STORING GAS IN LOW QUALITY GAS RESERVOIRS – INTELIGENT CONTROL AND INDUSTRIAL EXPERIENCES

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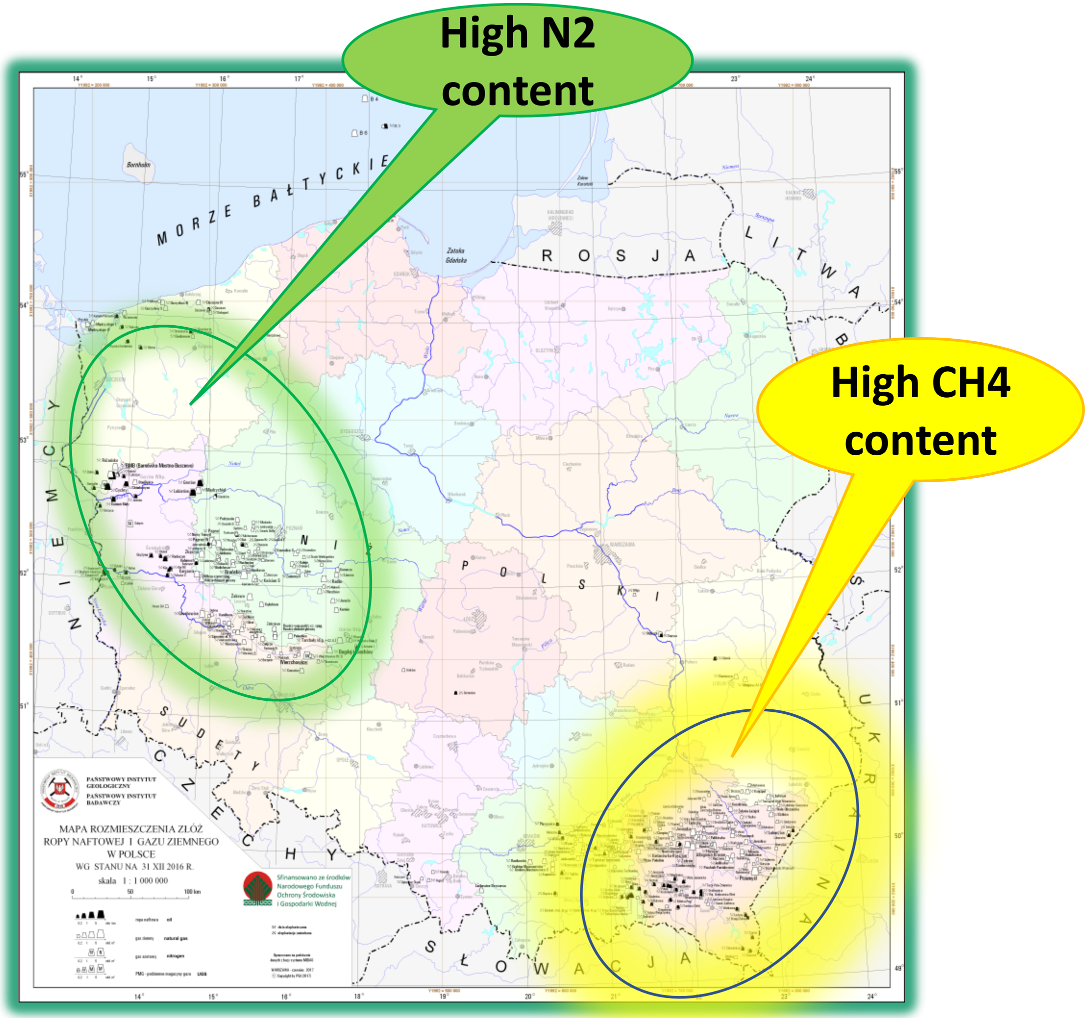
Polish Oil and Gas Company

Introduction

- Poland as gas importer – 13,7 bcm in 2017
- Poland as gas producer
  - Conventional gas: 3.8 bcm/yr
    - Reserves: 120 bcm
    - High metane content gas
    - Nitrogen rich gas
- Unconventional gas in Poland
  - Tight gas
  - CBM
  - Shale gas in Poland
    - Possible reserves: 5.3 Tcm
    - Still at preliminary stage



Bcm=10^9 m^3, Tcm=10^{12} m^3

Gas storage system in Poland source:https://ipi.gasstoragepoland.pl

High methane content	Working volume mm c.m. 2018/2019	Maximal withdrawal rate mm c.m./day 2018/2019
Brzeźnica	100,0	1,44
Husów	500,0	5,76
Mogilno	589,85	18,00
Kosakowo	145,50	9,6
Strachocina	360,0	3,36
Swarzów	90,0	0,93
Wierzchowice	1 200,0	9,60
Total:	2 985,35	48,69

