Potential value of Integrated Operations on the Norwegian Shelf

April 2006
Summary:

Epsis and ABB have conducted a study, commissioned by the Norwegian Oil Industry Association, to map the value of Integrated Operations on the Norwegian Shelf. The study has mapped this in greater detail than is available from previous work made by others.

The study is based on individual analysis of the following fields:

- Snorre
- Oseberg Øst
- Troll oil
- Gullfaks, including Gullfaks Sør
- Vigdis
- Troll gas
- Åsgard
- Ekofisk
- Oseberg
- Heidrun
- Brage

The fields mentioned above constitute a cross-section of the fields on the Norwegian Shelf as regards size, reservoir and fluid characteristics, development solutions and age. They represent 59 per cent of the remaining reserves on the Shelf.

The value potential of Integrated Operations has been estimated specifically for each of the fields mentioned above, in the form of increased recovery rates, increased and accelerated production and reduced costs. Estimates have been based on documented results from the implementation of IO measures in comparable fields, as well as conservative estimates of the effect of yet untried measures. In addition, the project estimated the potential from the other 41 per cent of the fields using calculated key figures from the analysis of the fields mentioned above and field characteristics. In total, this gives a realistic estimate of the value of Integrated Operations on the Norwegian Shelf.

The effect of Integrated Operations will create an added value in regard to the measures on which the fields have based their estimates for cost development and recoverable reserves. It is this added value which has been quantified in this report. No attempt has been made to estimate the effect of other measures to increase recovery rate.

The study is based on information made available to the project from the operators. The information has mainly consisted of forecasts reported to the NPD, RNB data, forecasts for OPEX and CAPEX (Wood-McKenzie data), as well as specific field information submitted in meetings with the field management on the individual fields.

The study concludes that Integrated Operations represent a potential value of NOK 250 billion (NVP). The basis for the estimates is a discount rate of 7 per cent and a price trajectory as indicated in the National Budget (NB2006), which is based on an oil price of $55 per barrel, falling to $34 per barrel in 2015.

The main contributor to the potential value is the accelerated production resulting from increased reserves and production optimisation. The total reserve increase is equal to a

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1 Reserves according to the Norwegian Petroleum Directorate’s resource categories 1, 2 and 3, i.e. reserves that are either already produced, currently being produced or where production is planned.
large new field on the Shelf. The costs associated with realising this value are NOK 25 billion (NPV) over the next 15 years.

Realising these values is dependant upon an aggressive implementation of Integrated Operations on the Norwegian Shelf. If the companies are unable to carry out this implementation rate, the values will be significantly reduced. A 3-year postponement of the implementation of the measures will create total values of NOK 94 billion (NPV), thus representing a loss of NOK 156 billion, of which NOK 31 billion represents the loss caused by discounting from 2008 till present.

If the companies choose a slower, but yet focused implementation strategy, the value of the IO will be NOK 160 billion (NPV), a reduction of NOK 90 billion of the estimated potential value. The cost related to such an implementation is estimated at NOK 18 billion (NPV).

Value and cost are estimated for the period from 2005 to 2015. Effects on and value of extended life-span have not been taken into consideration, but such effects will create further positive contributions to the value of IO. In an NPV estimate, however, these effects become marginal.

Sensitivity analyses have been conducted, representing at $20 and $40 per barrel. A price forecast from International Energy Outlook 2005 (IEO2005) has also been taken into account. For all these cases, increased production/reserves represented more than two thirds of the NPV contribution. Cost cuts were naturally found to have the largest effect percentage-wise at low oil prices.
1. Introduction

The oil companies on the Norwegian Shelf see Integrated Operations (IO) as one of the prioritised strategic tools which are to ensure a sustainable development for the companies. In addition to the activities in each individual oil company, OLF and the NPD have initiatives which are to increase the focus on Integrated Operations and contribute to quicker implementation on the Shelf.

Integrated operations will result in the following:

- Increased recovery
- Accelerated and increased production
- Reduced operating costs
- Longer life-span
- Higher safety levels

In 2004, Petoro made a calculated estimate of the potential from Integrated Operations on the Shelf. Presupposing a production increase of 2 per cent and a cost reduction of 20 per cent, Petoro estimated the added value potential at NOK 150 billion. In spite of the major potential and a strong focus on implementation in the oil companies, there are no more detailed value estimates for the Norwegian Shelf than those made public by Petoro.

This study has mapped the value of Integrated Operations on the Norwegian Shelf in greater detail than is available from previous work. Through analysing the values from Integrated Operations in detail for a selection of fields on the Shelf and using key figures from the detailed review of the estimate of values from the other fields, a value potential for the Norwegian Shelf has been calculated.

The study is based on information made available to the project from the operators. The information has mainly consisted of forecasts reported to the NPD, RNB data, forecasts for OPEX and CAPEX (Wood-MacKenzie data), as well as specific field information submitted in meetings with the field management on the individual fields.

The result of the project is a likely, but conservative potential gain from Integrated Operations for the Norwegian Shelf expressed as present value (NPV). In addition, the potential gain has been estimated in percentage in regard to the total value of the reserves on the Shelf. The project has also estimated the implementation costs, and a sensitivity analysis has been made for various oil price developments.

