[PS]Synergy Between Production of Natural Gas and Warm Water: A Reservoir Modeling Exercise Assessing Recovery Factor Sensitivity*

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Abstract

The Netherlands evolved from a net natural gas exporter to being a net importer. With renewable energy in The Netherlands still not able to fully replace natural gas as an energy source, the Dutch security of energy supply is at risk. On a local scale, especially for greenhouses, geothermal energy has proven to be a reliable replacement for natural gas as the primary heat provider. Yet with the ambition of the Dutch government to achieve a 49% CO_2 emission reduction in 2030, of which partly is assigned to the realisation of geothermal heat production, the maturation of the geothermal potential is too low. One of the main causes for this low maturation rate is the financial risk attached to both the exploration and exploitation phases of a geothermal project.

Synergy between hydrocarbon and geothermal exploitation could improve the aforementioned security of supply and simultaneously reduce financial risks of geothermal projects. The positioning of a geothermal doublet in the water leg of a gas field potentially extends field life and subsequent earnings from natural gas-production which in turn can be invested in the aligned geothermal project(s). This poster presents the results of two case studies, examining synergy at the Roden and Boskoop gas fields, that demonstrates geothermal production close to the gas-water contact that could delay water breakthrough in the gas well(s), potentially increasing the recovery factor.

The magnitude of increase of the recovery factor predominantly depends on the amount of aquifer support. Synergy in a weak aquifer (Boskoop case study) has no significant impact on the recovery factor. However, the addition of an artificial strong aquifer resulted in a 20% increase in recovery factor. Synergy with a moderate aquifer (Roden case study) resulted in a 3.3% increase in recovery factor.

Furthermore, although not as strongly, the magnitude of increase relies on positioning of the geothermal wells relative to gas producer(s), geothermal flow rate and potentially the permeability. This study also demonstrates that gas fields in a late stage of gas production could still benefit from the addition of geothermal doublets. It might be too late to achieve the full potential of synergy between gas and geothermal production, but a modest increase in recovery factor can still be expected. The Roden case study showed that a 1.1% increase in recovery factor could be achieved with the instalment of a geothermal system at a late stage of gas production.

Synergy between production of natural gas & warm water

A reservoir modeling exercise assessing recovery factor sensitivity

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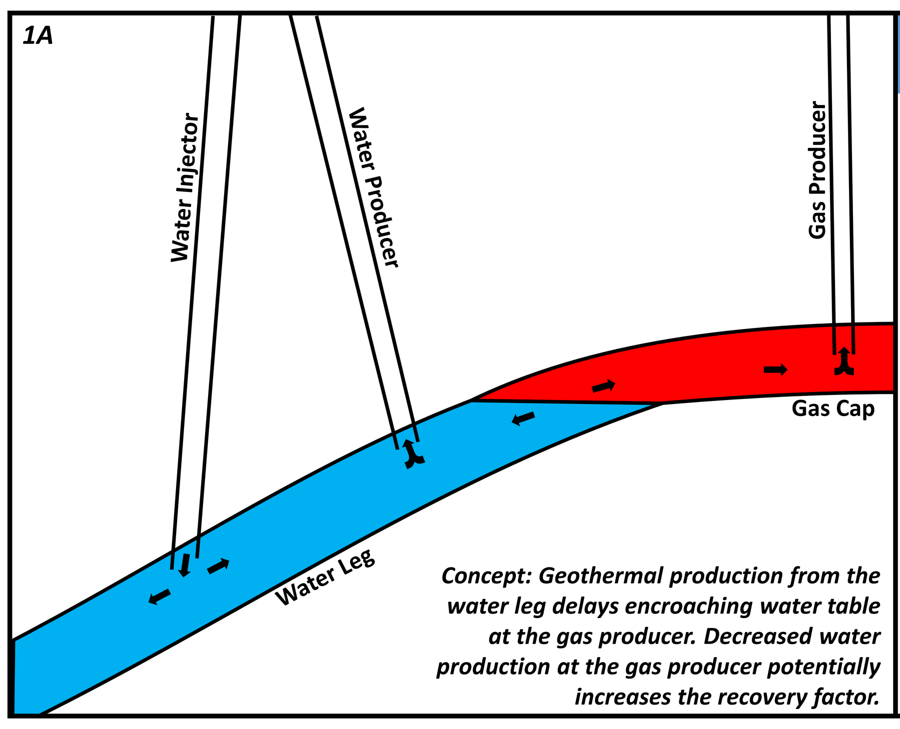
innovation for life

