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by secondary and tertiary production methods**

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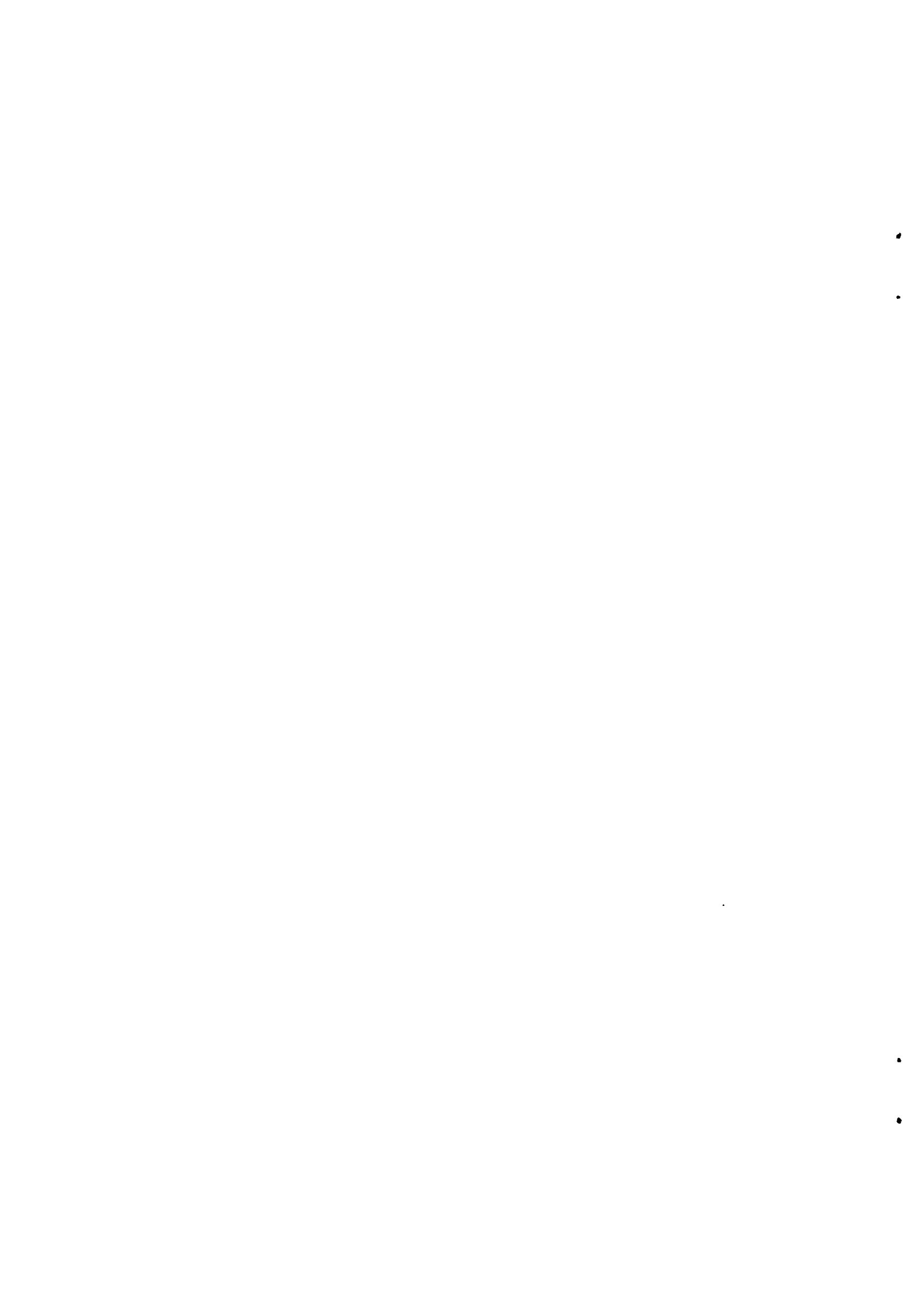
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## Energy requirement for north sea oil by secondary and tertiary production methods

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PREFACE

This work is a continuation of the effort to understand the resource requirements necessary for development of energy resources. In this particular paper we have concentrated on attempting to understand the energy to be expended to obtain an energy resource, e.g. North Sea crude oil.

This paper serves as an example of cooperation between work completed at two international organizations, the European Joint Research Centre, Ispra Establishment and The International Institute for Applied Systems Analysis.