The report is structured as described below:

- Chapter 2 defines Integrated Operations.
- Chapter 3 describes the preconditions for the project.
- Chapter 4 describes the value potential and provides a description of the model used to calculate this.
- Chapter 5 discusses the results and provides in-depth comments regarding the results.
- Chapter 6 sums up the conclusions from the project and provides an overview of elements not covered by the study, but which should be further looked into.
1.1 References


2. Definition of Integrated Operations

Norwegian Parliament White Paper No. 38 – on the petroleum activities - defines Integrated Operations as being:

"The use of information technology to change work processes to reach better decisions, remote-control equipment and processes, and to move functions and personnel onshore"

Several of the companies which operate, have participating interests or otherwise have activity on the Norwegian Shelf use other and closely related terms. Some of these are:

- Smart Drift/ Smart Operations (Petoro)
- Integrated Operations/ Integrated Operations (Statoil, OLF and others)
- eDrift/ eOperations (Hydro)
- Smart Field (Shell)
- Field of the future (BP)
- Real Time Operations (Halliburton)
- Smart Wells (Schlumberger)
- i-field (Chevron)
- eDrift (OD)
- Digital oil field of the future/ DOFF (CERA)
- Intelligent Field Optimisation and Remote Management/ INFORM (Cap Gemini)

This study uses the term “Integrated Operations”.

Integrated Operations contain three key elements, “use of information technology”, “changed work processes”, “moving functions” (change of Organisation). Each element alone does not fall under the definition of Integrated Operations. Information technology (IT) has long been used in connection with the planning and carrying out of drilling operations, in order to optimise production. Work processes are continuously improved to make maintenance and operations more efficient.

What is new in Integrated Operations is that IT is used as a strategic tool to make work tasks and decision processes in the extended oil and gas sector more efficient, and that an extensive reallocation of work tasks between sea and land and between operators and suppliers is underway. The result is new work processes where personnel, often in different locations, interact using IT and live data integrated in the work processes. Use of IT will create opportunities in the form of new advanced functions, but also a greater degree of automation of functions currently handled manually, i.e. data collation, report generation, planning, initiation, notification and coordination of tasks.
Most players on the Norwegian Shelf have gained experience from implementing several IO measures in their own organisations. These measures have aimed to increase production, increase reserves, or reduce operating and drilling costs. Many measures will have elements of IO built in. Below is a list of measures which typically have a large degree of IO built in, in that they facilitate new ways of conducting operations. The usefulness of these measures forms the basis for setting the value of Integrated Operations on the Shelf.

- **Production increase:**
  - Real-time interaction between involved activities and disciplines, e.g. by engineers monitoring compressors or wells from land, contacting the field if matters requiring action are discovered.
  - Use of dynamic simulation in connection with production and process analyses.
  - Use of analysis tools in critical work processes, where the tools extract and present available information from operating data (both historic data and in near real-time). One example of this is detection of scale in a well as a function of changed ratio between calculated influx and pressure conditions. Another example is an analysis of correlation between flare rate, wellhead and manifold pressure, which indicates which well is causing flaring. Such information can be hard to take in without special aids.
  - The use of interaction rooms to support work processes between land and sea and between operator and supplier (the measure also includes drilling, operations and maintenance). There are many examples of how interaction rooms create production increases through implementing the right measure earlier when situations demanding the involvement of support functions and experts occur. In some cases, work can be performed from such rooms which would otherwise have necessitated travelling out to the installations.
  - Continuous control/support from onshore specialists, both own and suppliers' on a 24-hour basis

- **Reserve increase:**
  - Consistent production and reservoir data (including seismic data)
  - Accurate reservoir models for optimal localisation of wells
  - Smart wells, real-time reservoir monitoring and management

- **Reduced operating and maintenance costs:**
  - Condition- and campaign-based maintenance
  - Transferal of administrative, surveillance, management and reviewing activities onshore
  - Reduced usage of experts offshore
  - Onshore remote control
  - Increased instrumentation and automation, and improved efficiency for monitoring and analysis functions
  - New ways of supporting the fields by centralising tasks, cross-field coordination and specialising service supplies to a larger degree
• **Reduced drilling costs:**
  – Fewer sidetracks with more accurate drilling
  – Real-time optimisation of path and drilling process
  – Reduced need for sending out specialists and service personnel
3. Method description

3.1 Introduction

The expectations for the value of Integrated Operations are:

- Increased recovery
- Accelerated production (production increase)
- Reduced costs
- Longer life-span
- Increased safety

To achieve the value potential above, investments are needed. The cost scenario will also change.

Typical costs of Integrated Operations are:

- Investment in new technology
  - downhole equipment / smart wells
  - fibre cable and other communication infrastructure
  - Replacement of equipment demanding frequent inspection or extensive maintenance
  - operations centres and collaboration rooms
  - control and IT systems upgrades
  - instrumentation
  - automated functions

- Change management, e.g. necessary organisational processes and measures to adapt field units and support functions to new organisation models. Examples of such measures are internal reorganisation, training, changed expertise profile through replacement of personnel or hiring of (new) services.

- Increased onshore costs (as a result of moving offshore tasks onshore)

The value estimates for the Norwegian Shelf are based on a bottom-up approach. The project has used the production and cost forecasts for a selected number of fields on the Shelf as its starting point. The present value of the fields has been estimated, both with and without Integrated Operations. In this manner, a value potential for each field has been calculated. To estimate the potential from the other fields not included in the selection, and for the Norwegian Shelf in total, the results have been extrapolated using relevant key figures. For a more detailed description of the extrapolation, see page 10.
3.2 Method description

The first step when estimating potential is establishing a baseline for the estimates, i.e. what would be achieved without implementing any of the measures one wants to estimate the potential for.