High nitrogen content	Working volume mm c.m. *as of 15.05.2015*
PMG Daszewo (Ls)	30,0
PMG Bonikowo (Lw)	200,0

Production regulation

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Case study: Wierzchowice UGS using lower quality gas as a cushion gas

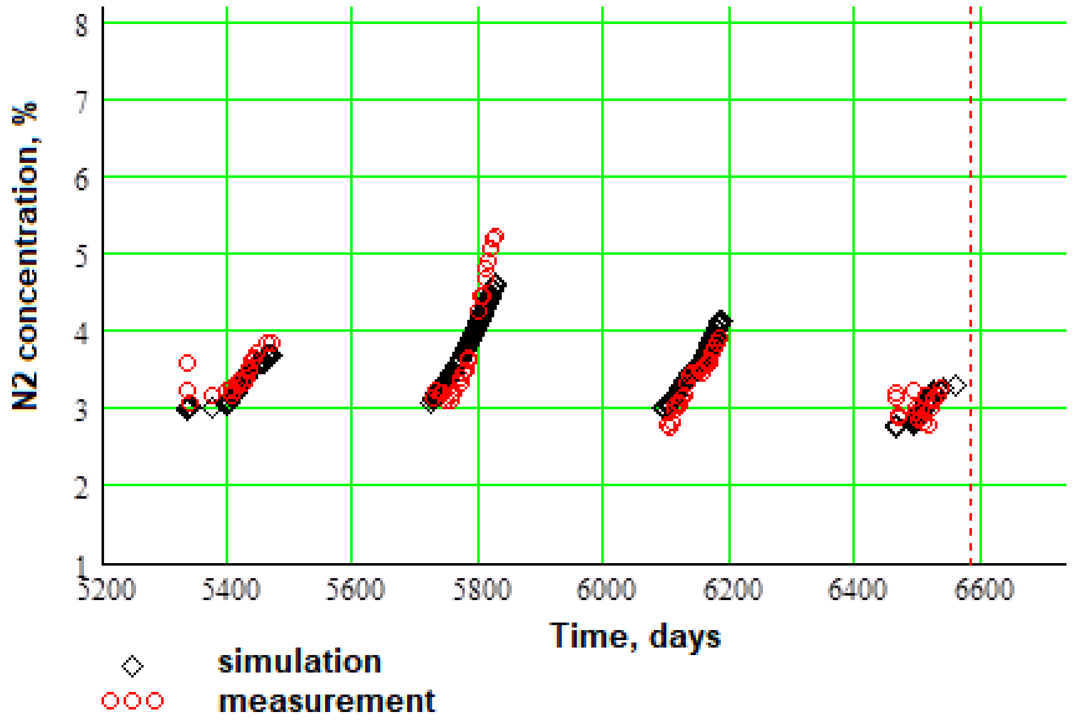
- Developed in a depleted reservoir of natural gas containing **29% of nitrogen**
- Gas remaining in reservoir: 4.1 bcm, part of that gas is employed as a cushion gas
- Energy remaining in reservoir: 113,5 billions of MJ. The economic value of that energy is about 679 millions euros.
- The same volume of a high quality gas would contain 160,3 bln MJ of energy that is equivalent to 959 millions euros.
- Difference: 280 millions euros

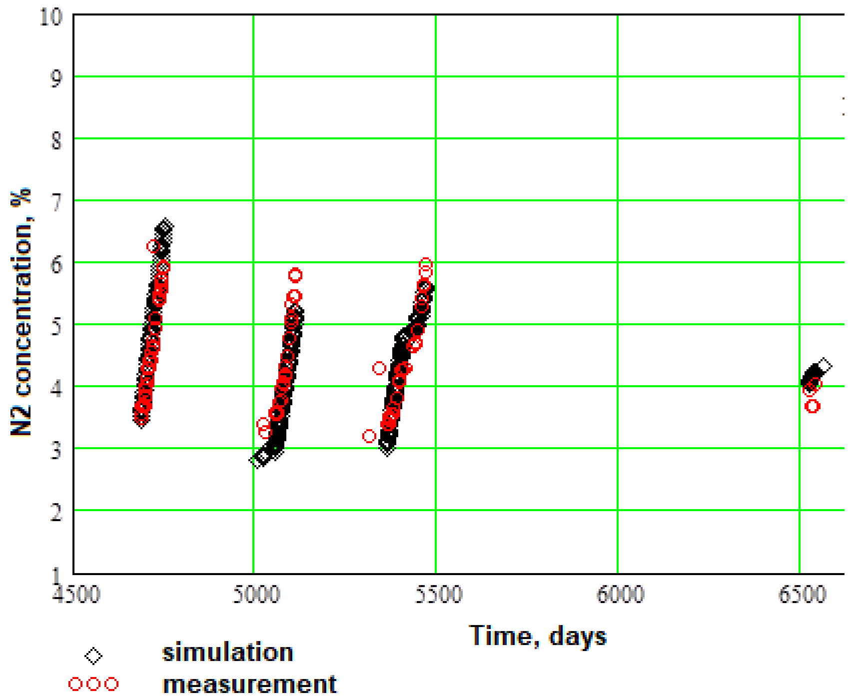
Gas composition problem

Component	**Native gas** mole fraction	**Injected gas** mole fraction
Nitrogen	**0.29**	**0.01-0.03**
Methane	0.70	0.96-0.985
…	…	…