ABSTRACT

This paper presents a review of the resources necessary to develop 13 UK offshore oil fields for purposes of obtaining primary recovered oil. An estimate is provided of the increasing energy requirement for a tonne of North Sea oil due to secondary production methods. Also presented is an estimate of the possible energy requirements should tertiary (enhanced oil recovery) techniques be undertaken in the North Sea.

Energy Requirement For North Sea Oil By  
Secondary and Tertiary Production Methods

By

R.J. Peckham and J.K. Klitz

INTRODUCTION

There is considerable interest today in the energy required for the extraction of resources. [1] It has been argued [2,3] that the energy required for extraction is as good a measure as any of the difficulty of accessing a resource. Therefore the estimate of energy requirements for extraction as a function of future production could serve as an indicator of future cost.

This paper presents an estimate of the increasing energy requirements for a tonne of North Sea oil (averaged over 13 specific fields) due to secondary production methods. An estimate is also made of the possible energy requirement should tertiary methods be embarked upon, though it must be stressed that it is not yet known whether tertiary methods will ever be used in the North Sea and this estimate is subject to large uncertainties.

PRIMARY OIL RECOVERY

Primary oil recovery is the reliance upon natural energy forms in the reservoir for the production of crude oil. Such natural energy forms include natural water drive, expansion of free gas, oil, water and solution gas, and capillary and gravitational forces.

To bring about the initial primary recovery of oil from the North Sea a large portion of resources has and is being expended in exploration, platform and pipeline construction, production well drilling, and the production process itself.

The development of thirteen commercially deemed oil fields in the U.K. sector of the North Sea requires directly or indirectly the following activities for primary recovery:

Total number of miles surveyed	310,700 (500,000 kms)
Exploration wells drilled	474
Appraisal wells drilled	169
Production wells drilled (637 anticipated to be drilled to complete the 13 fields)	293
Total number of miles of major crude pipelines constructed or under construction	487 miles (784 kms)
Total number of miles of field pipelines (crude) constructed or under construction	65.3 miles (105 kms)
Production platforms installed	11 (steel) 3 (concrete)
Production platforms under construction or being constructed or being installed	2 (steel) 4 (concrete)

The total amount of material and energy resources necessary for the construction of all facilities in the oil field in U.K. waters is 12.2 million metric tons. Energy materials represent the major quantity, 7.6 million tons, and structural and consumable materials represent 4.6 million tons of the total.

Because of the large amount of resources utilized for primary recovery it seems important to continue the evaluation of how larger quantities of oil can be obtained for the resources expended.

#### SECONDARY PRODUCTION METHODS

There is now a terminology problem regarding which technologies for enhanced oil recovery should be classified as "secondary" and "tertiary". This arises because the more sophisticated methods previously regarded as tertiary may come to be used in the earlier stages of field development in order to obtain the best overall return. Also some secondary techniques such as injection of water or gas could be termed "enhanced primary" methods if the primary



production was due to natural water or gas drive. For the present paper we will regard the injection of sea water as being the main secondary method in use in the North Sea. As shown in Table 1 water injection is being used (or planned to be used) in almost all North Sea fields currently under development. As far as can be ascertained the re-injection of natural gas is being used primarily as a means of storing the gas for later use and not as an aid to oil production. Consequently energy requirements for gas re-injection should not be counted as an input to oil production.

#### TERTIARY PRODUCTION METHODS

The term tertiary production encompasses thermal methods (e.g. steam-injection), carbon dioxide flooding, and chemical flooding (surfactants to reduce surface tension and ease the passage of oil through the rock and polymers to improve the efficiency of water injection). All these methods are still in the experimental stage for land-based fields and it is not known whether they will be used in the North Sea. However it is possible to make some general observations regarding tertiary recovery in the North Sea and then to make a tentative estimate of the possible energy requirements. Thermal methods are unlikely to be used in the North Sea for two reasons. First, they are best suited to higher viscosity crudes and the crude found in the North Sea is of low viscosity. Secondly, thermal methods are considered unsuitable for field depths greater than ~3000 ft because of the associated cooling problems. Thus it seems that carbon dioxide or chemical flooding are the only candidates for tertiary recovery in the North Sea. Of those we consider chemical flooding to be the more likely choice as this is known to be suitable for use after a water injection program and as stated above, water injection is being used in most North Sea fields.

## THE ANALYSIS

The analysis was carried out using data collected by J.K. Klitz as part of the IIASA (+) WELMM (++) analysis program [4]. This data base contains detailed information on all the facilities being used in, and associated with, the 13 fields currently in the most advanced stages of development. A complete WELMM analysis has been carried out for these fields up to and including primary production and this yielded a figure for the average gross energy requirement (+++) for crude oil (primary recovery) of 0.497 GJ/tonne, which compares well with other studies of single North Sea fields [5,6].