Baseline for this project is represented by recovery rate, production profiles and budgets as they were when the oil companies made their reports in the autumn of 2004 (revised national budget (RNB) 2005). Necessary background information for the establishment of baseline has been collected from publicly available information from the NPD, as well as internal company information in which forecasts for production and costs were made available for the project. The internal company information mainly consisted of forecasts reported to the NPD in connection with RNB forecasts for OPEX and CAPEX (Wood-MacKenzie data), as well as field-specific information handed over in meetings with field management on the individual fields.

For some fields, the plans and budgets include limited IO measures. These measures are mainly directed at drilling, but there are also some examples of measures directed at production and operation. These measures were taken into consideration when estimating the value of further measures for the individual field.

The information above was used to establish a production and cost profile for the chosen fields for the period from 2005 to 2015.

The production profile is represented by the total sales value of oil, NGL and gas. A typical production profile is:

![Production Profile](image_url)

**Figure 1** Typical production profile for a field. The profile shows falling production with a characteristic tail with very low production. For the fields on the Shelf, the degree of falling production will vary strongly in the period in question, 2005 to 2015. Some fields will have no drop in production at all in the period.
The cost profile includes both the operating and the investment budget, including drilling. A typical cost profile is:

![Cost Profile Graph]

*Figure 2 Typical cost profile for an individual field. Costs fall as a result of reduced production and efficiency measures, but also peak as a result of increased drilling, well operations, equipment investment, or special maintenance as a result of ageing or increased life-span for facilities or equipment.*

The two preceding graphs show how production falls steadily, while the total costs are not reduced to a corresponding degree. In addition, the annual costs vary as a result of varying annual drilling budgets.

Based on similar information for each of the selected fields, present value (NPV) was estimated.

The value potential for each field is represented by:

\[
\text{Value potential} = \text{NPV}_{\text{with IO}} - \text{NPV}_{\text{without IO}}
\]

To estimate potential present value for the individual fields if the fields implemented Integrated Operations, the following step-by-step approach was used:

1. What typical characteristics does field x have?
   a. Large oil field / gas field / small oil field
   b. Reservoir
   c. The concept for production and operation
   d. Production rate
   e. Age
   f. Technology level

2. For fields with the same characteristics as field x, are there publications, presentations, best practice available, or do personnel participating in the project have experience with improvement projects relevant for estimating possible increased value through the implementation of IO?
3. What is the current status on the field, as regards drilling, accelerated and increased production, increased recovery and reduced costs as seen in relation to the implementation of IO?

4. Preparing primary estimate for the value potential as regards drilling, recovery, production add costs through i) an assessment of relevant IO measures per field, ii) estimating the potential as regards already tried IO measures based on documented results from comparable fields, and iii) a conservative estimate of the potential of already untested measures. The measures assessed are listed in Chapter 2, page 6.

5. For fields with a great degree of uncertainty or relatively large importance (great impact on end-result), interviews with field management were conducted to adjust value potential. Correction of the expected usefulness of specific IO measures was a central theme in these interviews.

The updated production and cost profiles formed the basis for a new present value estimate for each of the fields with Integrated Operations.

Present value with and without Integrated Operations was estimated for a selection of the fields on the Norwegian Shelf. The selection has been specified further in Chapter 3.3 below. The total value potential for the Norwegian Shelf was extrapolated.

The basis for the extrapolation was average value creation and cost per Sm3 oil equivalent in remaining reserves. These key figures were estimated for the individual fields. The individual fields were divided into three categories, (i) Large oil fields, (ii) small oil fields and (iii) gas fields\(^2\), and the average value of the key figures was estimated for each of the field categories.

The fields not dealt with individually were divided into the three categories and the current reserve estimates for the fields were multiplied by value creation and cost in each category. In this manner, an estimate for the total value potential from Integrated Operations on the Norwegian Shelf was established.

3.3 Background data and assumptions for the value estimates

Of the 54 fields in the NPD’s overview of "Petroleum resources on the Norwegian Continental Shelf", the following fields have been used as the starting point:

- Snorre
- Oseberg Øst
- Troll oil
- Gullfaks, including Gullfaks Sør
- Vigdis
- Troll gas
- Åsgard
- Ekofisk
- Oseberg
- Heidrun
- Brage

\(^2\) Gas fields are defined to be gas and gas/condensate fields, and also include oil fields in the blow-down phase.
The fields above represent 59 per cent of the remaining reserves\(^3\) on the Norwegian Shelf. In addition, the selection has been made in order to have a good basis for extrapolating to the entire Norwegian Shelf. The selection of fields has therefore been made in order to cover the variation on the Shelf as regards the field’s size, reservoir and fluid characteristics, development solution and age.

![Remaining reserves graph](image)

**Figure 3 Remaining reserves on the Norwegian Shelf according to the NPD’s resource overview 31 December 2004.** The column “Others” includes the fields Ula, Fram, Sigyn, Veslefrikk, Urd, Statfjord Nord, Gungne, Statfjord Øst, Skirne, Embla, Jotun, Tor, Gyda, Huldra, Brage, Varg, Tambar, Vale, Sygna, Glitne, Heimdal, Hod, Murchison, Sleipner Vest, and Sleipner Øst

For each of the chosen fields, estimates for the potential for accelerated and increased production, increased recovery and reduced costs have been made according to the method described in Chapter 3.2.

The following applies for increased recovery/production:

- The production increase is mostly achieved through short-term and continuous optimisation of different activities using known technologies, resulting mainly in accelerated production. For a list of different measures evaluated, see page 6.
- For all the fields, the production increase is more than offset by the increase in reserves.
- We have in this project take into consideration, to as large a degree as possible, measures beyond those measures present in existing plans for production-promoting or production-increasing measures.
- Streamlining of the drilling process provides increased recovery, increased production and reduced costs.
- Pure IOR measures have not been included in the estimate, but further improvements of such through IO efforts have been included to some degree.

