

# **NorTex Petroleum Cluster**

**– Large Scale Collaboration Emphasizing  
Mobility Control and CO<sub>2</sub> EOR in Field Pilots  
in Texas**

by

**Prof. Arne Graue**

**Dept. of Physics and Technology**

**University of Bergen, NORWAY**

# NorTex Petroleum Cluster

- ✓ Texas and Norway leading regions within petroleum research and education
- ✓ Common interests
- ✓ Complementary expertise
- ✓ Energy and Environment

<http://www.nortexpetroleum.org>

# **Petroleum research relations between Texas and Norway**

- 1. MoU between Rice University and Petroleum Research School of Norway**
- 2. MoU between UT Austin and Petroleum Research School of Norway**
- 3. MoU between UiS and U. of Houston**
- 4. MoU between NTNU and UT Austin**
- 5. Several research collaborations between universities in Norway and universities in Texas**
- 6. Statoil's support of UT Austin, with possible expansion**
- 7. Energy initiative E2I at Rice University in 2012**

# Research Partners:

## 4 Universities in Texas, USA

- Rice University, Houston, TX, USA
- University of Houston, Houston, TX, USA
- University of Texas at Austin, Austin, TX, USA
- Texas A&M University, College Station, TX, USA

## 4 Universities in Norway:

- University of Bergen, Bergen Norway
- University of Stavanger, Stavanger, Norway
- University of Oslo, Oslo, Norway
- NTNU, Trondheim, Norway

## Industry partners

- Statoil Petroleum ASA
- Schlumberger

# **International and Inter-institutional Collaboration**

- Work Force**
  - PhD students (400+)**
- Communication and Information**
  - Adjunct Profs. from Counterpart Country**
- Industry Challenges Exposed to Academia**
  - Industry lecturers**

# Nasjonal forskerskole i petroleumsfag (NFIP)

## Petroleum Research School of Norway

[www.NFiPweb.org](http://www.NFiPweb.org)

Prof. Arne Graue  
Chairman of the Board

Dept. of Physics and Technology  
U. of Bergen



# Objectives

**Strengthen and coordinate petroleum research and education in Norway and Texas.**

**Emphasize industry challenges in academia.**

**Facilitate industry funding for adjunct and chair positions at the collaborating universities; especially emphasizing the NorTex collaboration for innovative results.**

