# Public progress report year 2

**Project title:** DRAG Reduction in Geothermal & District Heating systems to LOWer Investment and Operational Costs - **DRAGLOW**

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## Background

The energy transition required to reduce CO2 emissions presents technical and public challenges, one of which is the need to replace natural gas heating with a low carbon heat supply. Integrated low-enthalpy geothermal and district heating is a proven concept that can deliver low-carbon heat to the built environment, but major investments in new infrastructure with low returns are required. The use of Drag Reducing Agents (DRA's) can significantly reduce flow resistance in pipelines, allowing smaller pipe diameters, lower pumping power, and reduced heat loss in the network, thereby reducing CAPEX and OPEX. This will improve the economics and reduce risks of investments in infrastructure for sustainable geothermal heat production and heat/cooling distribution for industrial regions and urban built environment.

## Goal

The DRAGLOW project aims to assess the techno-economic viability of drag reducing agents (DRA's) for geothermal wells and district heating networks. The project focuses on developing technical knowledge by assessing DRAs at relevant conditions to geothermal district heating and cooling (DHC) systems and integrate the knowledge in design, business case and techno-economic tools for cost-effective geothermal DHC systems in built environments. Preliminary analysis suggests that substantial cost reductions (20-30%) are feasible by controlling flow resistance using DRA's in district heating systems both operations and capital investment. This project can enhance the knowledge on the use of DRA in geothermal DHC systems, derisk various factor which will impact the performance and reliability of these systems and accelerated the development of cost-effective geothermal DHC systems.

## Partners

The project partners cover the whole supply chain in the district heating and geothermal sector.

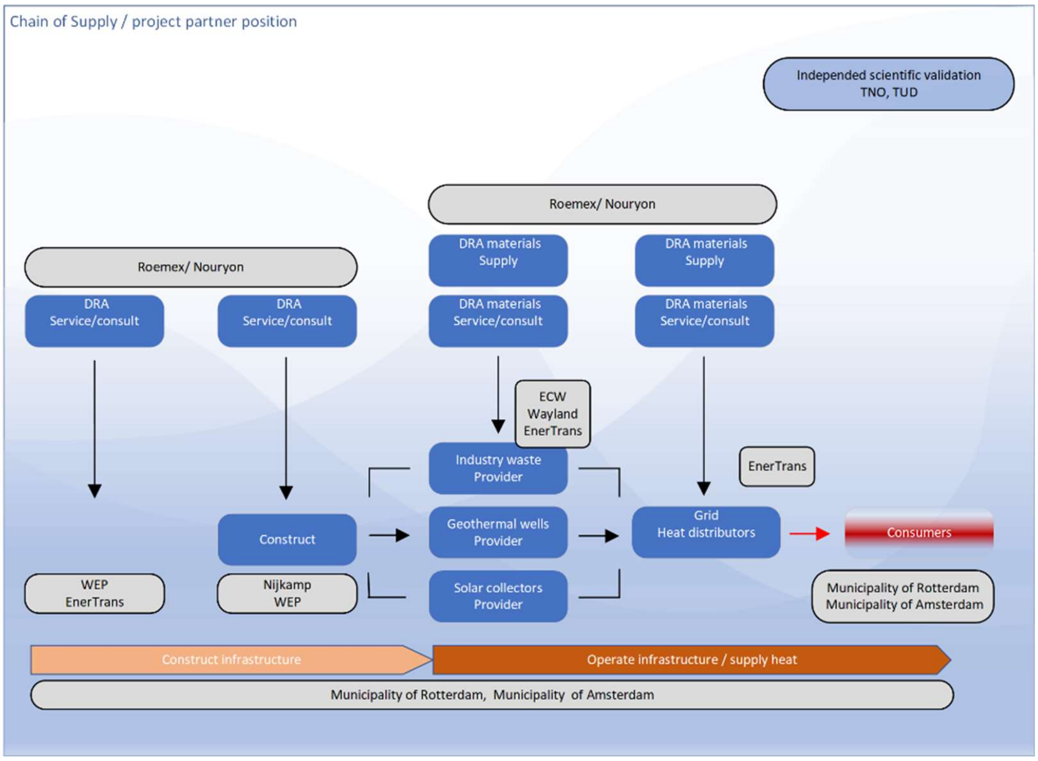

*Figure 1 – Project partner position in the supply chain.*

A list of the partners and their role in the project is given below.

**ECW**: End user, geothermal producer greenhouse grid operator, expert system & operational requirements, provide production and system design, geophysical production data. Co define experimental research program.
**Wayland Energy**: End user, geothermal producer greenhouse grid operator, expert system & operational requirements, provide operational data. Co define experimental research program.
**Gemeente Rotterdam**: Contribute with expertise public project requirements, regulation procedures, development frame work regional projects. Knowledge share
**Gemeente Amsterdam**: Contribute with expertise public project requirements, regulation procedures, development frame work regional projects. Knowledge share
**EnerTrans**: District heat system developer, end user, heat producer, grid operator, distributor. Consultant development of district heat project. Developer of DH system design models and engineering assessment models.
**Well Engineering Partners**: Expert design & engineering of geothermal wells, provide design expertise contribute to well design model development, engineering and geo-physical design data.
**Nijkamp Aanneming**: Expert engineering of district grid construction, provide test materials and co define experimental research program
**Roemex** Ltd: Supplier of DRA products, expert consult chemical for petrochemical and geothermal operations, operational requirements, international standards and regulations. Conduct detailed supplement laboratory measurement.
**Nouryon**: Supplier of basic DRA products, expert consult DRA (organic) polymers and surfactants, detailed measurements in lab analytical instruments, twin flow tests, test materials,.
**TU Delft**: Research organization. Basic research (post doc) and experiments to investigate DRA reservoir compatibility.
**TNO**: Research organization, Penvoerder: Project coordinator Experimental research investigate DRA performance for district heat and geothermal systems in large scale flow loop(s).
**KEMIRA** (this company is newly joined the consortium)**:** Kemira is a global leader in sustainable chemical solutions for water intensive industries. As a leading manufacturer of premium

