mD

S_{wi} *= 26 – 42 %*

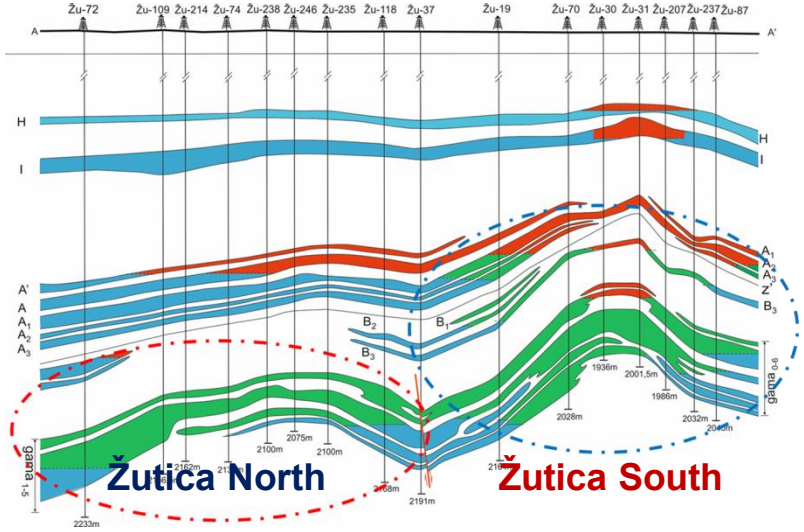
T = 97.7°C

P_i *= 183 bar*

P_b *= 137 bar*

33.4°API oil

Žutica



Primary recovery: 1966 - 1976

Secondary recovery (WF) : 1976 -2015

Tertiary recovery (EOR) : 2015 (Žutica North)

Miocene sandstones

f = 16 – 22 %

k = 5 – 90 mD

S_{wi} *= 26 – 42 %*

T = 110.7°C

P_i *= 211 bar*

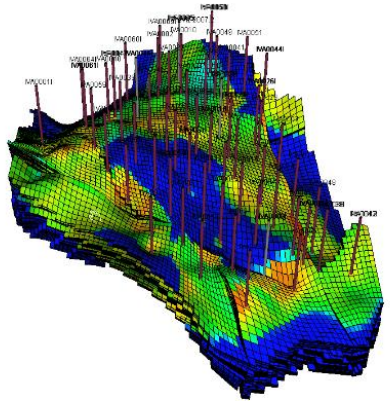
P_b *= 139 bar*

33.8°API oil

EOR PROJECT OVERVIEW

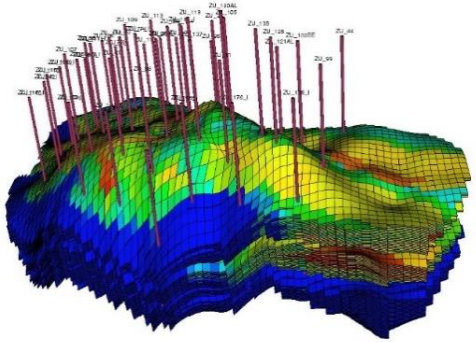
Ivanić

- *Start of CO_2 injection : October 2014*
- *Daily production before EOR: 579 boepd*
- *Current daily production: 1430 boepd*
- *43 Producers, 16 WAG Injectors*
- *Current pressure – 140-160 bar / MMP – 200 bar*
- *IMMISCIBLE WAG EOR PROCESS*



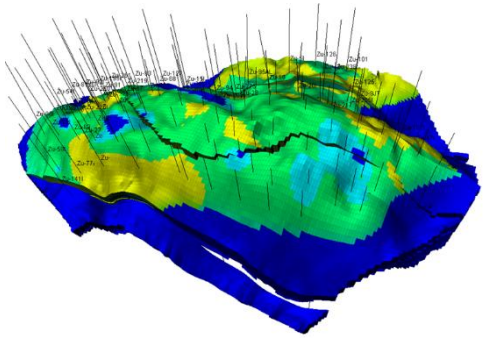
Žutica North

- *Start of CO_2 injection: October 2015*
- *Daily production before EOR: 68 boepd*
- *Current daily production: 521 boepd*
- *33 Producers, 8 WAG Injectors*
- *Current pressure – 210 bar / MMP – 210 bar*
- *MISCIBLE WAG EOR PROCESS*

