Comparing Innovation in Fuel Cells and Oil&Gas

Innovations in upstream oil and gas: the Norwegian experience

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Outline of presentation

1. Characteristics of the Norwegian oil and gas innovation system
2. The production of knowledge relevant to oil and gas innovations
3. The diffusion of knowledge relevant to innovations in oil and gas
4. Evidence from bibliometric analyses of three technological fields in upstream oil and gas
Characteristics of the Norwegian oil and gas innovation system

- Several governmental bodies involved in funding petroleum R&D
- A small set of public petroleum research institutions located in regional centres
- Oil companies drivers of innovation,
- ... but service companies emerging as drivers of innovation in some technological fields
Characteristics of the Norwegian oil and gas innovation system

Government organisations involved in funding research:

– **Ministry of Oil and Energy** (MOE)
  - Effectuates industrial policy in petroleum production
  - Administers legal/regulative framework of industrial development

– **Norwegian Petroleum Directorate** (NPD)
  - Resource management, ensuring that industry operators act in accordance with MOE guidelines

– **Norwegian Research Council** (NRC)
  - Manages government sponsored R&D programmes partly funded by MOE, NPD
    – FORCE (1997 →)
    – OFFSHORE 2010 (1999 →)
  - Initiates strategic research initiatives such as Centres of Excellence
## NRC financing of petroleum-related research 1995-2002 (Million NOK, nominal)

<table>
<thead>
<tr>
<th>Year</th>
<th>Strategic R&amp;D</th>
<th>Applied R&amp;D</th>
<th>Technology demonstration programmes</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>63,7</td>
<td>88,2</td>
<td></td>
<td>151,9</td>
</tr>
<tr>
<td>1996</td>
<td>71,0</td>
<td>71,3</td>
<td></td>
<td>142,3</td>
</tr>
<tr>
<td>1997</td>
<td>64,7</td>
<td>67,0</td>
<td></td>
<td>131,7</td>
</tr>
<tr>
<td>1998</td>
<td>69,5</td>
<td>62,0</td>
<td></td>
<td>131,5</td>
</tr>
<tr>
<td>1999</td>
<td>67,7</td>
<td>49,2</td>
<td>100</td>
<td>216,9</td>
</tr>
<tr>
<td>2000</td>
<td>76,5</td>
<td>47,6</td>
<td>80</td>
<td>204,1</td>
</tr>
<tr>
<td>2001</td>
<td>75,2</td>
<td>43,1</td>
<td>20</td>
<td>138,3</td>
</tr>
<tr>
<td>2002</td>
<td>86,1</td>
<td>34,6</td>
<td>20</td>
<td>140,7</td>
</tr>
</tbody>
</table>

Source: Karlsen ed. (2002)
Characteristics of the Norwegian oil and gas innovation system: R&D financing

Current expenditures on R&D in the offshore technology sector 1999 and 2001. Million NOK

<table>
<thead>
<tr>
<th>R&amp;D performing sector</th>
<th>1999</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>1185</td>
<td>1390</td>
</tr>
<tr>
<td>Institute sector</td>
<td>465</td>
<td>450</td>
</tr>
<tr>
<td>Higher education sector</td>
<td>110</td>
<td>80</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1760</td>
<td>1920</td>
</tr>
</tbody>
</table>

Source: NIFU/Statistics Norway 2003
Characteristics of the Norwegian oil and gas innovation system: R&D financing

R&D spending in oil companies from production license activities 1997-2000. Million NOK, nominal.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>(suppliers, R&amp;D institutes, HEIs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>1295</td>
<td>580</td>
</tr>
<tr>
<td>1998</td>
<td>1297</td>
<td>552</td>
</tr>
<tr>
<td>1999</td>
<td>1194</td>
<td>456</td>
</tr>
<tr>
<td>2000</td>
<td>1138</td>
<td>517</td>
</tr>
</tbody>
</table>

Source: NRC 2003
The production of knowledge relevant to oil and gas innovations

• The number of petroleum research scientists at Norw. public R&D institutes 2000

  – Christian Michelsen Research 26
  – IE (Institute for Energy Technology) 75
  – RF (Rogaland Research) 85
  – SINTEF Petroleum 60
  – SINTEF, other oil&gas 191
 TOTAL 437

Source: Lunde (2001)
The production of knowledge relevant to oil and gas innovations

Graduates in petroleum technological fields at Norwegian HEIs 1997-2001 (MSc and PhDs)

University of Oslo 58
University of Bergen 68
Norw. University of Technology 494
Stavanger University College 490
TOTAL 1110

Source: Karlsen ed. (2002)
Patterns of collaborative R&D in the oil&gas industry: integrators in the sectoral innovation system

- INFOIL/SESAME database on R&D projects within North Sea offshore oil and gas
- Typology of R&D partnerships including terms 'joint research, joint industry project, collaborative research'
- 73 projects, 146 organisations
- Network analysis reveals nexus agents, thematic R&D mediators
- Projects grouped in eight thematic areas (HSE, equipment and materials testing, data acquisition and processing, reservoir flow and dynamics etc.)