polyacrylamide polymers, we understand how critical the choice of chemicals is to the overall success of an operation. Our strong R&D capabilities ensure that the appropriate polymer properties are captured for optimal performance, considering the operating environment and process conditions. Kemira brings broad experience and know-how on developing and using high-performing polymeric friction reducers that provide economic, environmental and operational benefits for geothermal or energy district systems. Kemira provides support for laboratory measurements; products stability in desired temperature and salinity, core flooding testing protocol, and interpretation of results.

## Performed activities, obtained results and foreseen applications

### Result1 - DRA material selection

Result 1 has been successfully finalized. A detailed list of system requirements for both geothermal and DHC systems were collected and an extensive number of DRA were pre-selected for characterization and stability tests. From the extensive testing protocols which were performed, 5 environmentally friendly DRA were identified to be further tested in the project. The outcome of the work was summarized in a project report and it was presented in the European Drag Reduction and Flow Control conference 2022.
For more details, please refer to the attached report of Result1 which has been shared with RVO via email to 'Berg, B.C.H. van den (Bart)' Bart.vandenBerg@rvo.nl and 'E-Innovatie' e-innovatie@rvo.nl on 09-02-2023.

### Result2 - DRA performance assessment in the heat production and transport system

The goal of Result 2 is to assess the performance of DRA in turbulent pipe flows which are representative for production-injection casing of geothermal doublets and heat transport pipelines in the DHC systems. To conduct the tests in DRAGLOW project, a High Temperature – High Salinity (HTS) flow loop has been designed and constructed at TNO's "Rijswijk Centre for Sustainable Geo-energy" (RCSG)[1]. A schematic of this HTS flowloop is presented in Figure 2. The loop consists of two tanks connected to a loop with a total length of 40 meters and an internal diameter of 5 and 2.5 cm. Water or brine flows through the loop driven by a centrifugal pump or by using pressurized air to flow from tank to tank. The pressure drop is then measured at 4 locations in the loop to assess the flow development and impact of the pump and bend on the drag reduction. The temperatures and flow velocities at which measurements can be performed are based on an inventory of district heating systems and geothermal wells and are summarized in Table 1.

*Table 1 - Possible conditions in the HTS flow loop.*

| Parameter | Range in flow loop |
|---|---|
| Temperature (°C) | 20-115 |
| Pressure (bar) | 1-10 bar |
| Flow velocity (m/s) | 0.5-4.0 |
| Salinity (% by weight) | 0-30 |

The status of the measurement up to now, in scope of the DRAGLOW project the drag reduction performance of three surfactants was evaluated at different temperatures and flow rates for tap water (which closely resembles the water in a district heating network). These are two cationic surfactants (DRA #1 and #2), and a specially designed zwitterionic surfactant (DRA #12), which is biodegradable.

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[1] After considering all available equipment at TNO RCSG, and requirements of DRAGLOW project, TNO decided to invest in a durable equipment for such extensive temperature and salinity ranges in geothermal industry to make them usable for future developments and technology testing at RCSG. HTS flowloop is commissioned recently and DRAGLOW team is using this new set-up to conduct the tests.

DRA #1 and #12 have been selected in Result1 for their chemical and thermal stability, whereas DRA #2 has been used frequently in the literature on drag reduction and is used as a reference DRA.