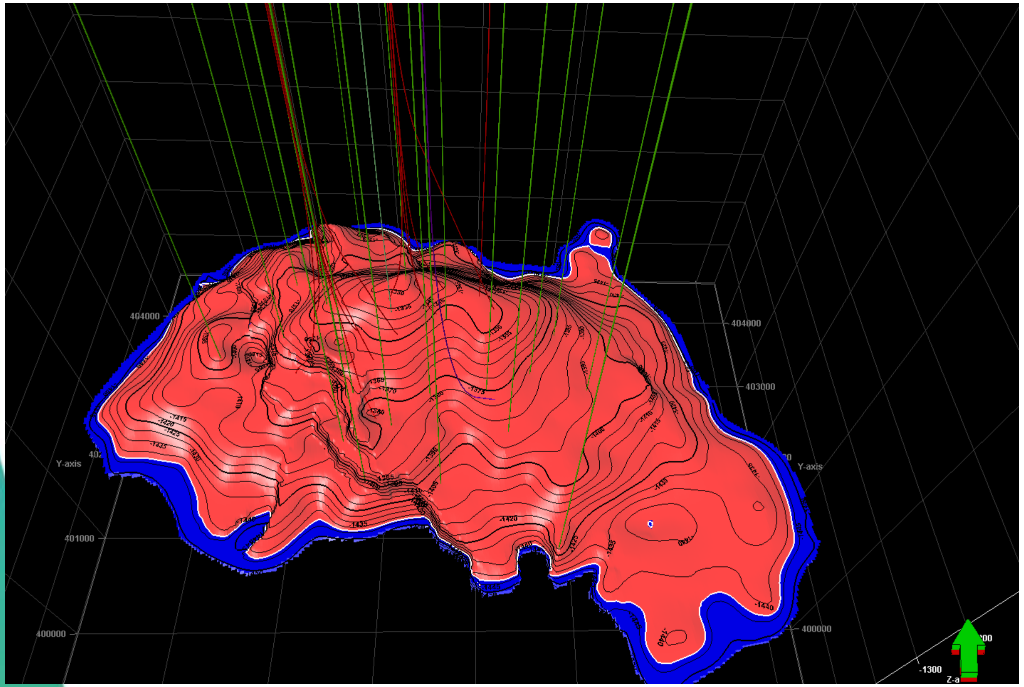
- Mixing of the injected gas and native gas and therefore variable composition of gas extracted from the storage.
- Controlling the injection and withdrawal operations by use of reservoir simulation technique