# **NorTex Petroleum Cluster Board Members and Deputies**

## **Elected Chairman of the Board:**

**Prof. Arne Graue, Dept. of Physics and Technology, U. of Bergen, Norway**

**Deputy: Prof. Tor Arne Johansen, Dept. of Earth Science, U. of Bergen, Norway**

## **Board Members:**

**Prof. Tad Patzek, Department Chair, Dept. of Petr. and Geosystems Eng., UT at Austin, TX, USA**

**Deputy: Prof. Ron Steel, UT at Austin, TX, USA.**

**Prof. Dan Hill, Department Head, Dept. of Petr. Eng., Texas A&M Univ., TX, USA.**

**Deputy: Assoc. Prof. David Schecter, Dept. of Petr. Eng., Texas A&M Univ., TX, USA.**

**Svenn Ferry Utengen, Vice President Unconventional, Texas Area, Statoil, USA.**

**Deputy: Bruce Tocher, Manager Unconventional Hydrocarbons, Texas Area, Statoil, USA.**

**Najib Abusalbi, Corporate University Relations Manager, Schlumberger, Houston, TX, USA**

**Prof. George Hirasaki, Dept. of Chemical and Biomolecular Eng., Rice U., TX, USA.**

**Deputy: Ass. Prof. Lisa Biswal, Dept. of Chem. and Biomolecular Eng., Rice U., TX, USA**

**Prof. Tom Holley, Director, Petr. Eng. Program, U. of Houston, TX, USA.**

**Deputy: Mike Nikolaou, Assoc. Prof. of Chemical Engineering, University of Houston**

**Prof. Svein Skjæveland, Dept. of Petr. Eng., U. of Stavanger, Norway**

**Deputy: Assoc. Prof. Merete Madland, Dept. of Petr. Eng., U. of Stavanger, Norway**

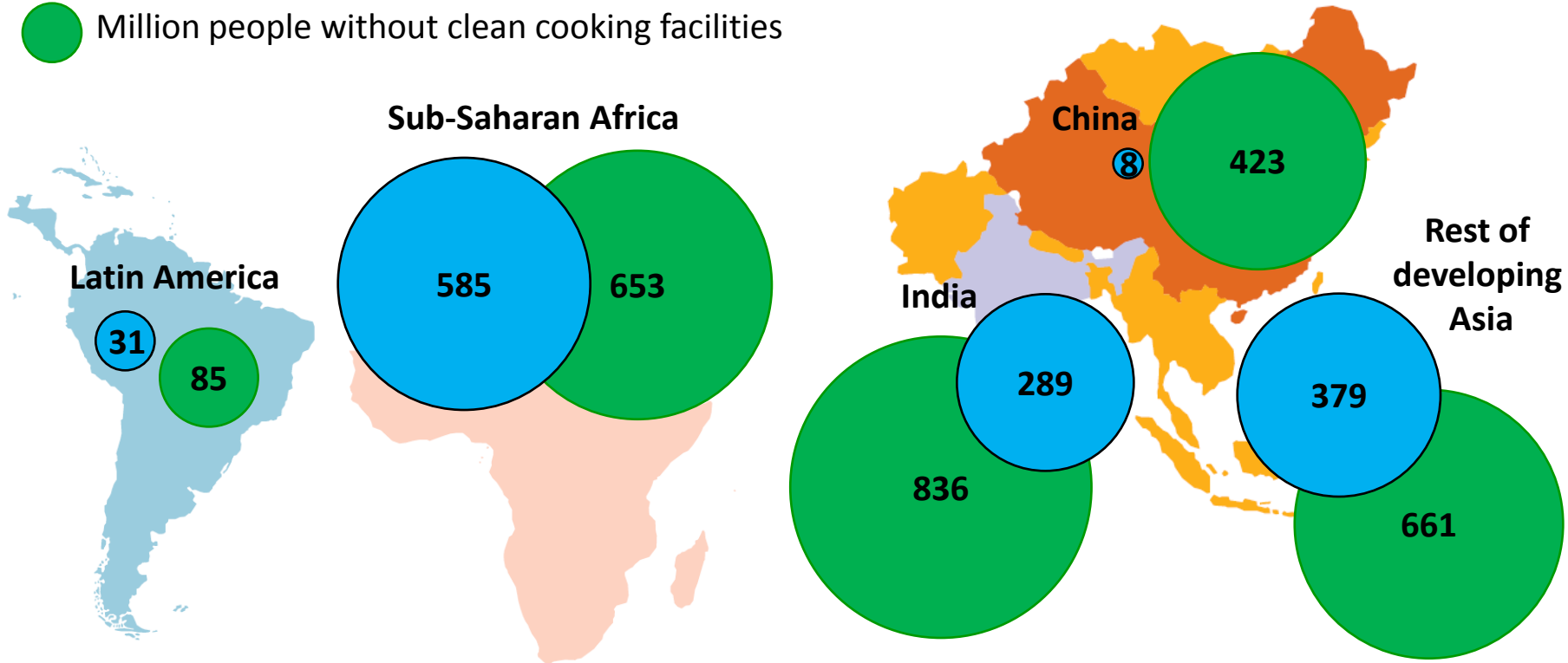
**Prof. Martin Landrø, Dept. of Petr. Eng. and Applied Geophysics, NTNU, Norway**

**Deputy: Prof. Ole Torsæter, Dept. of Petr. Eng. and Applied Geophysics, NTNU, Norway**



# Energy Poverty is Widespread

- Million people without electricity
- Million people without clean cooking facilities



*1.3 billion people in the world live without electricity  
& 2.7 billion live without clean cooking facilities*