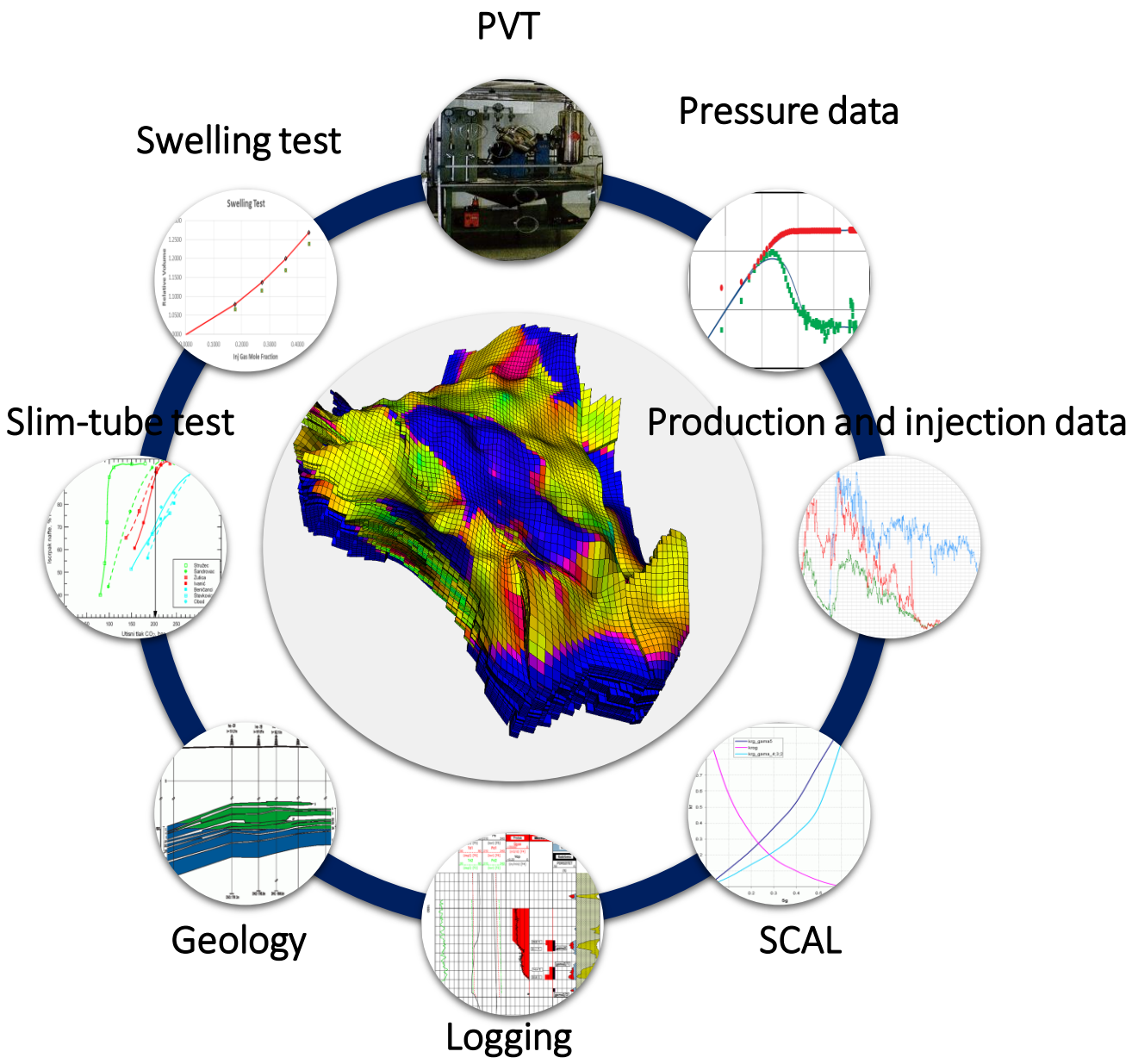


Žutica South

- *Start of CO_2 injection: Postponed due to low reservoir pressure, far from miscibility pressure (103-152 bar)*