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\(^3\) Reserves according to the Norwegian Petroleum Directorate's resource categories 1, 2 and 3, i.e. reserves that are either already produced, currently being produced or where production is planned.
The following applies for reduced costs:

- Moving personnel onshore is the most important contribution to cost reduction. The following assessments form the basis for moving personnel:
  - Tasks are, to a large extent, moved onshore and carried out by land-based personnel. This applies especially to planning tasks, logistics functions, administration and follow-up. It is still expected that several follow-up tasks and safety-related will have to be performed offshore.
  - An offshore position costs three times as much as an onshore position.
  - In addition to cost reductions when moving personnel, task simplification and task redundancy offshore as a result of equipment adaptations and replacement with less maintenance-demanding equipment have been taken into consideration. One example of this is the present technology for fiscal metering equipment which, used with information technology, makes it possible to monitor and follow up from land to a large degree. This can generate efficiency gains by making it possible to follow up the equipment on several installations with fewer people.
  - Cost savings are higher than the two-thirds saved by moving personnel onshore. The project has assumed that 20 per cent of the offshore cost savings will reappear as costs onshore.
  - Tariffs and other fixed contractual costs are not affected by IO measures.

Increased life-span for the fields is a result of reduced costs, increased production and increased reserves. The value of increased life-span (beyond existing plans and as a result of IO measures, ref. definition of baseline in Chapter 3.2) is not included as the model only covers the years 2005 to 2015, and none of the fields have scheduled a closure in this period.

As for technology, the project's starting point is that technology which has been employed by one company and has generated value is mature. Mature technology can be implemented immediately by other companies. In addition, conservative estimates have been made in which the value of known new technology is seen as promising, but the value has not been documented fully through installations in operation.

Costs related to the introduction of IO total MNOK 0 – 350 per field per year. The most important cost elements are investments in drilling in new wells and updating existing wells, upgrading instruments and control systems, as well as restructuring costs in connection with new ways of organising work. Training, testing and use of new technology will also entail considerable cost elements.

The implementation cost distributed over time is as follows:

- **Early phase (1-3 years):** infrastructure, operation centres, major upgrades, change management.

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4 For new technology, there will in most cases be different opinions among the operators on the Norwegian Shelf on whether the technology is mature. If there are companies on the Norwegian Shelf which, in spite of the technology being in use on comparable fields, do not consider the technology mature, and choose to postpone implementation due to extensive technology qualification or internal development, this is irrelevant for the value potential on the Shelf.
- **Late phase (3-10 years):** well investments / smart wells to increase recovery (improved flexibility and control options), as well as continuous investment in new technology.

Independently of the introduction of Integrated Operations one can expect reduced costs and a changed cost picture on the Shelf. In the project, this has been taken into consideration through only including those measures which can be categorised as IO measures in the value estimates. For instance:

- Existing equipment being replaced with equipment with a higher degree of regularity and lower maintenance costs is not in itself IO. However, if the new equipment entails inspection and maintenance being done in a new and more cost-efficient way, due to e.g. improved opportunity to monitor the condition and performance automatically, this constitutes an IO value.

- New and reasonable condition monitoring of engines is an IO measure, but replacement of the engine with better materials is not IO.

- Recompletion of wells is not in itself an IO measure, but installation or repair of downhole instruments with the intention of monitoring the well better is an IO measure.

Of the estimated total cost reduction forward in time which the project has defined, 60 per cent of the total reduction is represented by IO-dependant measures. (IO being the triggering factor).

The study assumes an aggressive implementation policy where the entire potential, both as regards relevant technology, organisation and other efficiency measures, is exploited fully. This also includes new technology which is expected to become available in the period until 2015. The measures will be implemented throughout the period, but with a high point early in the period, mainly over 5 years as follows:

- Cost reduction 3 years.

- Production-increasing measures 2 years.

- Measures creating increased recovery are also implemented after 5 years, and will fill up production to make the production increase last.

Measures have primarily been added in generation 1 (ref. /1/), which in this case are implemented immediately and widely. Generation 2 measures are implemented gradually, but only to a large extent from 2010 on. Transfer of personnel to land takes place as soon as it is technologically feasible and safe to do so. Long reorganisation processes have not been taken into consideration.

### 3.4 Documentation and results for the individual fields

To assess the value potential for each for the chosen fields, the project has received confidential information from the operators. In addition, some of the operators have given the project access to further internal company information through the interviews. The information has been used in the estimation of value potential for each of the individual fields. This information was released in under the condition of confidentiality.

Based on the facts, the project has estimated reserve increase, production increase, cost reductions and IO investments. The estimates were made field by field. There are considerable differences between the fields as regards opportunities and limitations for IO.
Examples:

- Increase in remaining reserves 0 - 34 per cent
- Production increase 0 - 6 per cent
- Cost reductions MNOK 0 - 550 per ear
- IO investment MNOK 10 - 350 per year

The actual figures, preconditions, measure assessments and the quantitative estimate results for the individual fields are not documented in this report. This is information which will not be released by the project. In addition, the collected results have been anonymised to make it impossible to calculate the contributions from the individual fields from the total.

As the goal of this project is to estimate a value potential for the Shelf in total, and not to rank individual fields, the information regarding the individual fields is not seen as relevant to the project's goal.