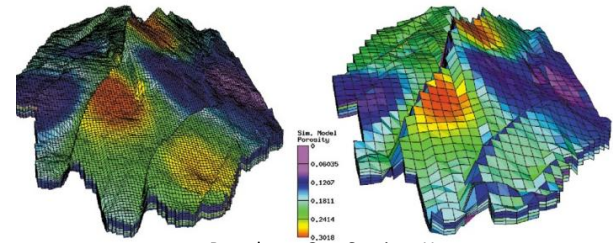


# The Global Energy Challenge

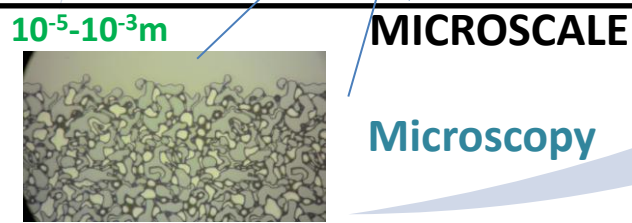
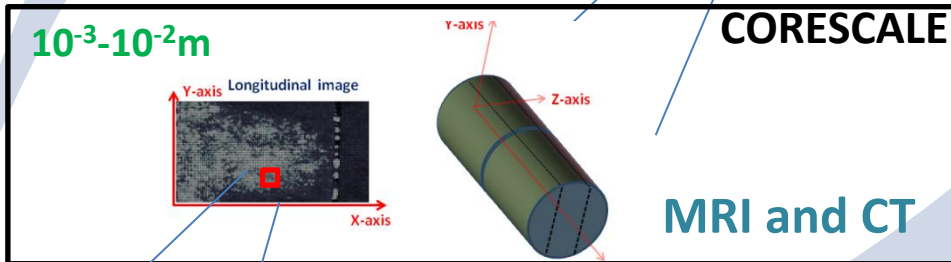
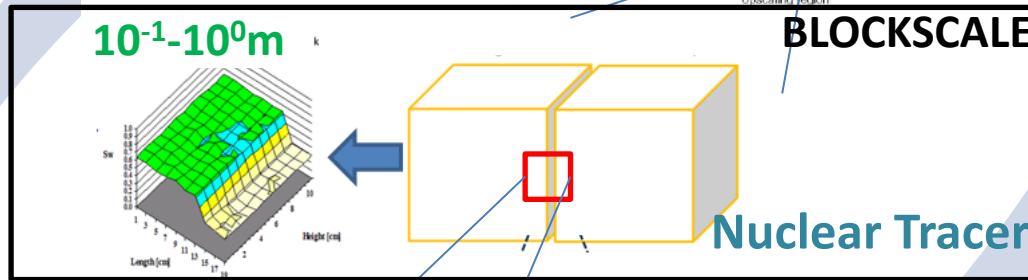
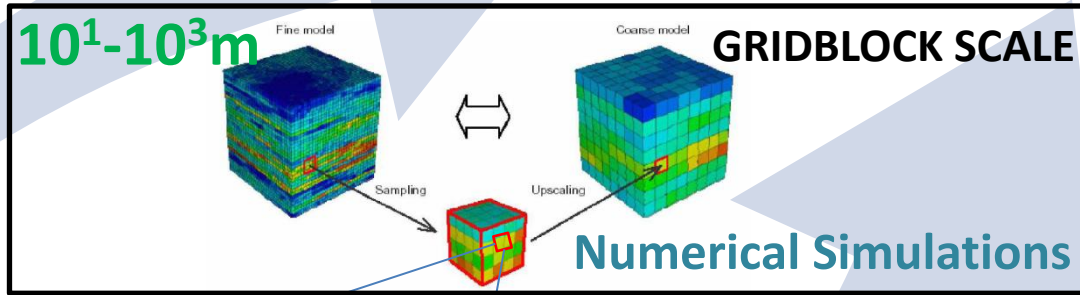
- More energy
- Cleaner energy
- Energy security – oil & gas

# Length Scales

$10^4 - 10^{10} \text{m}$



Petroleum Geo-Services Homepage  
www.pgs.com



# Imaging techniques

# Next Generation CO<sub>2</sub> Flooding

According to a US White Paper on CO<sub>2</sub> EOR, based on a report requested by US DOE from Advanced Resource International Inc., US import of foreign oil may be reduced by 30% if a "next generation CO<sub>2</sub> EOR technology" based on mobility control can be achieved.

Economically, based on an oil price of US\$ 85 and a CO<sub>2</sub> price of US\$ 40 per metric ton, 68 billion barrels of oil may be produced and will correspond to an increased oil production of 1,35 billion barrels of oil every year in the US for 50 years. Similar results on increased oil production may be obtained elsewhere, either based on CO<sub>2</sub> or other miscible gases like HC-gas; which was very successfully used in the North Sea pilot on the Snorre Field.

CO<sub>2</sub> for Enhanced Oil Recovery (EOR) within Carbon Capture Utilization and Storage (CCUS) represents a win-win situation; obtaining significant increased oil production while sequestering CO<sub>2</sub>. Early CO<sub>2</sub> breakthrough and poor sweep efficiency are the main challenges in CO<sub>2</sub> EOR and up-scaling of laboratory EOR to field performance is the ultimate challenge for the oil industry.

# *CCUS as EOR:* *Integrated EOR (IEOR) for CO<sub>2</sub> Sequestration* **CO<sub>2</sub> Foam for Mobility Control for EOR in Fractured Reservoirs in Texas**

**Collaboration:** 11 Universities in France, The Netherlands, UK, USA and Norway

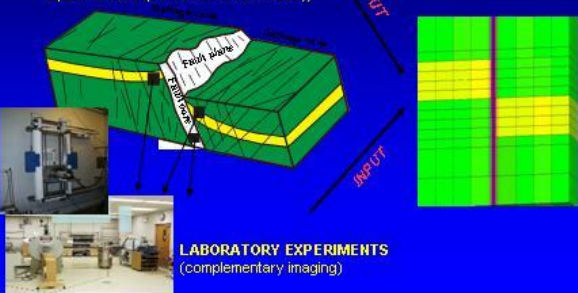
**Coordinator:** Arne Graue, Dept. of Physics, University of Bergen, NORWAY