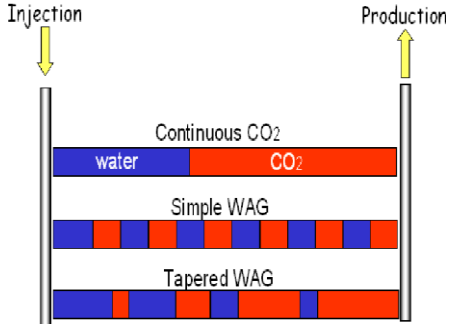


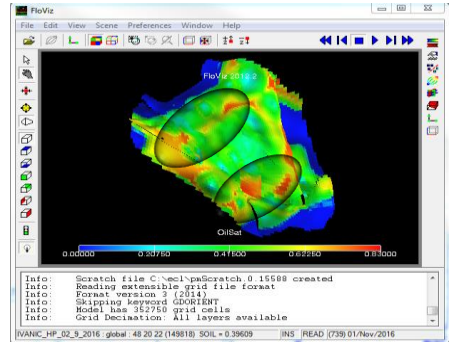
MONITORING OF CO_2 WAG PROCESS



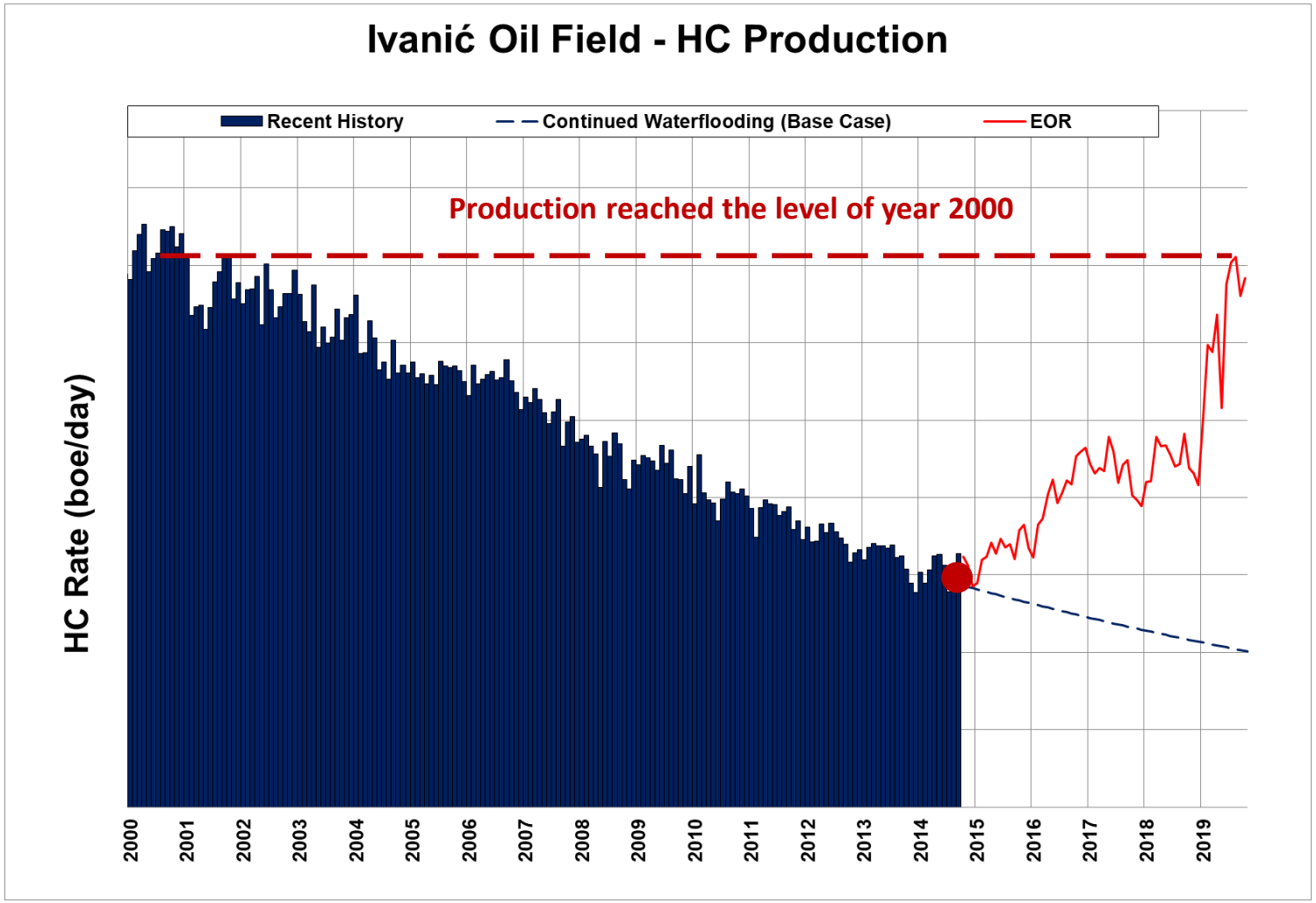
Using Numerical simulation in monitoring EOR process