### a. Secondary Production

In order to calculate the increasing energy requirement as production is phased in, it is necessary to know what quantity of oil can ultimately be attributed to secondary production (above that which would have been obtained by primary production alone) and then allocate the additional energy inputs accordingly.

let  $T$  = total oil in place, in MTOE  
 $R$  = recoverable reserves, in MTOE  
 $r_p$  = fraction of  $T$  recoverable by primary recovery alone  
 $r_s$  = fraction of  $T$  recoverable using primary and secondary methods  
 $\Delta r_s$  = additional fraction of  $T$  due to secondary recovery =  $r_s - r_p$ .

- 
- (+) International Institute for Applied Systems Analysis  
(++) Water, Energy, Land, Manpower and Materials  
(+++)  
Includes all direct, indirect and capital energy costs of landing one metric ton of crude oil onshore and transferring it to a refining facility.

The value for the recoverable reserves, R, is normally quoted assuming secondary recovery so:

$$R = r_s \cdot T \quad \dots[1]$$

Now let  $E_i$  = initial energy invested in field (construction platforms, pipelines, etc.) in GJ

$e_p$  = ongoing energy requirement for primary production, in GJ/tonne

$e_t$  = energy for transportation of crude to shore, in GJ/tonne

Since the initial investment  $E_i$  is made in equipment and facilities which are used in both the primary and secondary phases,  $E_i$  must be apportioned to oil produced in both phases. Thus the energy requirement for primary production,  $e_1$ , is given by :

$$e_1 = \frac{E_i}{R} + e_p + e_t \quad \text{GJ/tonne} \quad \dots[2]$$

Now let  $E_s$  = additional energy investment in secondary production facilities, in GJ

$e_{ps}$  = additional ongoing energy for secondary production, in GJ/tonne

A = quantity of oil recovered after secondary production starts, in tonnes.

$e_{ps}$  can vary with time so we have  $e_{ps} = e_{ps}(t)$ .

We need to define  $r'_s$  as the fraction of A attributable to water injection, that is:

$$r'_s \cdot A = \Delta r_s \cdot T$$

or

$$r'_s = \frac{\Delta r_s \cdot T}{A}$$

The fraction  $r'_s$  of the quantity A is extracted at an energy cost of

$$e_1 + \frac{E_s}{\Delta r_s T} + e_{ps}(t)$$

while the remaining fraction,  $1 - r'_s$ , of A have an energy cost of  $e_1$ .

Thus the energy requirement during secondary recovery,  $e_2(t)$  is given by:

$$e_2(t) = (1 - r'_s) e_1 + r'_s \left[ e_1 + \frac{E_s}{\Delta r_s T} + e_{ps}(t) \right] \text{ GJ/tonne}$$

which simplifies to:

$$e_2(t) = e_1 + r'_s \left[ \frac{E_s}{\Delta r_s T} + e_{ps}(t) \right] \dots [3]$$

For all fields the operating companies' estimate was taken for the recoverable reserves, R. In some cases estimates were also available for T, the total oil in place. Where this was not available it was calculated from [1] using either the quoted value of  $r_s$  or an assumed value of  $r_s = 0.41$  (the average of all available estimates of  $r_s$ ). In very few cases was there a figure for  $r_p$  and in general an assumed value of  $r_p = 0.2$  was used.