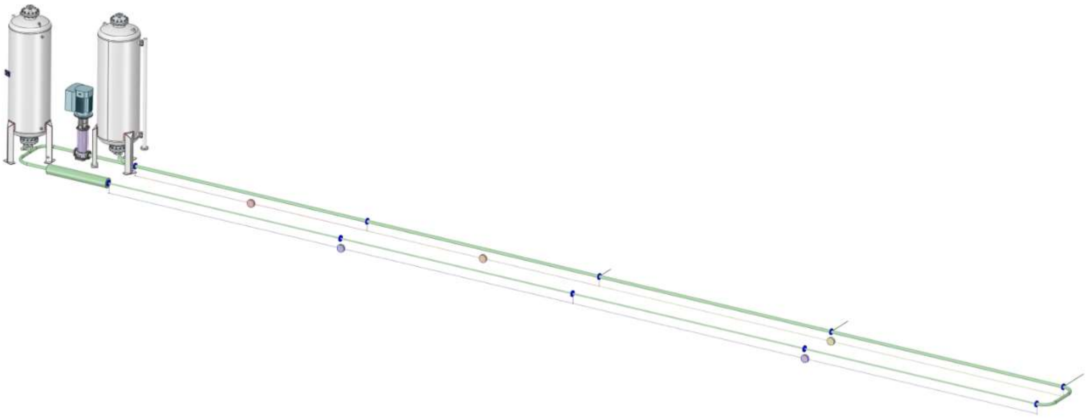


*Figure 2 – Schematic of the HTS flow loop located at TNO Rijswijk.*

Figure 3 shows the drag reduction performance as a function of flow velocity in a 2” pipe for DRA #1 (red triangles, 1000 ppm @ 40 °C), DRA #2 (blue circles, 2000 ppm @ 40 °C) and DRA #12 (green squares, 2000 ppm @ 80 °C). Figure 4 shows the drag reduction performance as a function of temperature at a flow of 1.6 m/s in a 2” pipe for DRA #1 (red line, 1000 ppm), DRA #2 (blue line, 2000 ppm) and DRA #12 (green line, 2000 ppm). These results show that the DRAs are able to reduce the drag up to about 80%, which is very significant and close to the best results obtained in literature. The actual drag reduction depends on the temperature, flow velocity and concentration of the DRA, which is DRA type dependent.

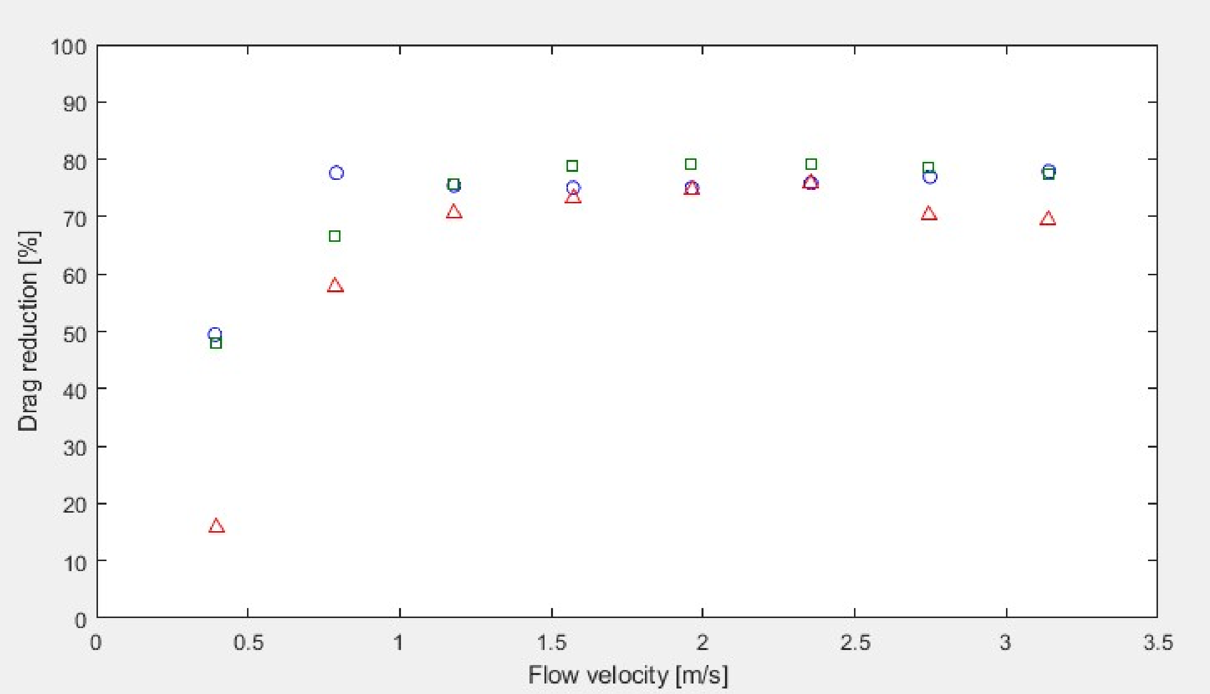


*Figure 3 – drag reduction performance as a function of flow velocity in a 2” pipe for DRA #1 (red triangles, 2000 ppm @ 40 °C), DRA #2 (blue circles, 1000 ppm @ 40 °C) and DRA #12 (green squares, 2000 ppm @ 80 °C).*