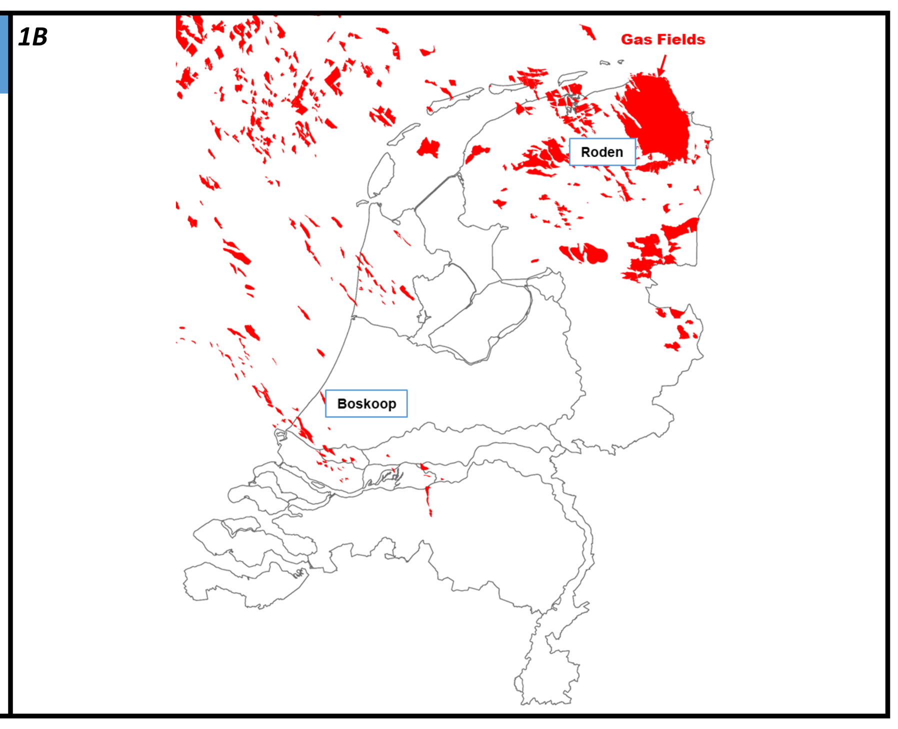


INTRODUCTION

- Interference between **gas- and geothermal production** can occur when hydraulic connection exists.
- Clever placing of the geothermal wells with regard to the producing gas well(s) can potentially create **synergy** between geothermal- and gas production (figure 1A).
- This synergy can be an **opportunity to enhance natural gas production** while providing **financial benefits for the development of geothermal systems**.

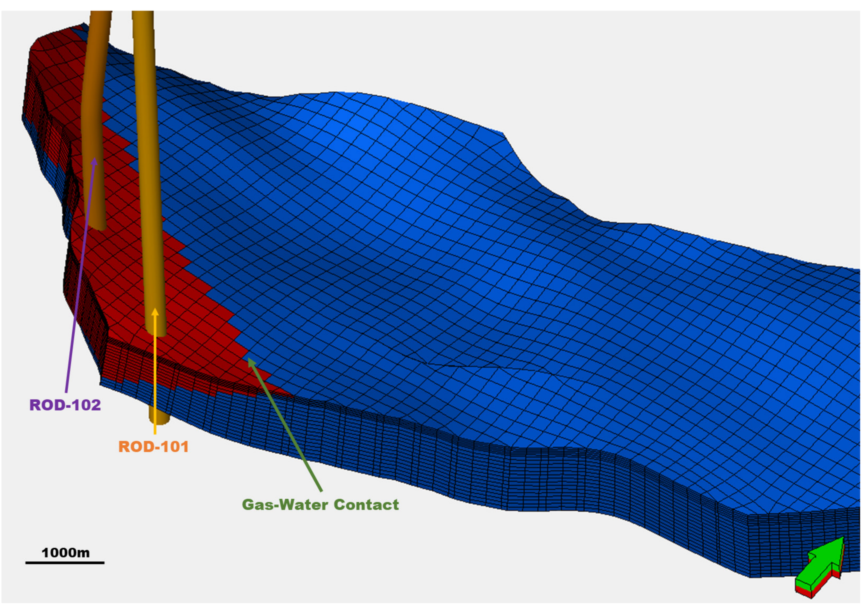
- **Research question**: What are the **critical elements** for synergy?