- ***Identify main field potential***
- ***Injection planning and prioritisation***
- ***Sensitivity analysis – Optimizing WAG process***
- ***Production forecast***



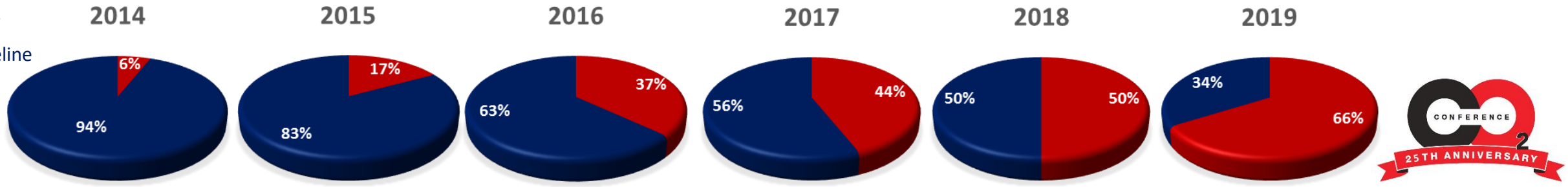


EOR PROJECT RESULTS

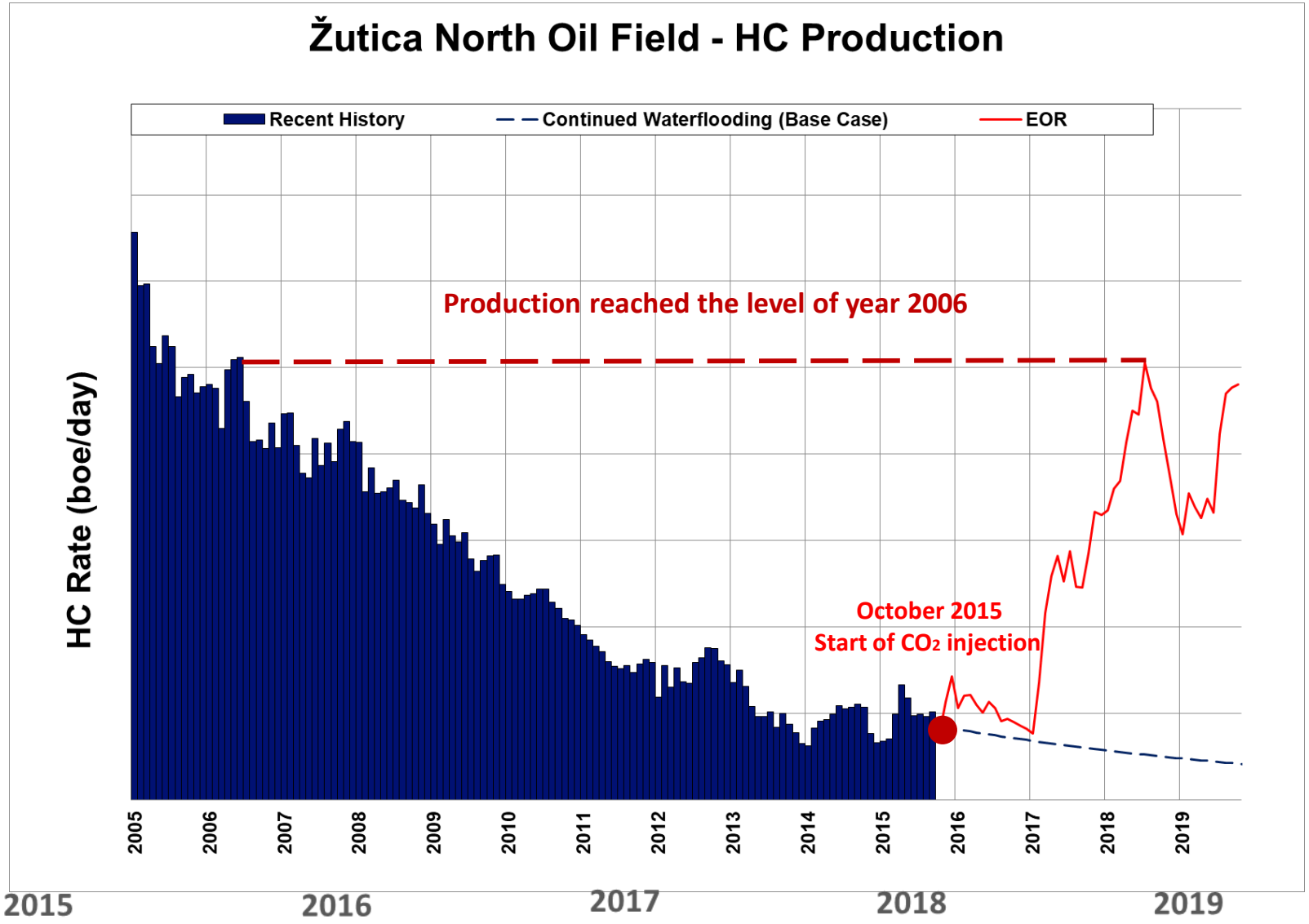


EOR

Baseline

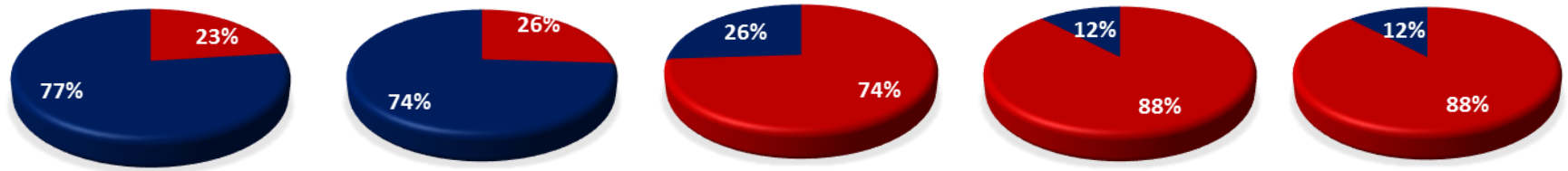


EOR PROJECT RESULTS



EOR

Baseline



CONFERENCE
25TH ANNIVERSARY

PRODUCTION ENGINEERING CHALLENGES

Challenges

- Integrity (Corrosion)/Increased number of well workovers
- Mature state of subsurface and surface systems
- Commingled wells (reservoir packages)
- CO_2 quantities
- Low reservoir pressure

Solutions

- Corrosion inhibition (batch inhibition, downhole injection), passive protection
- Introduce new ALS (ESP)
- Relining casing/pipeline
- Selective completion
- New CO_2 Compressor and Pumping Station/New source of CO_2
- Shut in producers with high w.c.

