

# Final report VISTA 2015

## **Project title: Upscaling of water-based EOR methods**

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Institution: NTNU / Sintef

Project duration: 1 October 2012 – 30 September 2015

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Project number: 6352

### **1. ½ A4 page with a popular presentation of the project (to be written by the scholar)**

This project is part of the research area of reservoir simulation, which in simplified terms is the use of computers to simulate the flow of oil, gas, water and other substances through a reservoir.

Creating a computer representation of an oil reservoir is difficult partly because of the wide range of physical scales. Whereas the flow through the rock takes place in tiny pores the size of a micro-meter, the distance between two wells can be more than a kilometer. To include all this information into a full size reservoir model is not even close to possible, and so the physical properties from the smallest sizes must be *upscaled* to larger sizes, which is a form of averaging the properties. A large part of this project has been considering upscaling of oil and water properties [2,5].

As many oil reservoirs today are mature, enhanced oil recovery has become increasingly important, where different techniques are used to increase the production. *Polymer* injection is one such technique, in which polymer is added to water and injected into the reservoir. Simulations including polymer have been studied in this project, and one of the issues considered is upscaling of polymer properties [1].

Another method of tackling the issue of scales is *multiscale methods*. In such methods, a solution is first estimated on a less detailed representation of the reservoir, which is fast to calculate. Then, this solution is projected onto a detailed reservoir representation. By repeatedly going back and forth between these two models during a simulation, one can obtain an accurate and detailed solution much faster than by just considering the detailed model. This project has included polymer into simulations using a recent multiscale method [3].

Also studied in this project is a specific physical property of polymer flow. Because the polymer molecules are relatively large, parts of the small pores in the oil reservoir are not accessible to the polymer, even though water and oil may be able to flow in this region. How to best create a mathematical model of this phenomenon has been studied in detail [4].

**2. Have there been any changes in the objective/goals during the project period? Did you achieve what was promised in the project description? (to be written by the scholar)**

The work performed in the project period has changed somewhat from the original project description, mainly due to new insight as the research progressed. Some topics of the description have been studied less, while some topics not in the original description have been worked on.

The main changes to the original project description are:

1. There have been more focus on two-phase upscaling than the project description suggested, resulting in two papers co-written with Carl Fredrik Berg in Statoil. This research topic has increased in volume partly because of expressed interest from researchers at Statoil.
2. The use of polymer in multiscale methods have been studied, resulting in a paper which is in review. This was not part of the original description. Multiscale methods are in some ways related to upscaling methods, and this work relates well to the overall topic of the project.
3. High-resolution schemes to model miscible flow were part of the original description, but have not been studied in this project.

**3. Publications (scholar)**

1. S. T. Hilden, K.A. Lie, X. Raynaud. Steady state upscaling of polymer flooding. ECMOR XIV, Catania, Sicily, Italy, 8-11 September 2014.
2. In review: S. T. Hilden, C. F. Berg. Rate dependency and upscaling of an unsteady flooding process, Transport in Porous Media.
3. In review: S. T. Hilden, O. Møyner, K.A. Lie, K. Bao - Multiscale Simulation of Polymer Flooding with Shear Effects, Journal of Computational Physics.
4. Unpublished: S. T. Hilden, H. M. Nilsen, X. Raynaud - A Well-Posed Model of Inaccessible Pore Volume for Polymer.
5. Unpublished: S. T. Hilden, C. F. Berg - Steady-State Two-Phase Upscaling of Realistic Field Models.

**4. Reflections on continuation of the project (to be written by the project director)**

There are several directions in which this project can be continued. For example:

- Extend the multiscale method to include other enhanced oil recovery methods,
- Include more polymer physics into the new simulation methods, e.g., hydrolysis, multi-component polymers, and salinity effects on polymer.