Typical N2 concentration profiles for selected wells, Wierzchowice UGS

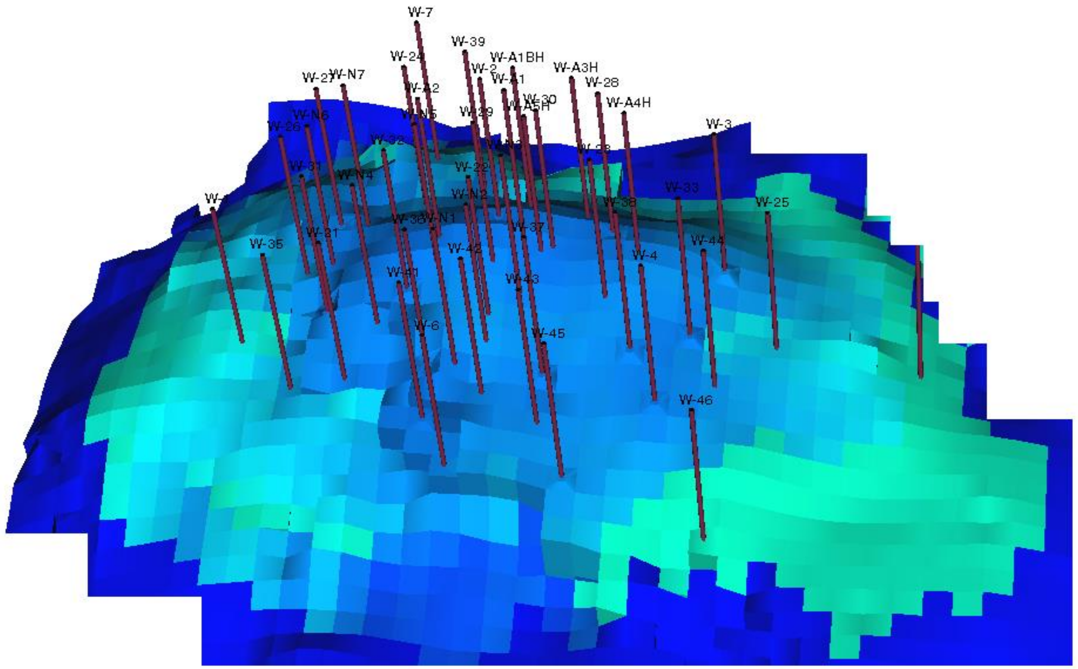




Visualisation and reservoir simulation



Structure

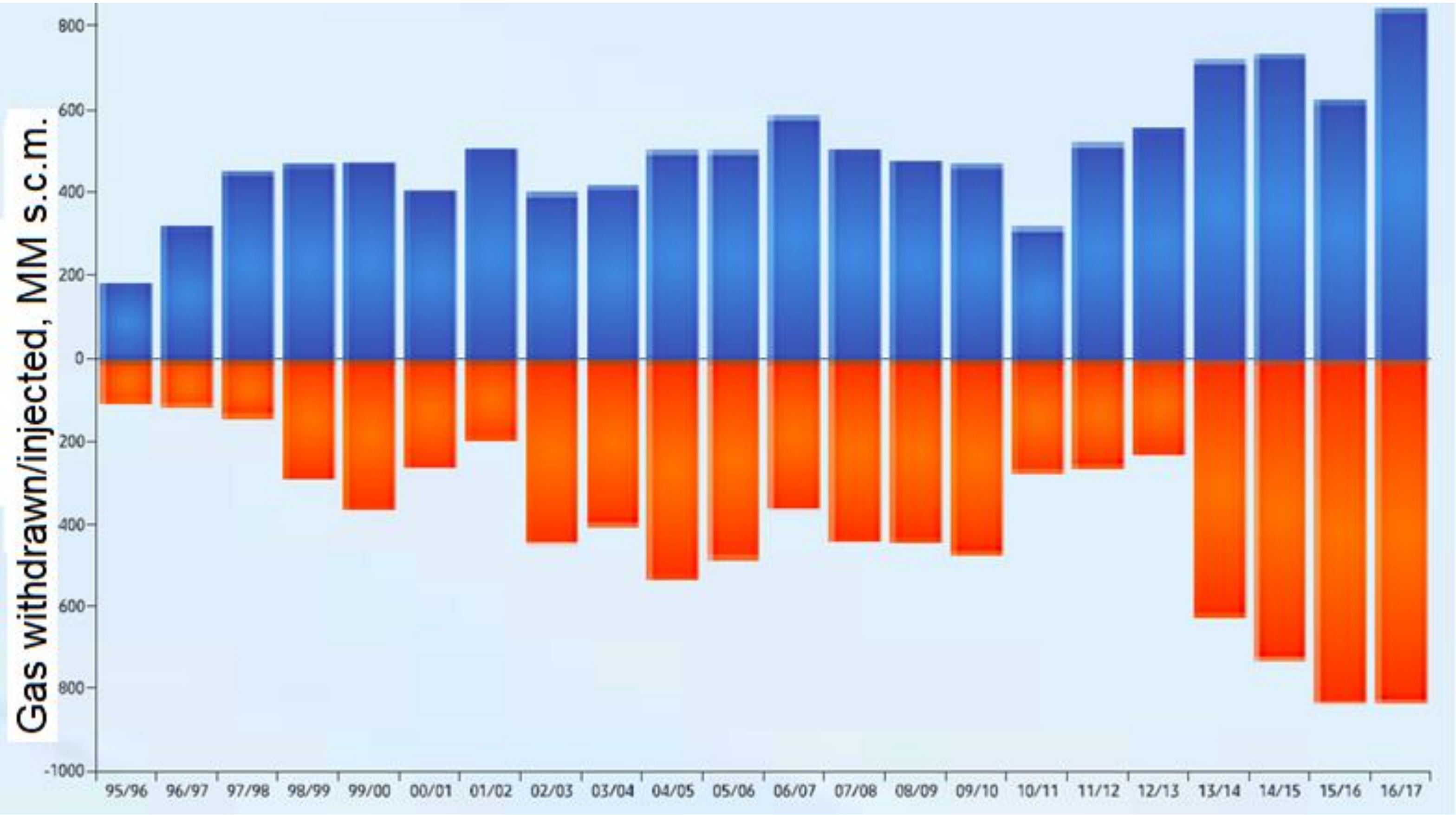


Simulated N2 concentration

No. Of wells:

- **Operational wells: 12 horizontal, 1 vertical**
- **Observation wells: 15**

History of the injection/withdrawal cycles for Wierzchowice UGS.