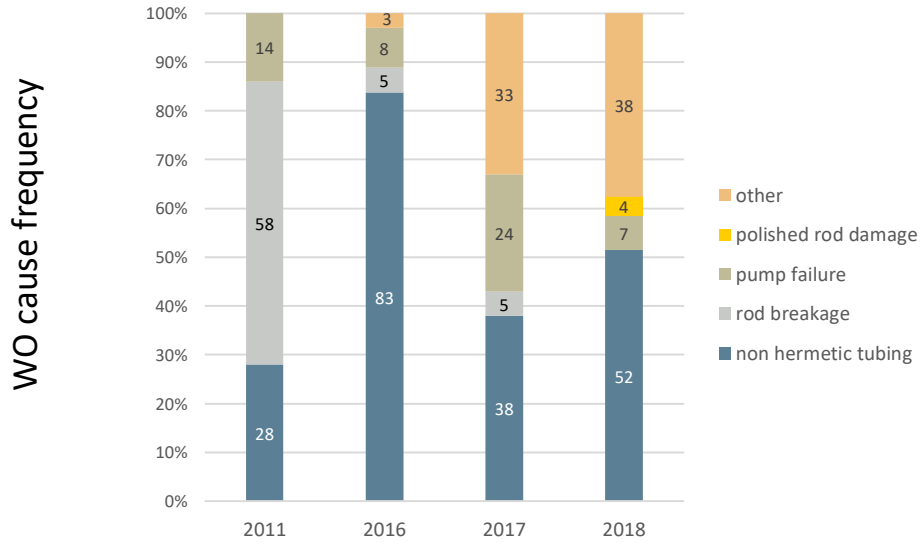
PRODUCTION ENGINEERING CHALLENGES

MECHANICAL ERROSION OF AL EQUIPMENT

Sucker rod pumps cause friction between rods and tubing while in operation

CORROSION ENVIROMENT

up to 75% CO_2 mol., 95°C, water cut ≈ 90%



FREQUENT WORK OVERS, HIGH OPEX DEMAND

Increase of number of WOs per production well per year up to 1.9 (in 2017)

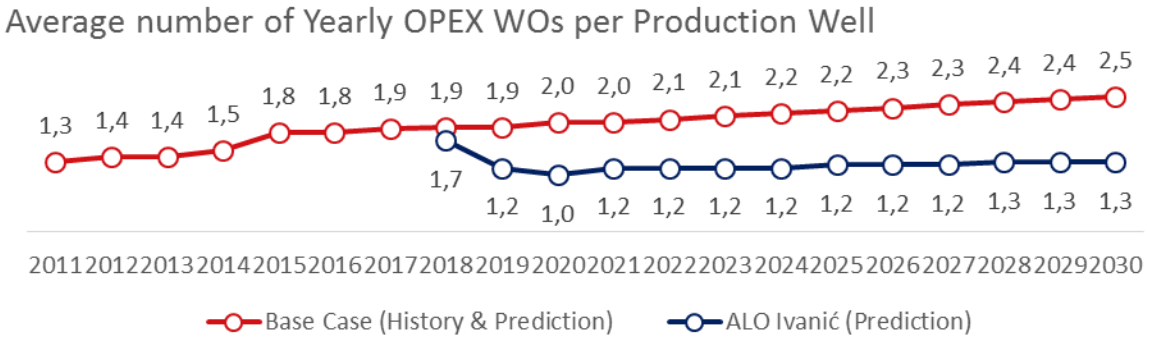
HSE RISKS

High risk of CO_2 leakage due to potential production casing integrity loss, stuffing box (SRP) became inadequate barrier for high amount of gas

PRODUCTION ENGINEERING CHALLENGES - ESP installation

DECREASE IN NUMBER OF WORKOVERS

Based upon the pilot program on two wells, predicted benefit in significant decrease in number of workovers (WO) which will result in high OPEX savings



PRODUCTION CONTROL and COROSION MANAGEMENT

The goal is to keep dynamic fluid level in the casing as low as possible by regulating the production with the frequency change. Thus corrosion inhibitor will reduce the corrosion rate both in the wellbore and casing.

HSE risks

Very high influence of corrosion on wellbore completion, with no production packers installed, high risk of CO_2 break-through due to endangered casing integrity.

ESP Equipment

Three completion ESP types + one slim ESP system in line with production quantities criteria

PFT Tri-Gator Penetrator

Cable penetrator through wellhead in line with ATEX and safe option for sealing

Simultaneous installation of ESP, cable and IL

New equipment for simultaneous installation of ESP, ESP cable and Injection line

HSE – Risk reduction during operation

Reducing the risk of potential uncontrolled CO_2 breakthrough due to reduced casing integrity or leakage of sealing elements

PRODUCTION ENGINEERING CHALLENGES - corrosion management

Inner tubing walls

- Inhibitor downhole injection line (continuous)

Outer tubing walls and casing

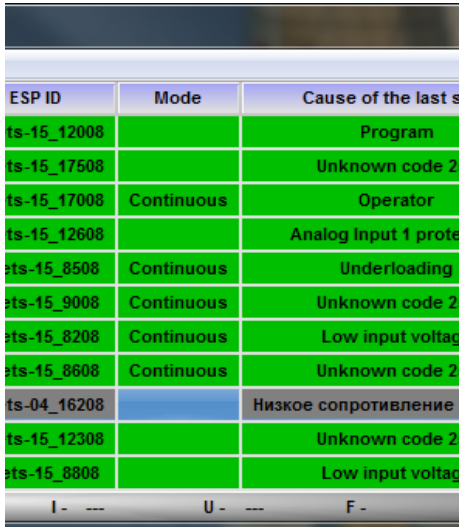
- Batch inhibition (oil soluble inhibitor), every 2 weeks