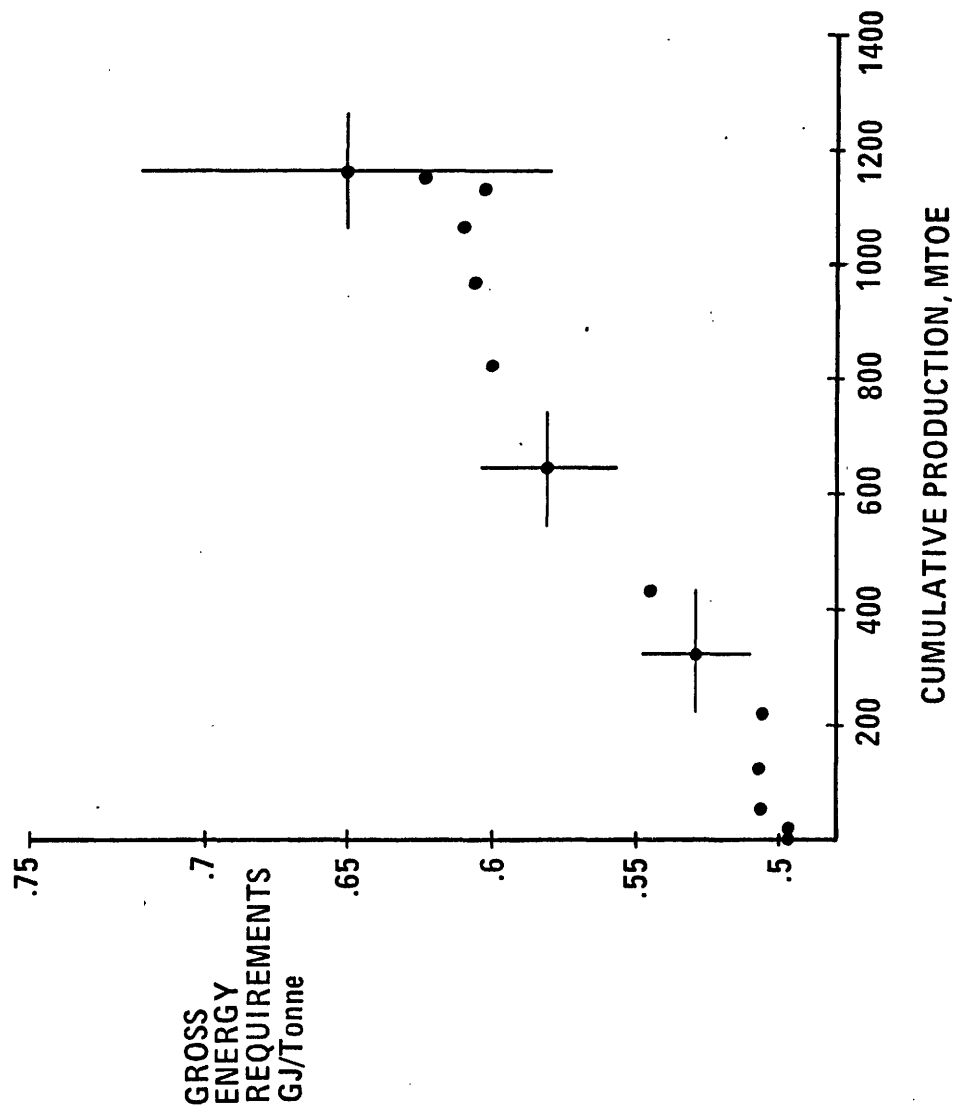
For each field a production profile was constructed using the operators' estimate of the time of start of production and the time, duration and magnitude of peak production. An exponential decay of 10% per annum was used for the declining phase.

The most important contribution to the additional energy investment in secondary production,  $E_s$ , is the provision of extra wells for the injection of water. Using the data collected in the IIASA study an energy analysis for a typical well (of 11,000 ft depth) was made and this was used in conjunction with available drilling data to find  $E_s$  for each field. Accurate figures for the planned numbers of production and water injection wells were available as well as details of numbers of wells to be drilled in a given year.

Further assumptions had to be made in order to estimate  $e_{ps}(t)$ . For most fields there is some uncertainty regarding the timing of the onset of water injection, the volume of water to be pumped and the pumping pressure. These parameters depend on characteristics of the field which can only be ascertained once production is under way. For example the Piper field has been found to have a substantial natural aquifer and may not now need additional water injection while in the Forties field water injection is already under way. However it is possible to make some general deductions from the available information. For example in all cases where water injection equipment is installed on a platform the capacity of the equipment, in barrels water per day, is equal to or slightly greater than the estimated peak production of the field, in barrels oil per day. In the case of the Auk field it is estimated that water injection of 70,000 b/d may be needed throughout the life of the field, while peak production is estimated at 50,000 b/d. From these facts we conclude that it is reasonable to assume that on average the rate of water injection continues at the maximum rate while oil production declines in the later stages. Knowing the flow rate, the pressure and the pump efficiency the energy requirement for pumping can be calculated. The manufacturers quoted pump efficiencies range from 28% to 32%; a figure of 30% was used. An injection pressure of 1250 p.s.i. at the surface was used throughout. Sensitivity calculations were made to find the effects on the final result of 50% uncertainties in either pressure or flow rate.