withdrawal

injection

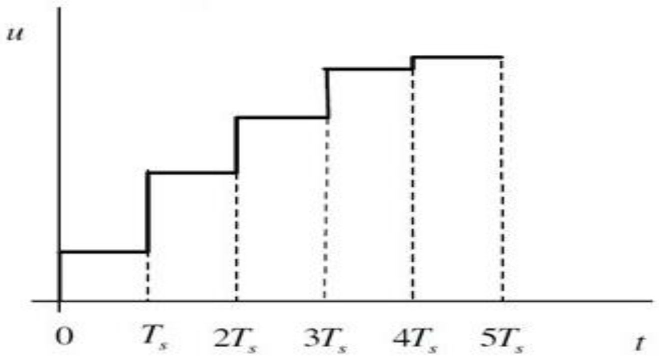
Well control based on computer simulation of the reservoir

- Reservoir simulation model in ECLIPSE 300 simulator
- Early approach: decisions based on the experience – effective but not guarantee an optimal decision
- Present approach: **to find time depended well controls that maximize energy produced from the storage**
- Method: parameterized decision tree – machine learning tool combined with the simulation model

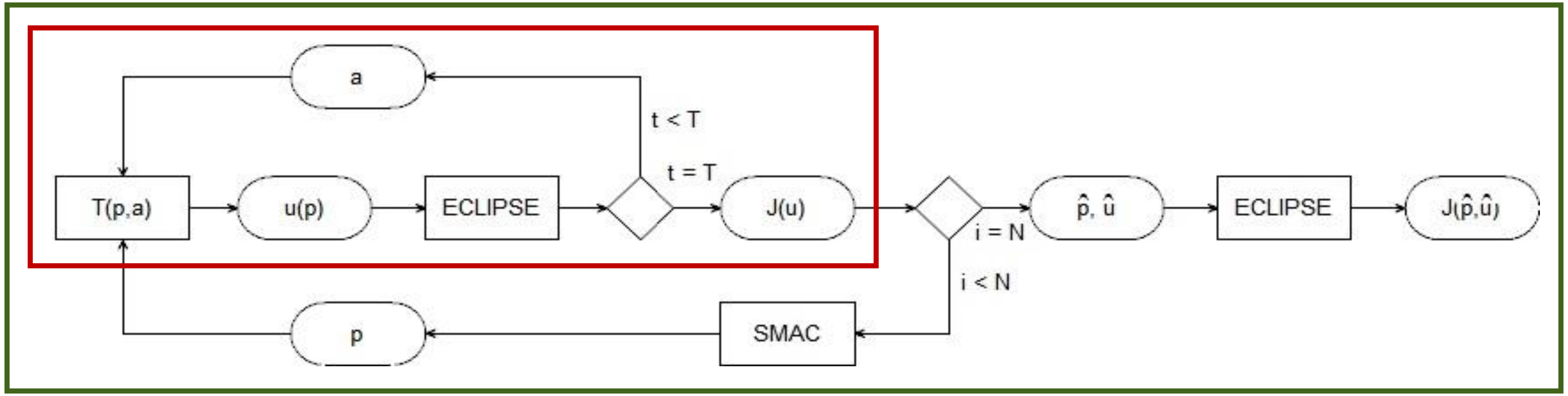
Intelligent optimization system to maximize energy produced from the storage

$$E_k(u_k) = \sum_{n=1}^{T}\left(\sum_{i=1}^{N} C_i\, y_{i,n,k}\, u_{n,k}\right) \quad (1) \qquad J(u) = \sum_{k=1}^{M} E_k(u) \quad (2)$$

$$\boldsymbol{J(\hat{u}) = \max_{u} J(u) \quad \hat{u} = [\hat{u}_1, \hat{u}_2, \ldots, \hat{u}_M]} \quad (3)$$



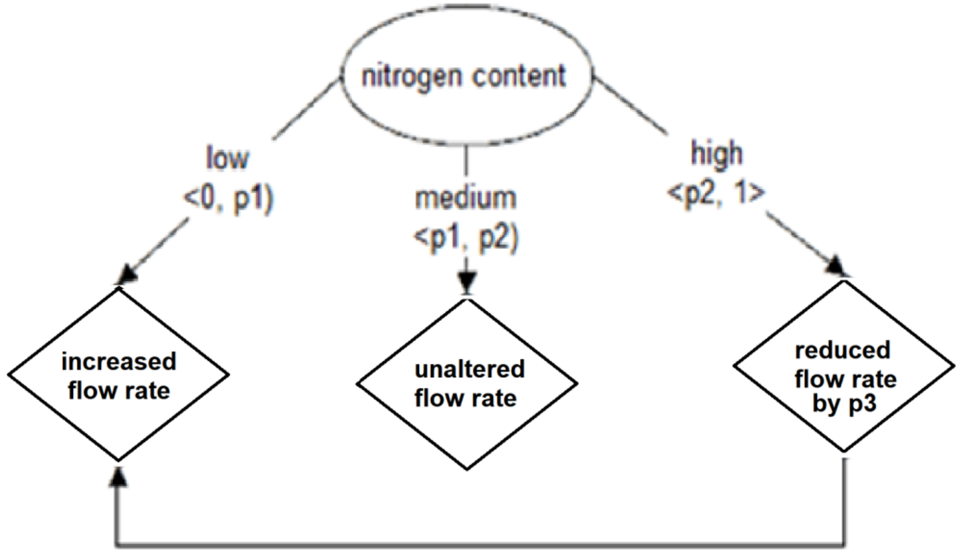
E_k – Energy produced by k-th well, J – total energy production, u – vector of well controls (flow rates), C_i – caloric value of i-th component, y – mole fraction