4. Results

4.1 Entry data for value estimates

The 11 fields studied make up a total reserve of 2,300 million Sm3 oil equivalents\(^5\) (o.e.). From this, a total of 1,160 million Sm\(^3\) o.e. are scheduled for production in the period 2005 to 2015. The value of this production, with production costs (operating costs, investments and CO2 taxes) deducted, represents a total present value of NOK 1,350 billion. The value estimate does not take taxation into consideration. Table 1 shows how the values are distributed among the individual fields.

<table>
<thead>
<tr>
<th>Without IO</th>
<th>MSm3</th>
<th>o.e.</th>
<th>NPV MNOK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field A</td>
<td>270</td>
<td></td>
<td>326,265</td>
</tr>
<tr>
<td>Field B</td>
<td>78</td>
<td></td>
<td>94,583</td>
</tr>
<tr>
<td>Field C</td>
<td>86</td>
<td></td>
<td>92,958</td>
</tr>
<tr>
<td>Field D</td>
<td>157</td>
<td></td>
<td>178,926</td>
</tr>
<tr>
<td>Field E</td>
<td>67</td>
<td></td>
<td>71,340</td>
</tr>
<tr>
<td>Field F</td>
<td>34</td>
<td></td>
<td>39,195</td>
</tr>
<tr>
<td>Field G</td>
<td>76</td>
<td></td>
<td>68,568</td>
</tr>
<tr>
<td>Field H</td>
<td>330</td>
<td></td>
<td>383,200</td>
</tr>
<tr>
<td>Field I</td>
<td>39</td>
<td></td>
<td>57,233</td>
</tr>
<tr>
<td>Field J</td>
<td>19</td>
<td></td>
<td>28,869</td>
</tr>
<tr>
<td>Field K</td>
<td>7</td>
<td></td>
<td>5,517</td>
</tr>
</tbody>
</table>

|        | 1,163 | 1,346,655 |

The calculation is based on an exchange rate of NOK 6.50 per $1, as well as a discount rate of 7 per cent. The oil price used is stated in Table 2.

\(^5\) Conversion factor for NGL in tonnes to Sm3 is 1.9
Table 1 Oil price according to the National Budget (NB 2006).

<table>
<thead>
<tr>
<th>Year</th>
<th>NOK/bbl</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>356</td>
</tr>
<tr>
<td>2006</td>
<td>350</td>
</tr>
<tr>
<td>2007</td>
<td>320</td>
</tr>
<tr>
<td>2008</td>
<td>285</td>
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<tr>
<td>2009</td>
<td>270</td>
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<tr>
<td>2010</td>
<td>263</td>
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<tr>
<td>2011</td>
<td>250</td>
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<td>2012</td>
<td>240</td>
</tr>
<tr>
<td>2013</td>
<td>230</td>
</tr>
<tr>
<td>2014</td>
<td>220</td>
</tr>
<tr>
<td>2015</td>
<td>220</td>
</tr>
</tbody>
</table>

4.2 Production and investment profile

The figures below show the production profile with and without IO for the 11 fields studied in detail in the analysis (Figure 4) as well as the respective investment profile (Figure 5). As seen in Figure 5, most of the investment will have to take place in the next 4 years in order for the identified potential to be exploited.

Figure 4 Production profile with and without IO for the 11 fields studied in detail

The total production increase for the Norwegian Shelf in the period 2005-2015 is estimated at 194 million Sm3 o.e., of which 64 million SM3 o.e. (33 per cent) is made up of the 11 selected fields in the period until 2015.
The total IO investment on the Norwegian Shelf in the period 2005 to 2015 is estimated at NOK 25 billion (NPV), of which 32 per cent is made up by the investments in the 11 selected fields. The costs for these fields are lower than the reserve base they represent. This is due to the manner in which the extrapolation was done. When we estimated costs for IO implementation, we estimated the costs for three categories: large oil fields, small oil fields and gas fields. The selection of fields had a sizeable contribution from large oil fields. These have considerably lower IO costs per cubic metre of oil than the small oil fields. This means that when we extrapolate to the entire Norwegian Shelf, the contribution from small oil fields will be more important, which in turn means that the costs of IO implementation will be higher, relatively speaking.

Figure 5 Estimated total IO investments for the Norwegian Shelf to exploit full IO potential.

Figure 6 Cost distribution between large oil fields, small oil fields and gas fields.
4.3 Results for the individual fields

The analysis shows that the value of IO varies considerably with the field characteristics. The present value of the 11 fields ranges from MNOK 1,500 to MNOK 23,000 (NPV). The main cause of the variation is the total amount of remaining reserves in the field, but other conditions, as described in Chapter 3, also affect the results.

![Net present value per field](image)

*Figure 7 IO value for the 11 selected fields in the period 2005 to 2015*

As regards the classification of the fields (ref. Chapter 3.2: gas / small oil field / large oil field) there are large differences in the value of the remaining reserves. The figure below shows the potential value of IO in the individual fields in relation to the remaining reserves [NOK/Sm3 o.e.]. Both large and small oil fields gain great effect from IO, but gas fields in general have a lower potential.

![Value of IO per unit remaining reserves](image)

*Figure 8 Value of IO per unit remaining reserves distributed by large oil fields (blue), small oil fields (yellow), and gas fields (red).*
4.4 Value of Integrated Operations on the Norwegian Shelf

When these results are extrapolated to all the reserves in all the fields on the Shelf, divided by categories small and large oil fields and gas fields, the result is an IO potential of **NOK 250 billion**, and the added production related to IO is estimated at 194 million Sm3 o.e. Table explores this in some depth.