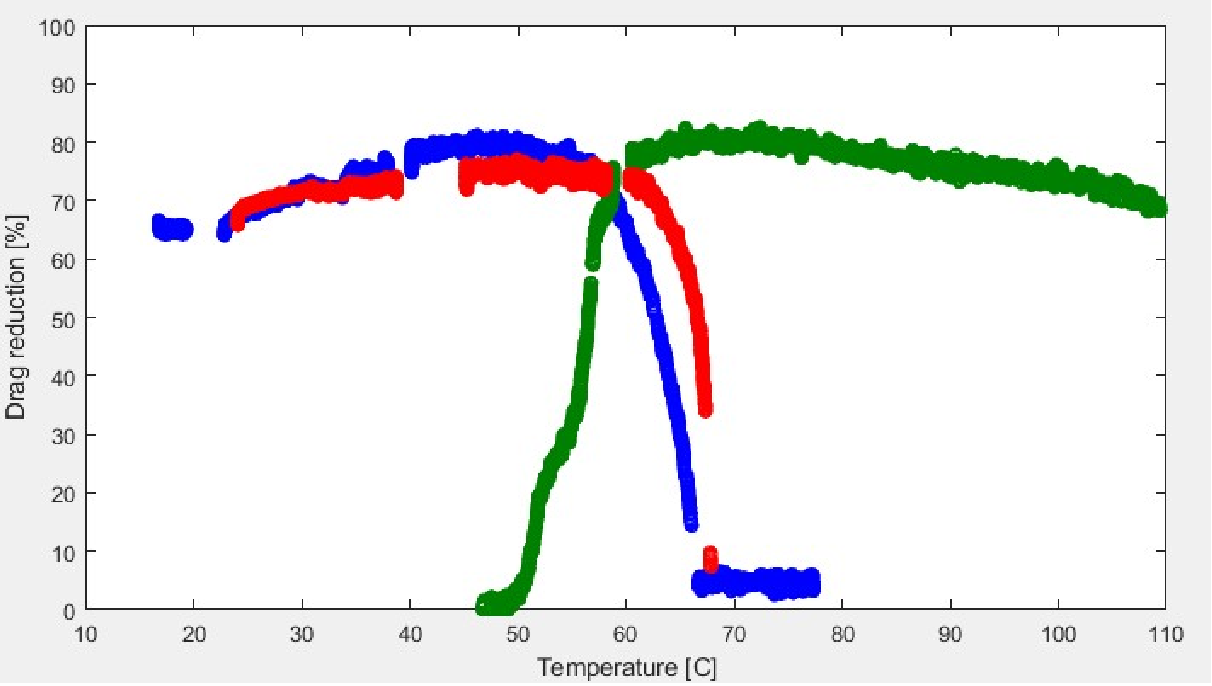


*Figure 4 – drag reduction performance as a function of temperature at a flow of 1.6 m/s in a 2" pipe for DRA #1 (red line, 2000 ppm), DRA #2 (blue line, 1000 ppm) and DRA #12 (green line, 2000 ppm).*

Table 2 gives an indication of the qualitative performance of the DRAs tested for various concentrations.

*Table 2 - qualitative performance of the DRAs tested for various concentrations in tap water. DRA names were anonymized*

| DRA | Concentration | Remark |
|---|---|---|
| #1 | 1000 ppm | No drag reduction observed |
| | 2000 ppm | Drag reduction up to about 60 °C |
| | 4000 ppm | Drag reduction up to about 70 °C |
| #2 | 100 ppm | Drag reduction up to about 50 °C, at low flow velocities |
| | 1000 ppm | Drag reduction up to about 65 °C |
| #12 | 500 ppm | Drag reduction above 90 °C |
| | 1000 ppm | Drag reduction above 70 °C |
| | 2000 ppm | Drag reduction above 60 °C |

In the HTS flow loop it is possible to evaluate the drag reducing agents at the relevant temperatures and at the relevant water chemistry. If a specific new chemical is being considered to tailor to specific needs in terms of operations (i.e. flow rate and/or temperature range) and water chemistry, or the compatibility of the DRA with specific filters or heat exchangers needs to be known this can be tested in the loop.

The current measurements at HTS loop will be performed at 1"and 2" lines. In order to establish scaling rules for larger diameters, a set of experiments in a different setup in Delft was performed at various pipe diameter from 1" to 6". A separate report was made for these tests which can be found in the attachment 1.

## Result3 - The effect of DRA's on well injectivity

### Activity 3.1. Critical review of existing models for the transport of DRAs in porous media (D1)

We have conducted a critical review of the existing models and numerical simulation tools for modeling the transport of DRAs by flow through porous media. We found that that few models have been specifically developed for the transport of surfactants and polymers by flow through porous medial, especially at the high flow rate regimes prevalent during DRA injection, at the near-wellbore conditions. Under these flow regimes, the polymers undergo a coil-to-stretch transition and bridging adsorption as opposed to layer adsorption at low flow rates (Zitha et al., 2001).

Viscoelastic surfactants used as DRAs on the other hand can be modelled by the same approach as polymers. However, in this case we expect the micellar structures to be destroyed by strong flows and to be reestablished at weak flows (low shear). For this reason the surfactant will have little impact on injectivity and we have decided to focus the rest of the modelling study on polymers.

Most of the tools used for modeling polymer flow through porous-media were developed in the context of the oil industry and more specifically for polymer flooding. This technique consists in the injection of polymer solution into an oil reservoir to reduce the mobility ratio between injected water and reservoir oil thus improving reservoir sweep efficiency. The increased viscosity of the polymer solution is achieved at the cost of reduced injectivity.

Predicting the injectivity as accurately as possible requires a fairly detailed description of polymer flow in porous media taking into account polymer retention, i.e. adsorption, mechanical entrapment and polymer rheology. Since the polymers proposed as DRA agents are like those used in polymer flooding applications based on polyacrylamide (PAM) or partially hydrolyzed polyacrylamide (HPAM) below we focus on these materials. Commercial reservoir simulators such as ECLIPSE, Schlumberger (https://www.software.slb.com/products/eclipse) and CMG IMEX (https://www.cmgl.ca/imex) use an heuristic polymer model which does not account for the injectivity. Hence robust research simulators where dynamic retention effects at strong flows can be incorporated are critically needed.