Combination of reservoir simulation and optimization tool - Sequential Model-based Algorithm Configuration (SMAC) to generate time depended flow rates for the wells

Parameterized decision tree for automatic generation of the controls for production wells

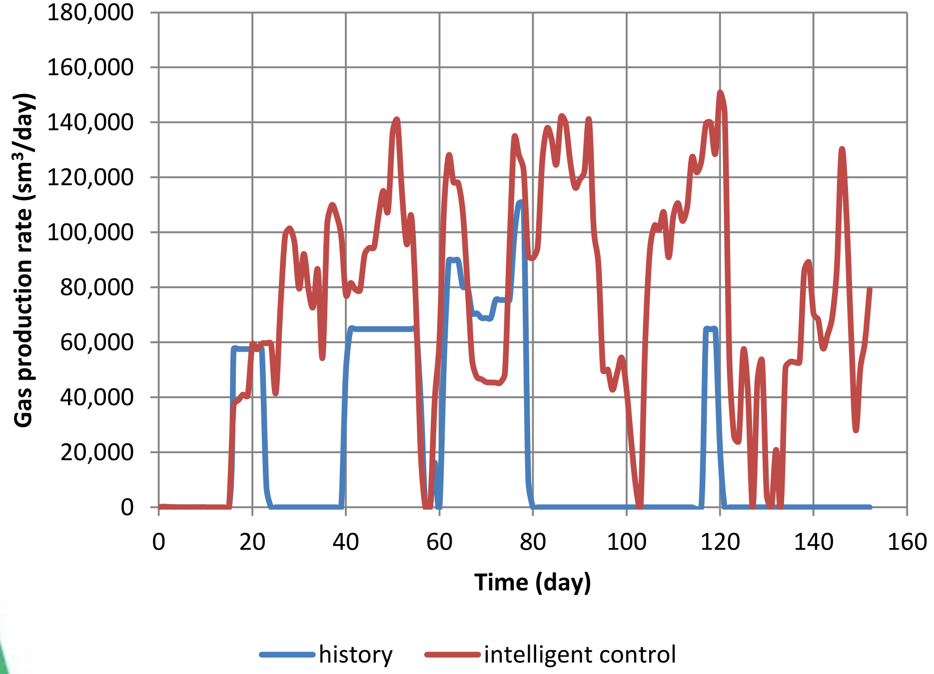
Initial flow rates of all wells were proportional to their productivity indexes. In the next consecutive time steps the well rates were updated according to the decision scheme:



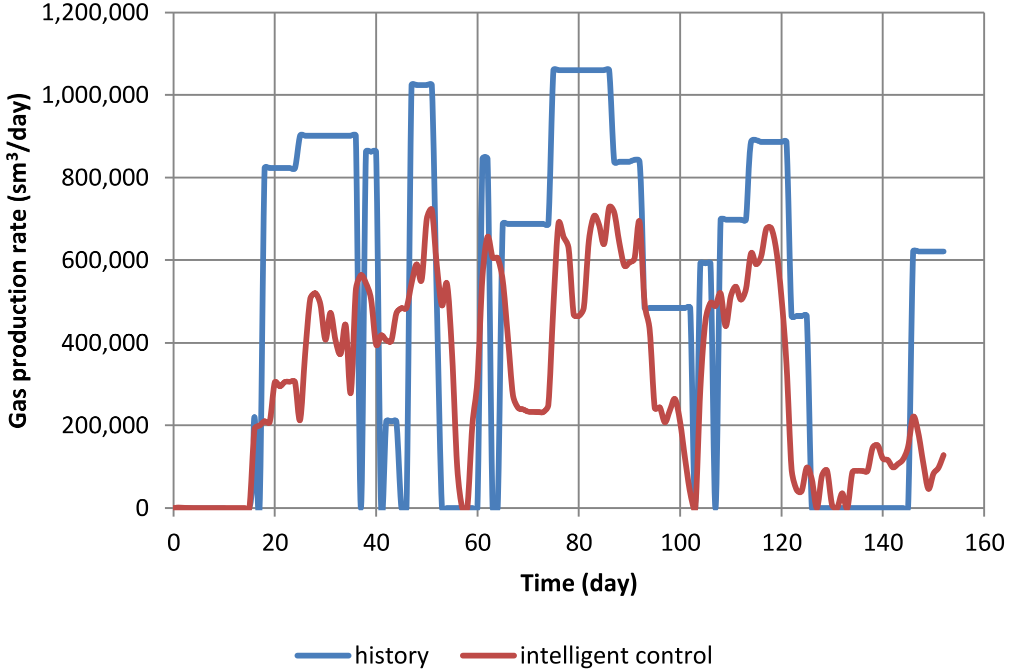
Arbitrary p1, p2, p3 replaced by optimized values 0.0217, 0.0374 and 0.2762 respectively (not intuitive)