- Two case studies looked into potential synergy at the **Roden** and **Boskoop** gas fields (figure 1B).
  - A first order approach reservoir model of the **Rotliegend reservoir** of each field was constructed.
  - Numerous parameters are tested, including **well placement**, **flow rate** and **aquifer strength**.

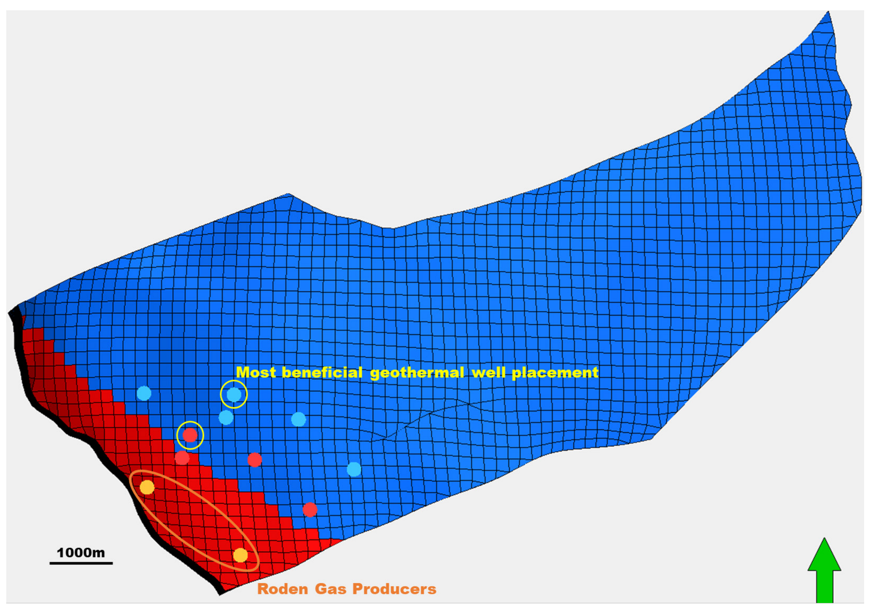


CASE STUDY #1: RODEN

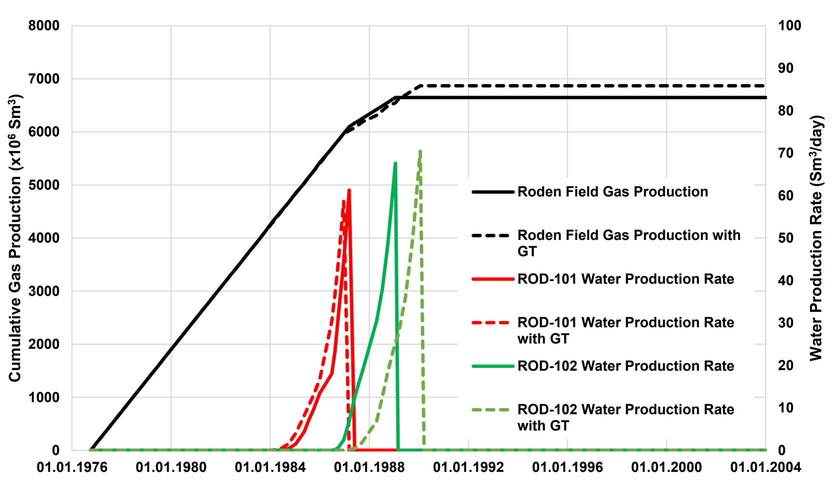
- Produced 6.5 BCM from Ten Boer (2m net) and Slochteren (135m net) reservoir.
- Both wells ROD-101 and -102 watered out, final production in 2002.