Table 2 IO potential for the Norwegian Shelf

<table>
<thead>
<tr>
<th></th>
<th>246 479 MNOK IO-potential (NPV)</th>
<th>25 082 MNOK cost (NPV)</th>
<th>6.0 % Increased NPV</th>
<th>5.5 % Increased production</th>
<th>3917.5 Sm3</th>
<th>63 NOK / Sm3 (value creation)</th>
<th>6 NOK / Sm3 (costs)</th>
</tr>
</thead>
</table>

4.5 Preset value distribution according to field type

The value of the fields on the Shelf is distributed as follows:

<table>
<thead>
<tr>
<th>Type of field</th>
<th>NPV [mrd NOK]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large oil fields</td>
<td>121</td>
</tr>
<tr>
<td>Small oil fields</td>
<td>25</td>
</tr>
<tr>
<td>Gas fields</td>
<td>101</td>
</tr>
<tr>
<td>Total</td>
<td>246</td>
</tr>
</tbody>
</table>

Per cent distribution of potential value as shown in the figure below. The greatest value is from the large oil fields with 48 per cent, while the gas fields are second with 42 per cent.

Figure 9 Per cent distribution of potential value on the Norwegian Shelf.
Figure 10 Per cent distribution of value of the different measures
5. Discussion with in-depth comment on results

5.1 Implementation rate

A precondition for realising the entire potential value is maximising implementation and uptake of new technology, changing existing work processes and implementing new ones. This will in many cases also entail entirely new ways of organising work.

Realising the total potential value for the Norwegian Shelf will depend very much on the IO implementation rate. The estimates are based on a fast implementation rate with the bulk of the investments lying 3 to 6 years into the future. This demands a considerable effort in the individual field units, both in showing will and ability to implement IO technologies, building new expertise and restructuring the operating organisation. However, the potential case is doable, not just theoretical. Measures will be implemented when technically mature. HSE is handled in a responsible manner. This will, however, be an important theme in the discussions between companies and employees. As suggested above, no time has been estimated for lengthy discussion between the two sides, nor for any consensus which limits the implementation rate.

Several fields on the Norwegian Shelf have already proven that considerable changes can be made over a short time horizon, and management in the operating companies is largely aware of the challenges. The change rate does, however, depend on several local and field-specific factors.

Examples of this are:

- large projects, such as upgrades linked to new field developments, restructuring which can monopolise all focus and all capacity in the affected operating units
- labour agreements
- expertise profile

A fast implementation rate entails financial risk as regards a successful implementation. It is assumed that the risk is moderate, as a large part of the short-term gain can be achieved using known and tested technology, while lasting increased production will require technology development and larger investments. Another aspect which must be considered is that there are major differences between the licenses as regards experience and ambitions.

The project recommends that the Norwegian Shelf as a whole should focus on the immediate implementation of known and tested technology and that OLF should facilitate the implementation of joint measures and the exchange of experience between companies and licenses.

The potential value represents a possible increased creation of value on the Norwegian Shelf. It is not evident that the companies on the Shelf will be able to realise the values. For smaller oil fields in particular, the fast implementation of IO is critical. Production from these fields is declining rapidly, and the NPV increase of 6 per cent requires an implementation policy as described in Chapter 3.
5.2 Sensitivity analysis as regards oil price

A sensitivity analysis as regards oil price has been made, representing $20 and $40 per barrel, as well as IEO2005, scenario 2.

![Value Norwegian Shelf](image)

**Figure 11 Value of IO per Sm3 o.e. on the Norwegian Shelf**

<table>
<thead>
<tr>
<th>NPV mrd</th>
<th>Value NOK/m3</th>
<th>Cost NOK/m3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$20/bbl</td>
<td>120</td>
<td>31.0</td>
</tr>
<tr>
<td>$40/bbl</td>
<td>226</td>
<td>58.0</td>
</tr>
<tr>
<td>NB2006</td>
<td>246</td>
<td>63.0</td>
</tr>
<tr>
<td>IEO2005, sc.2</td>
<td>197</td>
<td>50.0</td>
</tr>
<tr>
<td>Investments</td>
<td>25</td>
<td>50.0</td>
</tr>
</tbody>
</table>

**Table 3 Value and cost of IO as a function of different oil price trajectories**

The largest effect, percentage-wise, from cost reductions were found with low oil prices. However, for all the cases, increased production/reserves represented more than two-thirds of the NPV contribution.

<table>
<thead>
<tr>
<th>IOE2005, Scenario 2</th>
<th>Oil 2003 USD/bbl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2005</td>
</tr>
<tr>
<td>2005</td>
<td>43.63</td>
</tr>
<tr>
<td>2006</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
</tr>
</tbody>
</table>
## IOE2005, Scenario 2

<table>
<thead>
<tr>
<th>Year</th>
<th>2003 USD/bbl</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>35.25</td>
</tr>
<tr>
<td>2009</td>
<td>32.00</td>
</tr>
<tr>
<td>2010</td>
<td>31.00</td>
</tr>
<tr>
<td>2011</td>
<td>31.27</td>
</tr>
<tr>
<td>2012</td>
<td>31.53</td>
</tr>
<tr>
<td>2013</td>
<td>31.80</td>
</tr>
<tr>
<td>2014</td>
<td>32.07</td>
</tr>
<tr>
<td>2015</td>
<td>32.87</td>
</tr>
</tbody>
</table>

*Table 4 Oil price in 2003 US dollars according to the US Dept. of Energy 2005 International energy outlook (IEO2005), Scenario No. 2.*