Testing on the examples, one historical cycle – comparison of historical and optimized well controls

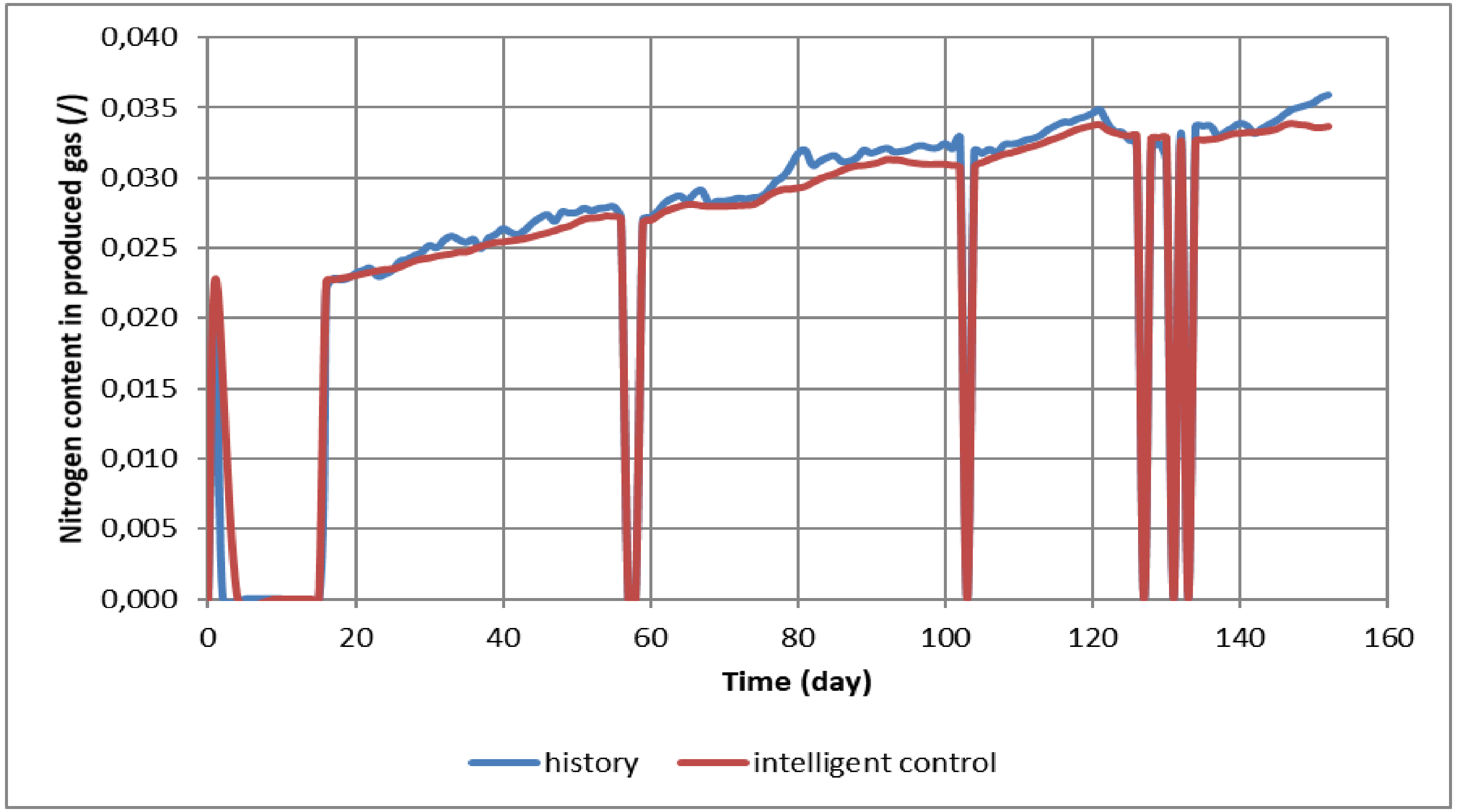
Well 1



Well 2

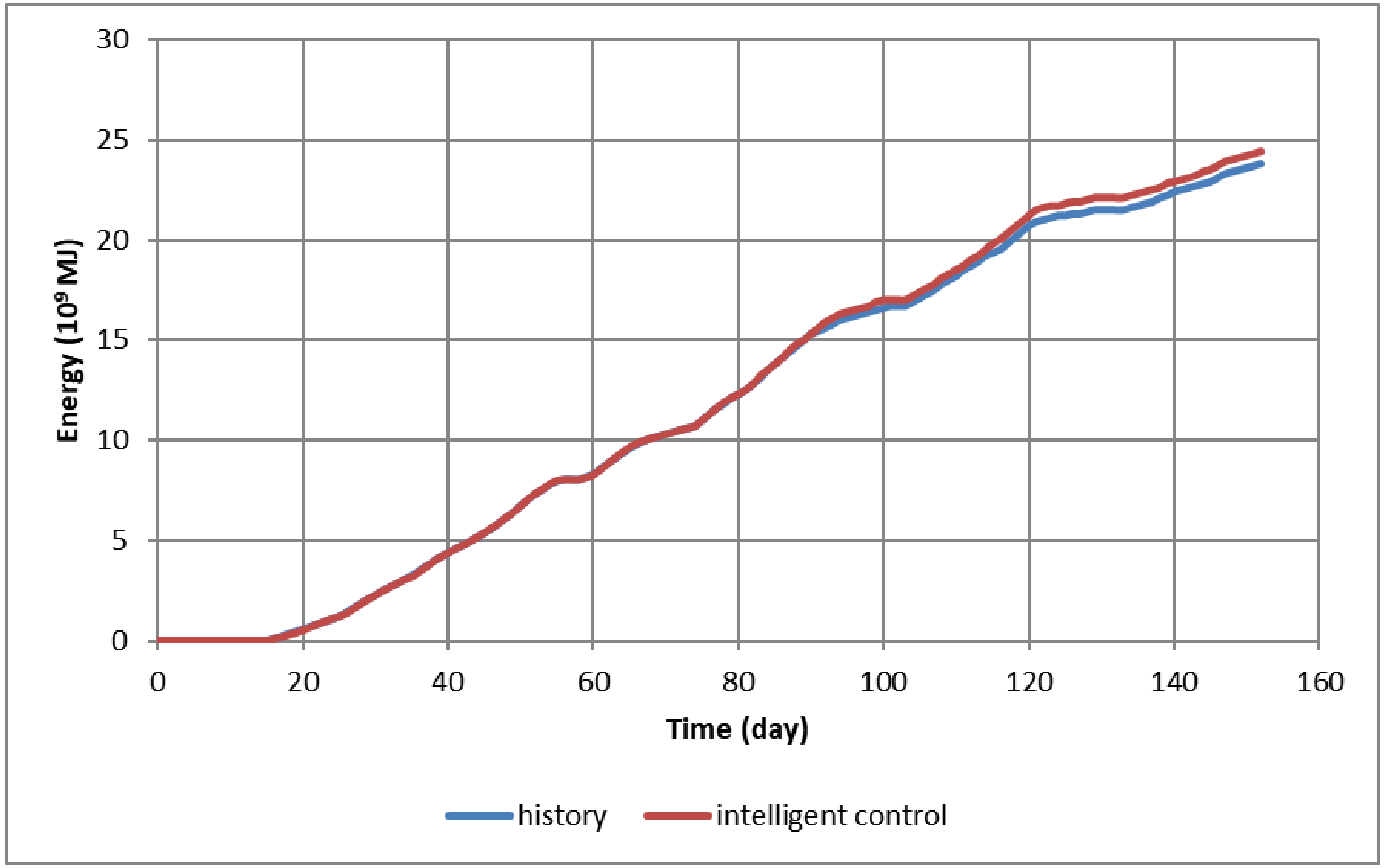


Comparison of the simulated nitrogen content in the produced gas obtained by the use of historical and optimized well controls



The cumulative nitrogen content in the produced gas was reduced by 2%

Energy production in one withdrawal cycle. Comparison of historical and optimized controls



The energy production was increased by 2.4% .
Economic value of the additional energy is 3.5 million € (If the energy price is 0.006 €/MJ)

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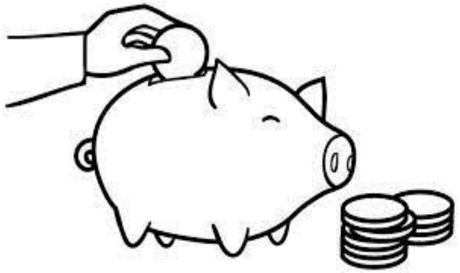
Conclusions

- Performance of the UGS can be improved significantly by artificial intelligence methods
- The example of Wierzchowice UGS, operated by Polish Oil and Gas Company, shows that storing high quality gas in lower quality reservoir can be effective both technically and economically.
- It is like saving money in the bank



„Save for a rainy day" – Aesop

Save for a cold day

Acknowledgements

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