**Funding:** The Research Council of Norway and oil companies

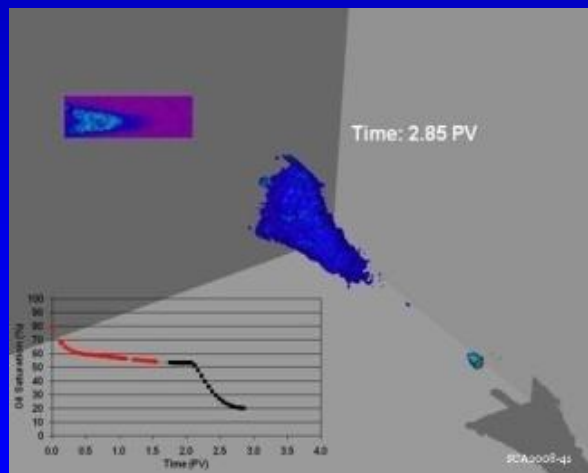
## Integration of Geology, Mathematical Modeling and Laboratory Experiments

**GEOLOGICAL ANALYSIS**  
(structural configuration & geometry, spatial and temporal deformation history)

**NUMERICAL SIMULATION**  
(domain decomposition, grid refinement, parallelization)



**Lab to pilot field test**



**MRI of CO<sub>2</sub> injection**



**Complementary NTI & MRI facilities**



# CO<sub>2</sub> Foam for Mobility Control for EOR in Fractured Reservoirs in Texas

## Project advantages:

- CO<sub>2</sub> is commercially available
- Foam and mobility control: quantum leap within EOR
- Researchers from 11 reputational universities
- Up-scaling; major challenge in oil recovery
- Fraction of costs of off-shore field tests
- Fast results: short inter-well distances
- 30 years experience in Texas on CO<sub>2</sub> EOR
- 4D seismic; seismic surveys before, during and after CO<sub>2</sub> injection establishes a field laboratory
- Mobility control may establish next generation CO<sub>2</sub> EOR flooding providing less than 10% residual oil in swept zones; establishing a new era in EOR; 137 billion barrels of oil will be the target in USA.

# Research Collaboration on CO<sub>2</sub> Foam for Mobility Control for EOR in Fractured Reservoirs

Coordinator: A. Graue, UoB

## Upscaling:

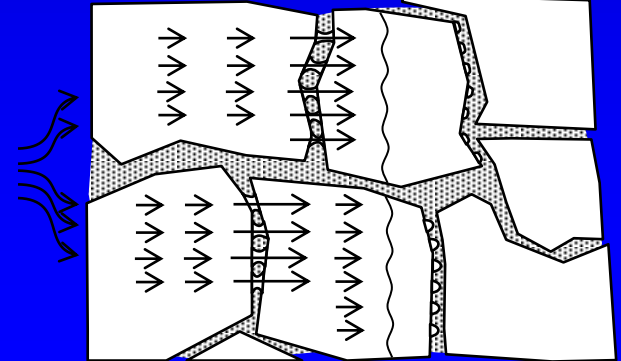
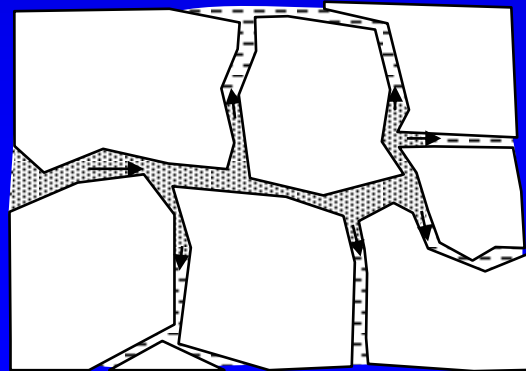
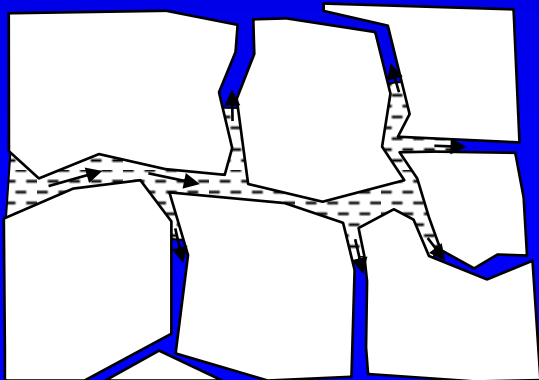
- Micro models
- Core analysis
- Blocks of rock
- Grid scale
- Field pilots

## Targets:

- Sor pore level
- Sor makro
- ROZ
- Heterogeneities
- Fractures

## Collaboration: 11 universities

- Rice University
- University of Texas at Austin
- Texas A&M U.
- Stanford U.
- Imperial College, London
- TREFLE, Bordeaux, France
- U. of Kansas
- New Mexico Tech
- TU Delft, The Netherlands
- NTNU , Trondheim, Norway
- University of Bergen, Norway



**Thank you!**