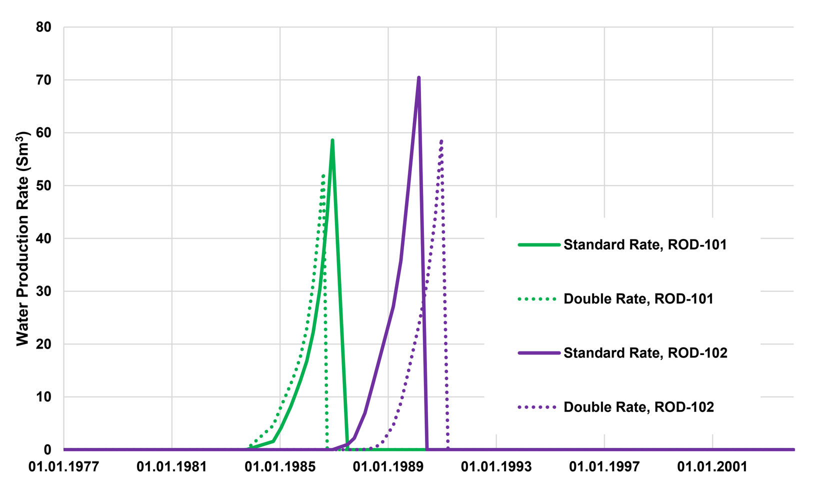
2A: 3D reservoir model of Roden Main Faultblock.



2B: Multiple tested well-configurations. Yellow encircled well-configuration shows 3.3% recovery factor increase.



***2C:** Gas production & water production rate with & without a geothermal doublet (leading to a 3.3% recovery factor increase).*



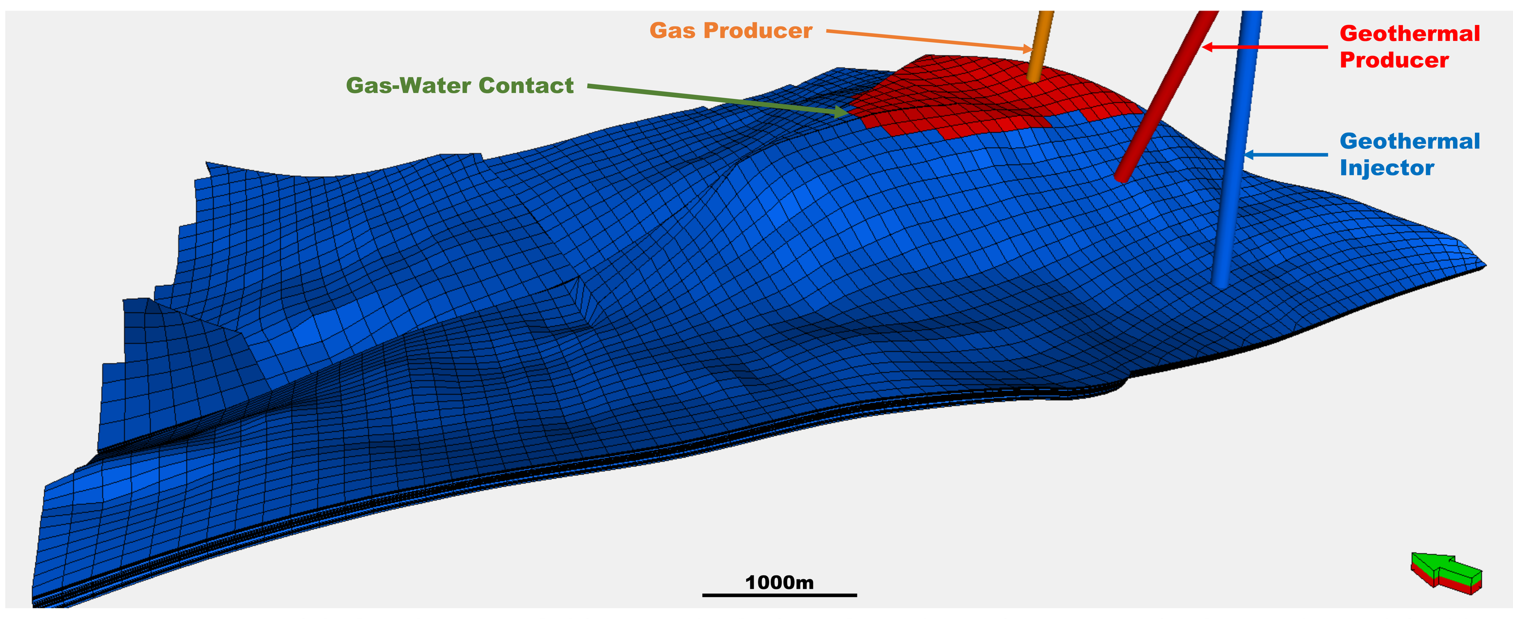
***2D:** Water production rates with standard geothermal flowrate (2875 Sm^3/day) and double geothermal flowrate (5750 Sm^3/day).*