## NB2006

<table>
<thead>
<tr>
<th>Year</th>
<th>Oil NOK/bbl</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>356</td>
</tr>
<tr>
<td>2006</td>
<td>350</td>
</tr>
<tr>
<td>2007</td>
<td>320</td>
</tr>
<tr>
<td>2008</td>
<td>285</td>
</tr>
<tr>
<td>2009</td>
<td>270</td>
</tr>
<tr>
<td>2010</td>
<td>263</td>
</tr>
<tr>
<td>2011</td>
<td>250</td>
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<td>2012</td>
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<tr>
<td>2013</td>
<td>230</td>
</tr>
<tr>
<td>2014</td>
<td>220</td>
</tr>
<tr>
<td>2015</td>
<td>220</td>
</tr>
</tbody>
</table>

*Table 5 Oil price development according to the Norwegian National Budget 2006 (NB2006)*
5.3 Sensitivity as regards implementation rate

5.3.1 Case 1: Three years postponement of IO implementation

If the implementation of Integrated Operations is postponed by three years from 2005, the total value of IO for the Shelf will be NOK 94 billion (NPV), and the added production resulting from IO will be 110 million Sm3 o.e. This drastic reduction is primarily due to declining production diminishing the value of the IO measures. The figure below provides further details on this.

![Pie chart showing percentage distribution of IO value with 3 years' postponement of IO measures.](image)

*Figure 12 Percentage distribution of IO value with 3 years' postponement of IO measures.*

*Table 6 IO potential with 3 years' postponement of measures*

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 318 MNOK IO-potential (NPV)</td>
<td></td>
</tr>
<tr>
<td>18 972 MNOK cost (NPV)</td>
<td></td>
</tr>
<tr>
<td>2.3 % Increased NPV</td>
<td></td>
</tr>
<tr>
<td>3.0 % Increased production</td>
<td></td>
</tr>
<tr>
<td>3917.5 Sm3</td>
<td></td>
</tr>
<tr>
<td>24 NOK / Sm3 (value creation)</td>
<td></td>
</tr>
<tr>
<td>5 NOK / Sm3 (costs)</td>
<td></td>
</tr>
</tbody>
</table>

The most important effects from postponed production measures on the present value are:

- Production is lost in the period preceding the implementation of measures
- Production is moved out of the time-frame used as a basis for the estimate
- The net present value effect of the delay

In the three years without measures, the 11 fields will produce 400 million m3 o.e. of their remaining reserves without implementing optimisation measures. In this process, the flow conditions in wells and reservoirs will develop without the optimal management and correction. Water and gas breakthroughs will occur in both wells and reservoir areas. New wells will be located less optimally than possible. Parts of this development are irreversible. A considerable portion of the delayed production, will thus be lost forever. In the model, delayed production until 2015, for these 11 fields alone, is estimated at approx. 30 million m3. As the model does not contain production profiles for the Shelf after 2015, it is not possible to determine how much will be lost forever. Extrapolating this loss to other fields as well as estimating what amounts that can be created later, is very uncertain. Further
losses from delayed implementation will arise as a result of the reserves being less when the measures are implemented later. Some IO measures will therefore not be financially viable and will not be implemented.

![Pie chart showing percentage distribution of different measures for case 1](image)

*Figure 13 Percentage distribution of different measures for case 1*

5.3.2 Case 2: Focused and realistic implementation rate

Value estimates based on assumptions of slower implementation rate for IO measures in the field units are shown here, where all opportunities are not exploited as fully and as early as possible. It is assumed that the companies work in a focused manner and according to their ambitions and strategies for Integrated Operations, and we have attempted to take into considerations technical and operational framework conditions. These kinds of assessments are extremely difficult to make, based on the data and information available in this project. Thus, there is a particularly large uncertainty associated with these results.

Production and reserves receive the primary focus from owners and operators. The gap between expectations and potential is the least in this area. Added production with IO measures is in this case 46 million m³, i.e. 18 million m³ less than the potential. The IO value in this case is NOK 164 billion (NPV).

![Pie chart showing percentage distribution of IO measures with a realistic and focused implementation](image)

*Figure 14 Percentage distribution of IO measures with a realistic and focused implementation.*
Table 7 Rough estimate of IO potential with focused implementation

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>164 066 MNOK IO-potential (NPV)</td>
<td></td>
</tr>
<tr>
<td>18 142 MNOK cost (NPV)</td>
<td></td>
</tr>
<tr>
<td>4.1 % Increased NPV</td>
<td></td>
</tr>
<tr>
<td>3.9 % Increased production</td>
<td></td>
</tr>
<tr>
<td>3917.5 Sm³</td>
<td></td>
</tr>
<tr>
<td>42 NOK / Sm³ (value creation)</td>
<td></td>
</tr>
<tr>
<td>5 NOK / Sm³ (costs)</td>
<td></td>
</tr>
</tbody>
</table>

The consequences of a slower and less aggressive implementation rate than assumed in the potential estimate are greatest for the small and marginal fields. The effort seems to be more time-critical for these, while the larger oil fields are better off if there are delays. The gas condensate fields will also suffer under a slower implementation. This is in part due to time-critical fluid production.

In many fields, there seems to be a stronger focus on measures for increased production than on cost measures. This means that the difference between expectation and potential is relatively less for production than for costs.