→ Oil operators nexus agents for R&D cooperation together with – but to a lesser extent – governmental agencies and public research institutions. Service companies relative specialists operating within thematic subsets

Source: Acha & Cusmano (2001)
The diffusion of knowledge relevant to innovations in oil and gas

Demand
Consumers (final demand) and producers (intermediate demand)

Oil companies
Global National

Intermediaries
Private R&D institutes
Prof. knowledge brokers

Education and Research System
Professional education and training
Higher education and research
Public sector research institutions

Mature SMEs
New Technology-based Firms

Infrastructure
Banking, venture capital
Legal and information system (IPRs)
Innovation and business support system (public, private)
Industry standards and norms of corporate behaviour
# Measures used to protect IPRs 1999-2001 in upstream oil and gas

<table>
<thead>
<tr>
<th>Industry</th>
<th>No. of innovative companies</th>
<th>Filing for patent protection</th>
<th>Strategic secrecy</th>
<th>Strategically complex systems design</th>
<th>Time advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream oil &amp; gas</td>
<td>36</td>
<td>67%</td>
<td>62%</td>
<td>27%</td>
<td>29%</td>
</tr>
<tr>
<td>Total private sector</td>
<td>3416</td>
<td>18%</td>
<td>31%</td>
<td>19%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Evidence from bibliometric analyses of three technological fields in upstream oil and gas

- **3D/4D visualisation of geological data**
  Search terms: graphical computing, computer graphics, visual computing, visualisation, volume data, stereo display, active stereo, passive stereo, visual interpretation, integrated visualisation, visual modelling, voxels, HPV, HPC

- **Horizontal drilling**
  Search terms: horizontal drilling, advanced wells, extended reach drilling (ERD), sidetrack drilling

- **Underwater production**
  Search terms: underwater production, deep water drilling, petroleum production, oil exploration, subsea production, offshore oil production
Bibliometric sources:

- ISI Web of Science
- ISI Proceedings
- INSPEC
- ETDE World Energy Base of the International Energy Agency
- ISI’s NCR – National Citation Report for Norway
- ISI’s JPD – Journal Performance Indicators on Diskette
Bibliometric indicators calculated include:

- Number of published papers (P)
- Numbers of citations received by those papers (C)
- Average number of citations per paper (CPP)
- Expected citation rate for papers chosen (XCR)
- Share of non-cited papers (%Pnc)

- Main Norwegian institutions publishing in the three chosen technological sub-fields
- Share of internationally co-authored papers
- Main co-authoring countries
- Main co-authoring foreign R&D institutions
<table>
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<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of published papers (P)</td>
<td>205</td>
<td>1962</td>
<td>3358</td>
<td>320</td>
</tr>
<tr>
<td>Numbers of citations received by those papers (C)</td>
<td>761</td>
<td>19960</td>
<td>18213</td>
<td>663</td>
</tr>
<tr>
<td>Average number of citations per paper (CPP)</td>
<td>3,71</td>
<td>10,17</td>
<td>5,42</td>
<td>2,07</td>
</tr>
<tr>
<td>Expected citation rate for papers chosen (XCR)</td>
<td>3,40</td>
<td>9,20</td>
<td>4,63</td>
<td>1,99</td>
</tr>
<tr>
<td>Share of non-cited papers (%Pnc)</td>
<td>44,88</td>
<td>21,92</td>
<td>30,02</td>
<td>55,00</td>
</tr>
</tbody>
</table>

Share of publications by sector:

Norwegian publications. 1991-2002 (N=205)

- Institute sector
- Private business sector
- Universities and university colleges
Institutions active in publishing in chosen sub-fields 1991-2002:
International co-authorships 1991-2002: the R&D core in Oil&Gas

Statoil

University of Bergen

SINTEF Group

NTNU

University of Oslo

Norsk Hydro

Amoco

Philips Petr

Rogaland Research

Statoil

ELF

University of New Castle

University of New Mexico

University of Karlsruhe

Univ Bahia

Univ Aquitain

Univ Waterloo

US Geol Survey

ABB

Gubco

Ecole Normale

Shell UK

Stanford U

Texas Univ

Univ Miami

US Geol Survey

Mexco Oil

Ecole Normale

New Mexico State

New Mexico Tech

Texas Tech

ABB

Hokkaido Univ
Main R&D institutions by publications 1991-2002:

- HEIs and public petroleum research institutes
  - University of Bergen
  - NTNU – Norwegian University of Science and Technology
  - University of Oslo
  - SINTEF Group
  - Rogaland Research

- National oil companies
  - Statoil
  - Norsk Hydro
  - (Saga Petroleum)
… a closing digression on applications of 3D/4D visualisation in oil and gas

- Data: interviews with practitioners, key informants in Norwegian oil companies and specialised ICT service companies
- Introduced to oil&gas in Houston as a knowledge spillover from Houston health technology cluster
- Negligible knowledge spillovers oil&gas → health/medical imaging in Norway
- At the organisational level: new disciplinary collaborations in interpreting geological data
- From enhancing oil and gas recovery rates (economic motive) to accelerating organisational learning (process innovation motive)