- 19 ESP + IL installed in Ivanić oil field
- Extension of the project on Žutica North and Žutica South oil fields

Future development

- Corrosion coupons and ER probes (fall 2019)
- Monthly formation water chemical composition analysis

PRODUCTION ENGINEERING CHALLENGES - opportunities

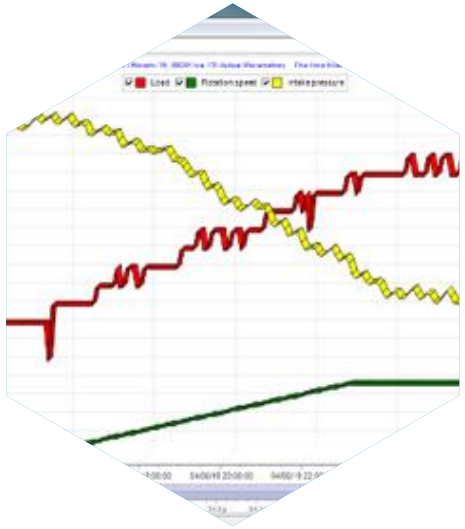


ESP ID	Mode	Cause of the last s
ts-15_12008		Program
ts-15_17508		Unknown code 2
ts-15_17008	Continuous	Operator
ts-15_12608		Analog Input 1 prote
ts-15_8508	Continuous	Underloading
ts-15_9008	Continuous	Unknown code 2
ts-15_8208	Continuous	Low input voltag
ts-15_8608	Continuous	Unknown code 2
ts-04_16208		Низкое сопротивление
ts-15_12308		Unknown code 2
ts-15_8808		Low input voltag

I - --- U - --- F -

REAL TIME MONITORING

SCADA application on GS IVA2 with engineering connections for real time monitoring



DATA HISTORY

Surveillance, alarming, data history, reporting

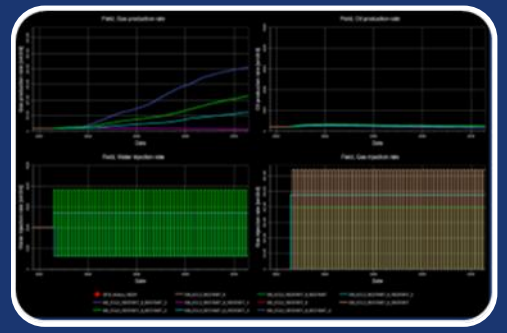
REPORTING

New equipment enabled optimizing the production (drawdown), data analysis and real-time performance monitoring (optimal pump work area

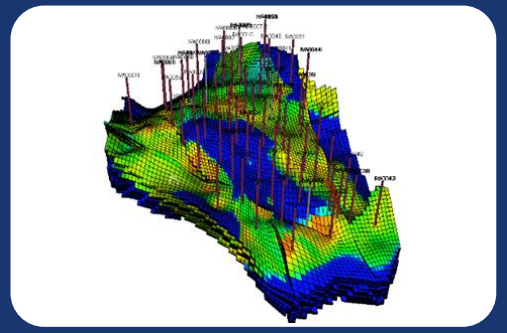
PRODUCTION OPTIMIZATION

Programming pump operation modes specifically for each well (start mode, operational mode, work in cycles…)