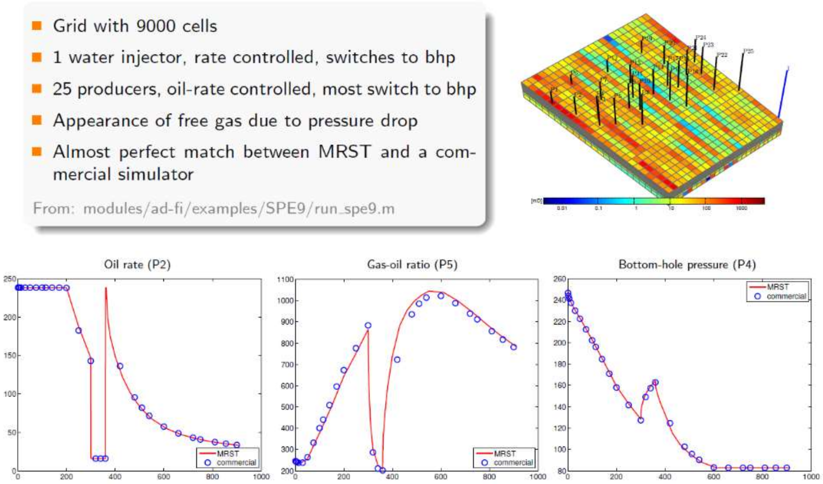
One of the most commonly used research simulators is the UTCHEM simulator (https://csee.engr.utexas.edu/research/industrial-affiliate-programs/chemical-enhanced-oil-recovery/ut-chem-simulator) developed at the University of Texas at Austin. UTCHEM is a multicomponent, multiphase, three-dimensional chemical compositional reservoir simulation model. The flow and transport equations are as follows:

- A mass conservation equation for each chemical species
- An overall mass conservation equation that yields a pressure equation when combined with a generalized Darcy's law
- An energy conservation equation

Another research simulator that has been used for simulation of geothermal reservoirs is DARTS which was developed at the TU Delft (https://darts.citg.tudelft.nl/). DARTS is an advanced the simulation framework is based on the recently proposed Operator-Based Linearization (OBL) approach, which helps to decouple the complex nonlinear physics and advanced unstructured discretization from the core simulation engine. The framework is targeting the solution of forward and inverse problems.

A third research simulator MRST was developed by SINTEFF

(https://www.sintef.no/projectweb/mrst/). MRST offers a rather comprehensive black-oil and compositional reservoir simulators capable of simulating industry-standard models and also contains graphical user interfaces for post-processing simulation results. However, similar to MATLAB, MRST is not primarily a simulator, but instead it is developed as a research tool for rapid prototyping and demonstration of new simulation methods and modeling concepts. It offers a wide range of data structures and computational methods that can easily be combined to develop custom-made modelling and simulation tools. Figure 5 illustrates the application of MRST to a water flooding problem.



- Grid with 9000 cells
- 1 water injector, rate controlled, switches to bhp
- 25 producers, oil-rate controlled, most switch to bhp
- Appearance of free gas due to pressure drop
- Almost perfect match between MRST and a commercial simulator

From: modules/ad-fi/examples/SPE9/run_spe9.m

*Figure 5 – example of a simulation using MRST and comparison with a commercial simulator.*

Considering the interplay between physical-chemical properties of DRAs and properties of prototypical clastic formations found in the Dutch geothermal fields and the maturity of the software it was decided to proceed with MRST.

### Activity 3.2: Phenomenological modelling of the transport of DRAs

None of the simulators discussed above can directly be applied for the modeling of polymer flow in porous media since they miss the coupling of rheological effects at high flow rates with retention. For this reason we propose improved model where these effects are taken into account.

We consider flow regimes where layer adsorption of undeformed polymer molecules (weak flows) and bridging adsorption of stretched ones (strong flows) occur either separately or simultaneously. The model for polymer transport taking into account these effects consists of a system of partial differential equations, describing respectively polymer mass conservation for the layer and bridging adsorption fractions, layer and bridging adsorption kinetics and the Darcy's law.

The system of equations is treated analytically to gain insight into the behavior of the concentrations of deformed and undeformed polymers and polymer and the resulting permeability reduction. We found that, in the case of simultaneous layer and bridging adsorption, the concentration profile seem to exhibit an unusual superposition of traveling waves, consistent with a slower propagation of the bridging adsorption wave with respect to the layer adsorption one. This shows that flow induces a separation of short and long chains.

### Activity 3.3: Core-flood testing of DRAs transport in porous media

A standard core-flood test rig and protocols were used to test the adsorption and the injectivity of surfactants and polymers in porous media. The chemicals were the 5 candidates selected in Result 2 for further testing. The cores were made of Bentheimer sandstone a relatively clean outcrop which is a good representative of sandstone reservoirs in the Netherlands.

The measured adsorption levels at week flow for all polymer tested are consistent with those reported in the literature for similar type of polyacrylamide based polymers. This suggest that the modification of the polyacrylamide to ensure high thermal stability did not affect the polymer-rock interactions.

At strong flows however a certain polymers showed only a slight increase in flow resistance whereas other showed a continuously increasing pressure drop most probably due to the bridging adsorption. Because the bridging adsorption results from the interplay between rheology (polymer molecule stretching) and adsorption, it seems that for the polymers showing only a slight increase in flow resistance, adsorption is weak. This will be tested more extended duration injectivity experiments.

**Activity 3.4: Numerical modelling and history-matching of the core-flood tests**

This activity started recently and is ongoing now. No tangible results to show yet.