For each of the 13 fields a profile for the energy requirement was constructed using equations [2] and [3] for the primary and secondary production phases. The weighted average energy requirement was then calculated and this is shown as a function of cumulative production in Fig. 1. The vertical error bars show the results of the sensitivity calculations described above. Uncertainties in the timing of events are estimated to be  $\pm 1$  year in the early stages, rising to  $\pm 3$  years in the later stages; these lead to the horizontal error bars in Fig. 1. It is worth noting here

FIGURE 1. THE INCREASING ENERGY REQUIREMENT DUE TO SECONDARY PRODUCTION METHODS FOR 13 NORTH SEA FIELDS.



that by taking an average over 13 fields at least some of the uncertainties will cancel out.

b. Tertiary Production

As already stated it is not known whether tertiary production will be embarked upon in the North Sea or what the results would be. Consequently the analysis for this stage is very simple and is based on what is known for chemical injection programs in other parts of the world. Most information is available for fields in the U.S.A. where chemical injection is being used to follow secondary water injection. The different estimates given in the literature [7,8] for the possible increase in recovery factor due to tertiary methods range from 5% to 20%. For the present 13 fields under consideration these figures correspond to an extra production of 56 to 224 MTOE.

The best available estimates for the requirements in chemicals per additional barrel of oil produced [9] are:

$10_{-3}^{+5}$  lbs petroleum sulfonates

3 lbs alcohols

$1_{-}^{+}$  1/4 lbs polymers

In energy terms these chemical inputs correspond to an extra 1.78 to 3.19 GJ per additional tonnes of oil produced. If we assume the ongoing energy requirements for running platform, pumping etc. are the same as in the secondary phase then the above range of uncertainty in the energy for chemical is 2 orders of magnitude greater than other conceivable energy inputs such as the transport of the chemicals by sea from the U.K. to the platform.

The extremes of the possibilities of tertiary production are shown below:

	Min.	Max.	
Extra Production (for 13 fields):	56	224	MTOE
Gross Energy Requirements	2.43	3.84	GJ/tonne

## CONCLUSIONS

The increase in the average energy requirement due to secondary production techniques has been calculated for 13 specified fields in the North Sea. The gross energy requirement increases from 0.497 to 0.651 GJ/tonne; that is from 1.12 to 1.5 percent of the calorific value of the crude oil produced.

The possibilities of tertiary production have been calculated based on data available for chemical injection programs in the U.S. fields. The possible extra production from the 13 fields due to tertiary techniques is between 56 and 224 MTOE at an energy requirement of between 2.43 and 3.84 GJ/tonne. While we recognize that in practice it will be costs and not energy requirements which will determine whether tertiary methods are embarked upon, even the higher figure for the energy requirement represents less than 10% of the calorific value of the crude produced, indicating that tertiary methods for increasing the productivity of North Sea fields are worthy of more detailed consideration.



TABLE 1

THE 13 FIELDS COVERED BY THE ANALYSIS

FIELD NAME	WATER INJECTION PLANNED	ESTIMATED RECOVERABLE RESERVES. MTOE
ARGYLL	NO	4
AUK	YES	10
BERYL	YES	54
BRENT	YES	270
CLAYMORE	YES	68
CORMORANT	YES	22
DUNLIN	YES	79
FORTIES	YES	243
HEATHER	YES	20
MONTROSE	YES	20
NINIAN	YES	149
PIPER	YES	108
THISTLE	YES	74

REFERENCES

- [1] A. Verbraeck (Ed.), *Proceedings of the Ninth International INO Conference*, 1976.
- [2] W.G.B. Phillips, D.P. Edwards, *Metal Price As A Function of Ore Grade*, Resources Policy, September 1976.
- [3] Malcolm Slessor, *Energy Analysis, Its Utility and Its Limits*, IIASA, in preparation for publication, 1978.
- [4] J.K. Klitz, *North Sea Oil: Resource Requirements for U.K. Development*, IIASA Publication, 1978.
- [5] D.F. Hemming, *Energy Requirements of North Sea Oil Production*, Open University Research Report No. ERG 010, 1975.
- [6] E. Macleod, *Process Analysis on BP Forties Field*, Strathclyde University, 1976.
- [7] Lewin and Associates Inc., *The Potential and Economics of E.O.R.*, 1976.
- [8] V. Pominov, *Methods for Increasing the Recovery of Liquid and Gaseous Hydrocarbons From Underground Deposits*, Report to E.C.E., Geneva, March 1977.
- [9] C.W. Perry, *Chemicals for Microemulsion Flooding in E.O.R.*, Gulf University Research Consortium, 1977.