Scenario	Cumulative Gas Production in January 2004					
	ROD-101		ROD-102		Roden Field	
	x10^9 Sm^3	%	x10^9 Sm^3	%	x10^9 Sm^3	%
Base Case	3.049	100.0	3.597	100.0	6.646	100.0
Parallel GT Producer & Injector	3.259	106.9	3.214	89.3	6.473	97.4
Parallel GT Injector & Producer	2.780	91.2	4.038	112.3	6.817	102.6
Perpendicular GT closest to ROD-102 (Figure 2C)	2.980	97.8	3.888	108.1	6.868	103.3
Perpendicular GT closest to ROD-101	3.160	103.7	3.401	94.5	6.561	98.7
Perpendicular GT between ROD-101 & -102	3.105	101.8	3.588	99.8	6.693	100.7
Perpendicular GT at GWC closest to ROD-102	2.922	95.8	3.798	105.6	6.720	101.1
GT Injector furthest from ROD-101	3.160	103.6	3.582	99.6	6.742	101.4
Two Doublets	3.107	101.9	3.677	102.2	6.783	102.1
GT Flowrate doubled (5750 Sm^3/day) (Figure 2D)	2.882	94.5	4.156	115.5	7.038	105.9
Start GT at water breakthrough ROD gas producers	3.049	100.0	3.676	102.2	6.673	101.2

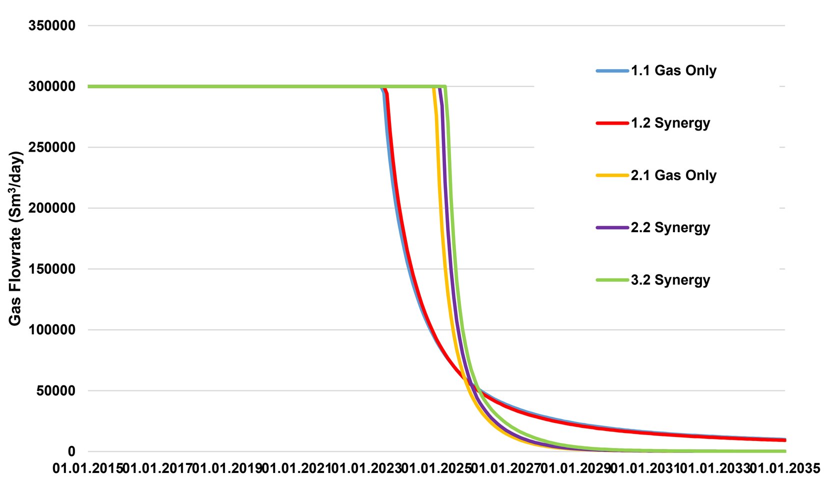
***Results:** Cumulative gas production for each tested scenario. Gas production rate 300k Sm^3/day, but depending on BHP & water influx. "Perpendicular GT closest to ROD-102" well configuration used to test impact flow rate & timing.*