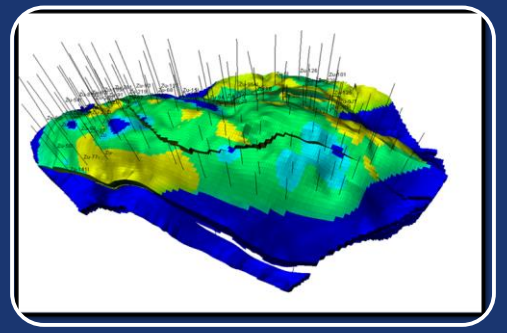
EOR PROJECT NEXT STEPS



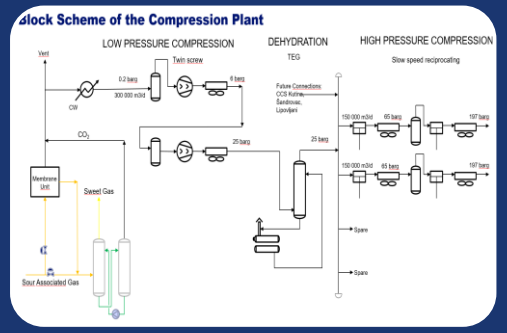
Continuous monitoring process



Models calibration

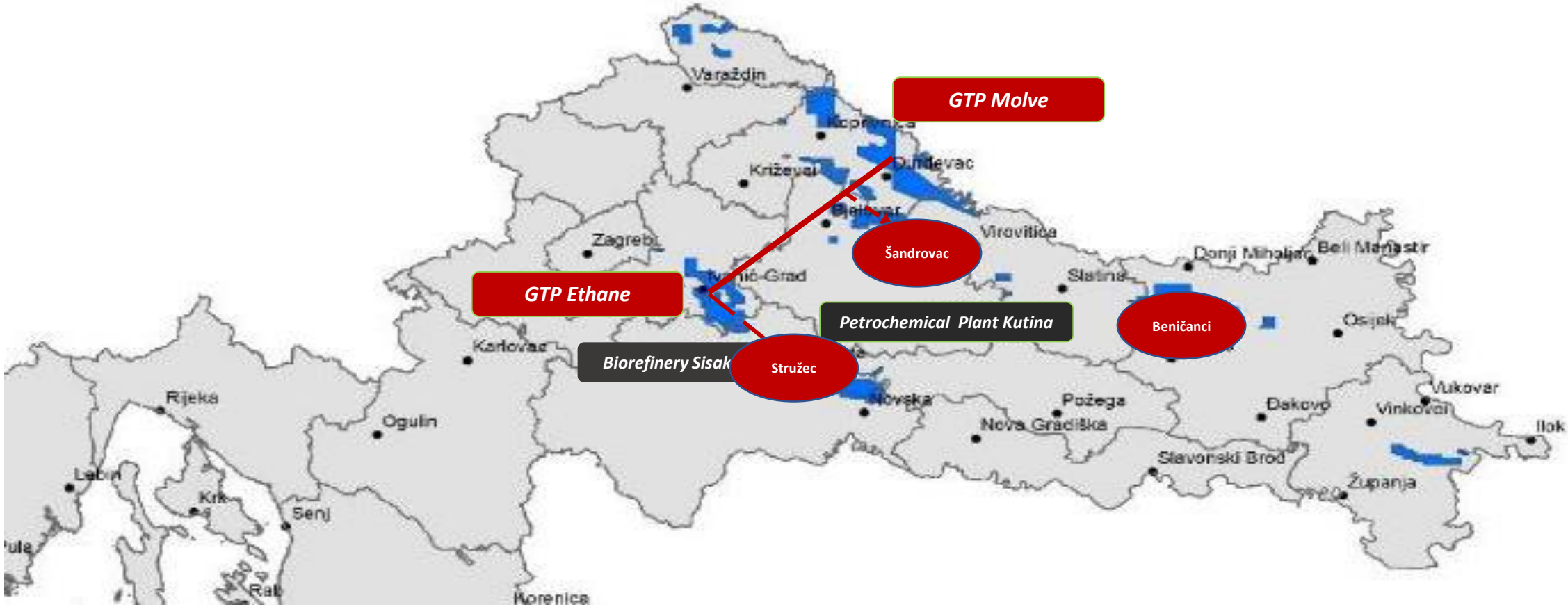


Starting CO_2 injection in the Žutica South Oil Field



Construction of new CO_2 Compressor Station

POTENTIAL EOR TARGETS



- *Šandrovac oil field has natural CO_2 source – Miocene sandstone reservoir*
- *Stružec and Beničanci could be developed with a new source of CO_2*
- *Exploring other potential CO_2 sources (Biorefinery Sisak and Petrochemical plant in Kutina)*

CONFERENCE CO2 25TH ANNIVERSARY


Thank you for
your attention!