**Activity 3.5: Near-wellbore reservoir simulation of the injection of geothermal water containing the DRA (D5)**

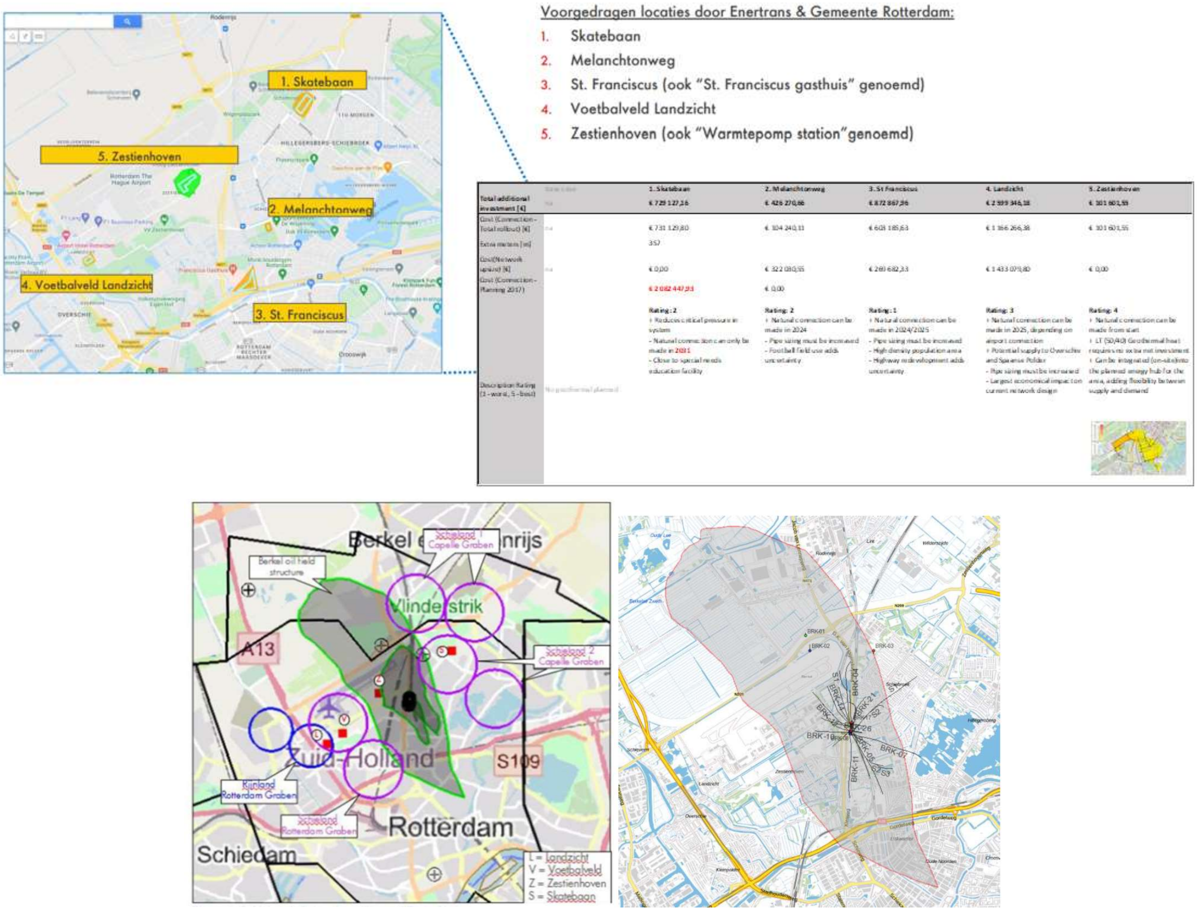
We are in the process of collecting the required data to construct a geologically realistic near-wellbore reservoir models. We plan to start the numerical simulations after gathering the required data.

## Result4 - Simulation models, DRA parameter implementation

To start with the Baseline Schiebroek project model we have finalised and validated this model on numerous datasets provided by the municipality, housing corporations and public available databases. We have an full detailed dynamic supply and demand model available. A flexible source, supply and demand model is the result.

The base model is developed and made capable of implementing different fluid dynamics for assessing the DRA results and determine the effects on the flowrates, pipe size diameters. This function developed, within this project, has been made by Schneider Electric available for worldwide usage by license owners of the Termis (Eco Struxure) users.

Within the model and the physical area we have defined and assessed the possible Geothermal well locations based on both surface and subsurface classifications.



Voorgedragen locaties door Enertrans & Gemeente Rotterdam:

1. Skatebaan
2. Melanchtonweg
3. St. Franciscus (ook "St. Franciscus gasthuis" genoemd)
4. Voetbalveld Landzicht
5. Zestienhoven (ook "Warmtepomp station"genoemd)

| Total additional investment [€] | [illegible] | 1. Skatebaan<br>€ 729 127,26 | 2. Melanchtonweg<br>€ 426 270,66 | 3. St Franciscus<br>€ 872 867,96 | 4. Landzicht<br>€ 2 599 346,18 | 5. Zestienhoven<br>€ 101 601,55 |
|---|---|---|---|---|---|---|
| Cost (Connection - Total rollout) [€] | n/a | € 731 129,80 | € 104 240,11 | € 608 185,63 | € 1 166 266,38 | € 101 601,55 |
| Extra meters [m] | | 357 | | | | |
| Cost(Network upsize) [€] | n/a | € 0,00 | € 322 030,55 | € 260 682,33 | € 1 433 079,80 | € 0,00 |
| Cost (Connection - Planning 2017) | | € 2 082 447,93 | € 0,00 | | | |
| Description Rating (1 - worst, 5 - best) | No geothermal planned | **Rating: 2**<br>+ Reduces critical pressure in system<br>- Natural connection can only be made in 2031<br>- Close to special needs education facility | **Rating: 2**<br>+ Natural connection can be made in 2024<br>- Pipe sizing must be increased<br>- Football field use adds uncertainty | **Rating: 1**<br>+ Natural connection can be made in 2024/2025<br>- Pipe sizing must be increased<br>- High density population area<br>- Highway redevelopment adds uncertainty | **Rating: 3**<br>+ Natural connection can be made in 2025, depending on airport connection<br>+ Potential supply to Overschie and Spaanse Polder<br>- Pipe sizing must be increased<br>- Largest economical impact on current network design | **Rating: 4**<br>+ Natural connection can be made from start<br>+ LT (50/40) Geothermal heat requires no extra net investment<br>+ Can be integrated (on-site) into the planned energy hub for the area, adding flexibility between supply and demand |