![Pie chart showing percentage distribution of different measures for case 2](image)

**Figure 15 Percentage distribution of different measures for case 2**

Note that extrapolated profiles are based on the assumption that IO activity is equally large for all fields as for the 11 fields studied in particular. It is likely that the activity on the less-focused fields will lag somewhat, but if so, this will include production, IO costs and savings. Especially for the realistically focused case, this may yield a slightly too high implementation rate, resulting in too high value. This may reduce NPV value somewhat.

5.4 Limitations to the model and uncertainties in the results

During the estimation of the total potential value, several assumptions have been made. This chapter comments on the most important assumptions.
Regarding investments:
The total investments in the model are NOK 25 billion (NPV) or NOK 33 billion in nominal costs. There is much uncertainty in this number, as it includes both young technology and new development, and as the IO costs for the individual field in this study have been categorised very roughly. The uncertainty is assumed to be in the range +100 per cent to -30 per cent (high/low estimate of costs).

![Figure 16 IO investment profile for the entire Norwegian Shelf related to the total potential (Base Case), as well as postponed implementation 3 years (Case 1), and for a focused and realistic implementation (Case 2).](image)

The figure above shows how the investment need relates to the implementation strategy.

Regarding extrapolation of values:
The selected individually analysed fields represent 59 per cent of the remaining reserves on the Norwegian Shelf. The selection covers the variations on the Shelf as regards field size, reservoir and fluid characteristics, development solution and age.

A detailed assessment of these fields provides a good basis for understanding the potential of Integrated Operations on the Norwegian Shelf, as such a large portion of the remaining reserves has been included.

In addition, it is an advantage that 5 of the 11 fields are large oil fields, as the large oil fields represent a considerable portion of the potential value.

Regarding present value estimate:
The study is based on data until 2015. This means that the project has not taken into consideration the effect on the life-span of the Shelf and matters resulting from increased life-span for the installations. In spite of such matters being of great importance to the society at large, they are of less importance to NPV, as most of these matters lie more
than ten years into the future. This means that the results are relevant as regards documenting the socio-economic gain from the value itself, but the results are of limited use for assessments which lie more than 10 years into the future.

Regarding reserves:
Most fields which the project has been in contact with believe the reserves will increase as a result of implementing Integrated Operations. This is implicitly included in the estimates, inasmuch as increased reserves are one of the factors which form the basis for the NPV estimates are made. As the project has looked at the period until 2015 in its basis for the NPV estimates, these must be considered as conservative estimates of the IO potential on the Shelf.
6. Conclusion and suggestions for further efforts

6.1 Conclusion

The conclusions from this work are that the value of Integrated Operations represents a potential of NOK 250 billion (NVP). The costs required to realise this value is NOK 25 billion (NPV) over the next 15 years.

The basis for the estimates is a price trajectory as given in NB2006, and a discount rate of 7 per cent. Sensitivity analyses representing $20 and $40 per barrel have been made. A price forecast from the US DOE in International Energy Outlook 2005 (IEO2005) has also been considered. With an oil price as defined by IEO2005, the potential is NOK 200 billion (NPV).

The largest contributing factors to the potential value are reserve increase and accelerated production as a result of production optimisation. Total increased production in the period, 194 million Sm3 o.e., is equivalent to depleting a large new field on the Shelf.

This value requires an aggressive implementation on the entire Shelf. If the companies choose a phased and less aggressive implementation, the potential will be significantly reduced. For example, a postponement of 3 years will mean a loss of value (NPV) of more than NOK 150 billion, of which approximately NOK 30 billion is due to 3 years’ discount. A conservative and realistic implementation rate would create a value of more than NOK 160 billion (NPV), which is approximately NOK 90 billion less than the total potential.

For all sensitivity estimates regarding varying oil prices, increased production/reserves made up more than two thirds of the NPV contribution. The largest effect from cost reductions, percentage-wise, was found with low oil prices.

The value potential represents a possible increased value creation on the Norwegian Shelf. It is not obvious that the companies on the Shelf will be able to realise the values. Realising these values demands a more offensive implementation rate than is the case today.

6.2 Suggestions for further efforts

The objective of this study has been to assess the most likely value for the IO potential on the Norwegian Shelf. Within the scope of the study, it has only been possible to assess the further strategy for implementing Integrated Operations to a limited extent. The results from the study, however, indicate a number of conditions which should be of interest to society (the authorities) and the industry.

Elements which should be examined further include:

- Importance to Norwegian society.
  The value from the increased production and the consequences of the investments will be of great importance to Norwegian society.

- Giving priority to research efforts and joint tasks.
  How should the research effort be given priority to ensure and, if possible, increase the gain from IO measures?

- Giving priority to implementation measures.
  Which measures should be given priority to ensure significant gains from limited implementation means (cost/benefit of the individual measures)?

- Giving priority to field types and operating models.
  Choice of development solution affects the possibility of gains from IO.
Important contributions in these evaluations, which could be derived through a further study of this project, are:

- **Uncertainty** – the range and the most important uncertainty factors.
- **Ranking** the different input factors and measures as regards value.
- **Individual differences** in different fields, types of fields, etc.
- **Importance of extended life-span.**

The importance of the extended life-span is only to a small degree included in the present estimates, as these do not take into consideration what will happen after 2015. This provides a conservative estimate of the IO value.

### Table of revisions

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<td>Document expanded with description of delayed implementation of IO measures, as well as estimate of total investment profile for the Shelf. Base case based on NB2006 figures for oil price development.</td>
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OLF - The Norwegian Oil Industry Association
BJ - Bård Jansen (ABB)
HH – Halvard Høydalsvik (Epsis)
JEN – Jan-Erik Nordtvedt (Epsis)
HIM – Håvard I. Moe (ABB)