CASE STUDY #2: BOSKOOP

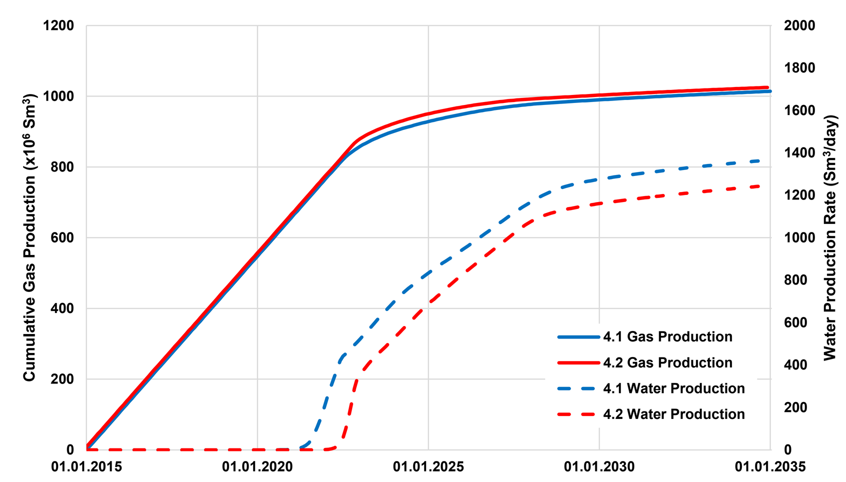
- Gas discovered in 1995, but deemed uneconomical: stranded field.
- Volpriehausen residual gas, Slochteren gas-bearing (50m net).
- Located close to future heat grid



***3A:** 3D reservoir model of Boskoop gas field. Using the findings from the Roden case study, the geothermal doublet was placed perpendicular with respect to the gas producer.*



***3B:** Gas production rates for each scenario as listed in the table below.*



***3C:** Gas production & water production rate with & without a geothermal doublet having strong aquifer support (Case 4).*

Scenario		Doublet Rate (Sm^3/day)	Avg. Perm. (mD)	Cum. Gas Production (x10^3 Sm^3)	%
1. Boskoop reservoir properties	1.1 Gas Only	-	9.8	1,111,129	100.00
	1.2 Synergy	800	9.8	1,113,232	100.19
2. Increased Permeability	2.1 Gas Only	-	90	1,148,457	100.00
	2.2 Synergy	800	90	1,147,885	99.95
3. Increased Permeability + Increased Doublet Rate	3.2 Synergy	2400	90	1,147,815	99.94
4. Increased Permeability with strong aquifer support (Figure 3C)	4.1 Gas Only	-	90	689,838	100.00
	4.2 Synergy	800	90	828,673	120.13

***Results:** Cumulative gas production for each tested scenario. Gas production rate 300k Sm^3/day, but depending on BHP & water influx. Increased aquifer support does increase magnitude of recovery factor increase, but also leads to earlier water breakthrough. Case 4 Cum. Gas Production was picked with max limit of water production rate of 100 Sm^3/day. Higher water production rates yield lower recovery factor increases (500 Sm^3/day ≈ 8% recovery factor increase).*

CONCLUSIONS

- The two case studies demonstrate it is possible to (significantly) **increase the recovery factor**.
- Addition of a geothermal doublet in the water leg of a gas field provides **potential benefits** for development of a gas field (**increase field life**) and a geothermal system (**reduced financial risk**).
- **Aquifer strength** is the **main critical element** for synergy to be beneficial.
- **Well placement** and **geothermal flow rate** are lesser critical elements.
- Beneficial synergy can still be achieved at **later stages of natural gas production**.

FUTURE RESEARCH

- **Refinement** of the static (grid size) and dynamic (time step) reservoir models.
- Test impact of **permeability thickness**.
- Introduce **heterogeneous** reservoir property distribution.
- Test **optimum flow rates** for gas- and geothermal wells.
- Test **optimum** geothermal production well **placement** and independently geothermal injection well **placement**.
- Find **optimum flow rates** in combination with **optimum well placement**.