*Figure 6 – Schematic of baseline project and developed model*

‘To implement and assess the geothermal well reference data we were waiting for ECW to provide data. Due to Internal issues within ECW (merge) there is a delay with providing data by them. To limit the risk of delaying the result progress we have agreed within the result to switch to another reference dataset provided by WEP. This process is started now and in execution. We are expecting to reduce the delay to a minimum of 1 or 2 months. The flowloop model as developed and set up is implemented within the Termis model and fully operational. DRA testing results and characteristics can be implemented and assessed in the model.

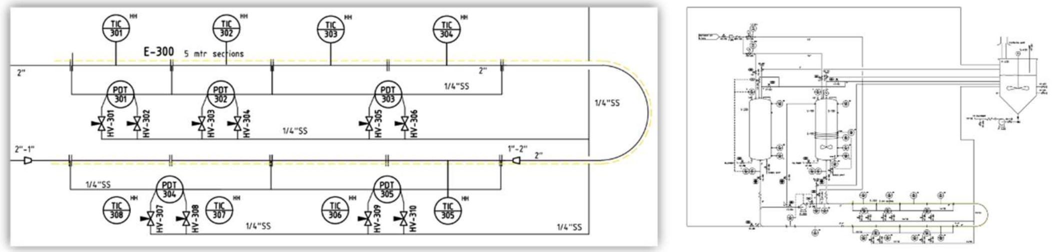


*Figure 7 –flowloop model*

## Result5 – Pilots, roadmap for implementation

An initial risk registry for the implementation of the DRA in geothermal and DHC systems were made by ECW as part of activity 5.1. There are still some gaps in filling the information with respect to the operational practices and constraints which will be progressed in the next few months[2].

| category | Risk ID | Risk Title (event) | Risk Description | TECOP | Risk mitigation action | Risk owner | Risk Status |
|---|---|---|---|---|---|---|---|
| | R-1 | more corrosion | as a result of mixing pure DRA with pure CI downhole, CI might loose its property, leading to corrosion | | | | |
| | R-2 | less friction reduction | as a result of mixing pure DRA with pure CI downhole, DRA might loose its property, leading to reduced DRA effect | | | | |
| | R-3 | Incompatibility of pure DRA with pure Corrosion Inhibitor | as a result of mixing pure DRA with pure CI downhole, Gunking might occur, leading to blockages | | | | |
| | R-4 | high friction in capillary line | as a result of mixing pure DRA with pure CI downhole, high viscosity might occur, leading to high injection pressure in capillary line | | | | |
| | R-5 | less friction reduction | due to mechanical shear in the ESP downhole, the DRA might be degradated , leading to ineffective DRA property | | | | |
| | R-6 | sand/solids build-up in separator | as a result of the DRA sand consolidation could occur, leading to insufficient sand/solids removal and therefore build-up of sand/solids in the separator | | | | |
| | R-7 | gas drying inefficiency | As a result foaming due to the DRA in the separator, liquid carry-over to the gasdryer could occur, which could lead to inefficient gas drying | | | | |
| | R-8 | less friction reduction | as a result of the centrifugal boosterpump, the DRA could be degraded mechanically and could lead to ineffective DRA property | | | | |
| | R-9 | reduced time between (warm) filter change-outs | due to the presence of DRA, the bag or/and cartridge filters might be blocked more frequent, resulting in shorter time between filter change-outs (1, 5, 10 micron) | | | | |
| | R-10 | reduced heat transfer and blockages in heat exchangers | due to the presence of DRA, fouling might occur in the heat exchangers, which could result in reduced hear transfer and eventually blockages | | | | |
| | R-11 | reduced time between (cold) filter change-outs | due to the presence of DRA, the cartridge filters might be blocked more frequent, resulting in shorter time between filter change-outs ( 1 micron) | | | | |
| | R-12 | less friction reduction | as a result of the centrifugal injectionpump, the DRA could be degraded mechanically and could lead to ineffective DRA property | | | | |
| | R-13 | more corrosion | due to the presence of diluted DRA in the system, the corrosion inhibitor might be less effective, which could result in more corrosion | | | | |
| | R-14 | injectivity decline | due to long-term injection of the DRA chemical, impairment could occur in the reservoir during injection, which could lead to injectivity decline | | | | |
| | R-15 | no injection of DRA | if the DRA chemical is not allowed by the authorities via the permit | | | | |
| | R-16 | lumps (fisheyes) in DRA, leading to blockages | if applicabale: when the DRA is not dissolved properly, lumps (fisheyes) could be present which could lead to blockages in the system | | | | |
| | R-17 | less friction reduction | when the supply of DRA chemical is not sufficient, less friction reduction can be encountered | | | | |
| | R-18 | less friction reduction | when the price of the DRA chemical is to high to support the required friction reduction | | | | |
| | R-19 | less friction reduction or blockages | onsite quality control is required of incoming DRA chemical to check its property (shelf-life!) | | | | |
| | R-20 | less friction reduction | chemical DRA injection skid failure | | | | |
| | R-21 | less friction reduction or blockages | lack of organizational recourses and expertise | | | | |
| | R-22 | less friction reduction or blockages | when mixing the DRA with the Geowater a full compatibility check is required | | | | |
| | R-23 | Inconclusive result of the friction reduction | friction reduction should be measurable in the facilities | | | | |
| | R-24 | vacuum injection well | could the DRA friction reduction result in vacuum injection and what would be the impact of this? | | | | |

*Figure 8 – Initial risk registry for geothermal plants (sample)*

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[2] Based on the plan this result should start in Q3 2023.

**Result6 – Techno-economic benefits of applying DRA**

Gathering and assessing the techno-economic benefits of the usage of DRA's within both geothermal wells and district heating grids resulted in 7 different financial models. Most of the models are related to the district heating and supply part of the whole system, as expected. All models are more or less equal to each other. Objective and results are similar although they vary on detail with regards to their main purpose and funding demand.

Assumption of the project team was that implementing both the geothermal well and the district heating should visualize possible sub-optimalisations in either the well operations or grid operations. Simulations did result in sub optimalisations for now. Extend simulations will be executed in the next period. For now it is not expected that both financial models should necessarily be integrated with each other, but this is still in scope.

The project team has simplified the techno-economic benefits model as much as possible and is optimizing this for public usage via a web-based tool. Both models are ready for use and integration of DRA lab results. Exchange of data from the first results are scheduled and will we executed and updated in the next period.

## Contribution of the project to the goals of MOOI

The developments in the gas-free neighborhoods, i.e. aardgasvrije wijken, requires a significant transition from fossil-based heating systems to sustainable sources. Geothermal energy can play a significant role in the energy transition and is expected to grow rapidly in the coming years. The Masterplan Aardwarmte, a roadmap for the future of geothermal energy in the Netherlands, suggests that geothermal energy could grow to supply 5% of the total Dutch heat demand in 2030 and 22% of the total heat demand in 2050. However, in order to achieve these goals, the number of geothermal wells requires to grow to 175 in 2030, and 700 geothermal wells in 2050. Currently around 22 geothermal wells have been drilled, indicating a significant growth required to achieve these plans.

Additionally, it is expected that new DH systems will be developed in a near future to connect geothermal and other heat sources to dwellings. The cost effectiveness of geothermal energy deployment and sustainable heat transport with the current technologies is marginal, both on the capital and operational expenditure (CAPEX and OPEX). Currently the wells and heat network pipelines are installed with a relatively large diameter to deliver a higher flow rate and thermal power dictated by the heat demand. The cost and emission associated with the manufacturing, drilling, installing and operating current systems are crucial factors in further developments of sustainable heat supply and transport. Smaller diameter wells are cheaper to drill with a lower CO2 footprint considering the manufacturing and drilling process, approximately 15-20% cheaper than a conventional diameter well, and in the mindset of the 700 well target set for 2050 this could result in a CAPEX reduction of 500 million to 700 million euros.

However, production and transportation from smaller diameters pipelines to meet the same heat demand would require an enormous power for the pumps to supply and transport the thermal energy leading to a higher OPEX. An extensive infrastructure for the heat networks is required to be developed including kilometers of pipelines with several pumping stations. Additionally, power consumption by the pumps for the production and transport of the sustainable heat has a significant impact on the OPEX of these systems and needs to be optimized.

An integrated approach to reduce OPEX and CAPEX, defined as the integral cost, of geothermal heat production and distribution could accelerate the role of sustainability in meeting the heat demand. This project aims to provide a novel system solution for making the collective heat and cold supply more economically competitive as well as sustainable and improve spatial integration of DH systems. The focus of this project is on employing environmentally friendly drag reducing agents coupled with the system design to minimize the integral cost. The current project is envisioned to reach the following outcomes:

- Reduction of investment CAPEX (aim - 20% to 30%)
- Reduction of operational costs OPEX both (aim -15% to 30%)

- Provide fit-for-purpose solutions, including geothermal well and DH system with reduced diameters, by the product and service providers for the sustainable heat supply sector.
- Novel approaches for chemical injections aiming at cost reductions in the geothermal doubletsand DH systems.

## Publications

- Nimwegen, A.T., Jones, S., Fischer, H., Driessen, R., Shoeibi Omrani, P., "*The Characterization of drag reducing agents for application in low-enthalpy geothermal wells and district heating systems*", European drag reduction and flow control meeting, 2022
- Sian Jones, Ronald Driessen, Dries van Nimwegen, Pejman Shoeibi Omrani, Pacelli Zitha, *Drag Reducing Agents for Geothermal Applications*, Porous Media for a Green World: Energy & Climate at InterPore2023
- D. van Nimwegen, J. van 't Westende, H. Fischer, H. Pereboom, G. Heerens, P. Shoeibi Omrani(TNO), S. Jones, P. Zitha (TUDelft), H. Oskarsson, A. dos Santos (Nouryon), M. Hessampour (Kemira), P. Wilkie (Roemex), *DRAGLOW: Drag Reduction in Geothermal District Heating and Cooling Systems to lower investment and operational costs*, Geothermal Rising Conference 2023 (abstract submitted)

## Further information

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