The Bigger the Better?

Contents: Data analysis and discussion concerning economies of scale, with particular reference to ethene manufacture.

Time: 2 periods or more, depending on how many parts are tackled.

Intended use: GCSE Chemistry and Integrated Science. Links with work on petrochemicals, ethene and cracking.

Aims:

- To complement and revise prior work on the manufacture and uses of ethene.
- To develop awareness of the idea of economies of scale in industry, and how they arise.
- To develop awareness of some of the problems associated with large production units.
- To provide an opportunity to practise data-handling skills.

Requirements: Students' worksheets No. 105.

This unit is in three parts.

Part 1 Are bigger crackers better?
Part 2 Is bigger always better?
Part 3 What about other industries?

Part 3 could be omitted if time is short.

The unit can be tackled on an individual basis, though some of the questions, particularly Q.15 onwards, would be most effectively answered working in small groups.

Less able groups may need some guidance with the calculations in questions 1–12. The calculations for the medium-size cracker have been entered in the table as an example for students to follow. Students should work through the calculations for at least one of the other two sizes of cracker to get a feeling for the way the various costs break down. However, if they are finding the calculations heavy going, it would probably be best to give them the answers rather than let them get bogged down. The answers are given in the table below.

Table 3 – Answers

	large cracker	*medium cracker*	*small cracker*
Q.1	3.5 tonnes	3.5 tonnes	3.5 tonnes
Q.2 Naphtha cost	£595	£595	£595
Q.3 Energy cost	£110	£110	£110
Q.4	£330 million	£230 million	£110 million
Q.5	£ 99 million	£ 69 million	£ 33 million
Q.6	500 000 tonnes	300 000 tonnes	100 000 tonnes
Q.7 Fixed cost	£198	£230	£330
Q.8 Total costs	£903	£935	£1035
Q.9	2.5 tonnes	2.5 tonnes	2.5 tonnes
Q.10 Income	£550	£550	£550
Q.11 Net cost	£353	£385	£485
Q.12 Profit	£ 47	£ 15	– £85

Notes on some of the questions

Qs. 13 and 14 Students will find that the large cracker is the most profitable, with the small one actually making a loss. This is because the larger the cracker, the smaller the fixed costs per tonne of ethene produced.

Qs. 15 to 18 These questions look at the problem of over-capacity, which is considerable in Britain and is likely to become more so as Middle East producers start to manufacture their own higher value petrochemical products.

Qs. 19 and 20 Communication is not a particular problem in large crackers because so few people are involved, but in more labour-intensive industries, communicating in a large plant can be difficult. In a large cracker, telephones and two-way radios are used.

Q. 23 Students may need help here, since they may not be sufficiently familiar with local industries to answer all the questions. It may be profitable to pool the experience of the whole class.

It would be most valuable if the unit could be followed by a visit or visits to local industry.

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THE BIGGER THE BETTER?

This unit looks at the economies of scale – the idea that large industrial plants are cheaper to run than small ones. Economies of scale have led to huge factories being built. But why? Why are large plants cheaper – and are they always better? We will use as an example the manufacture of ethene from petroleum.

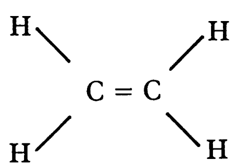
Part 1 Are bigger crackers better?

Why make ethene?

Over a million tonnes of ethene are made in Britain every year. That is 20kg for every man, woman and child.

And why should every man, woman and child *want* 20kg of ethene? Well, it is not much use on its own, but it is very useful for making other things.

The molecule of ethene contains a double bond.



This makes it reactive enough to join up with other molecules, and even with itself. Many different chemical products can be made from ethene.

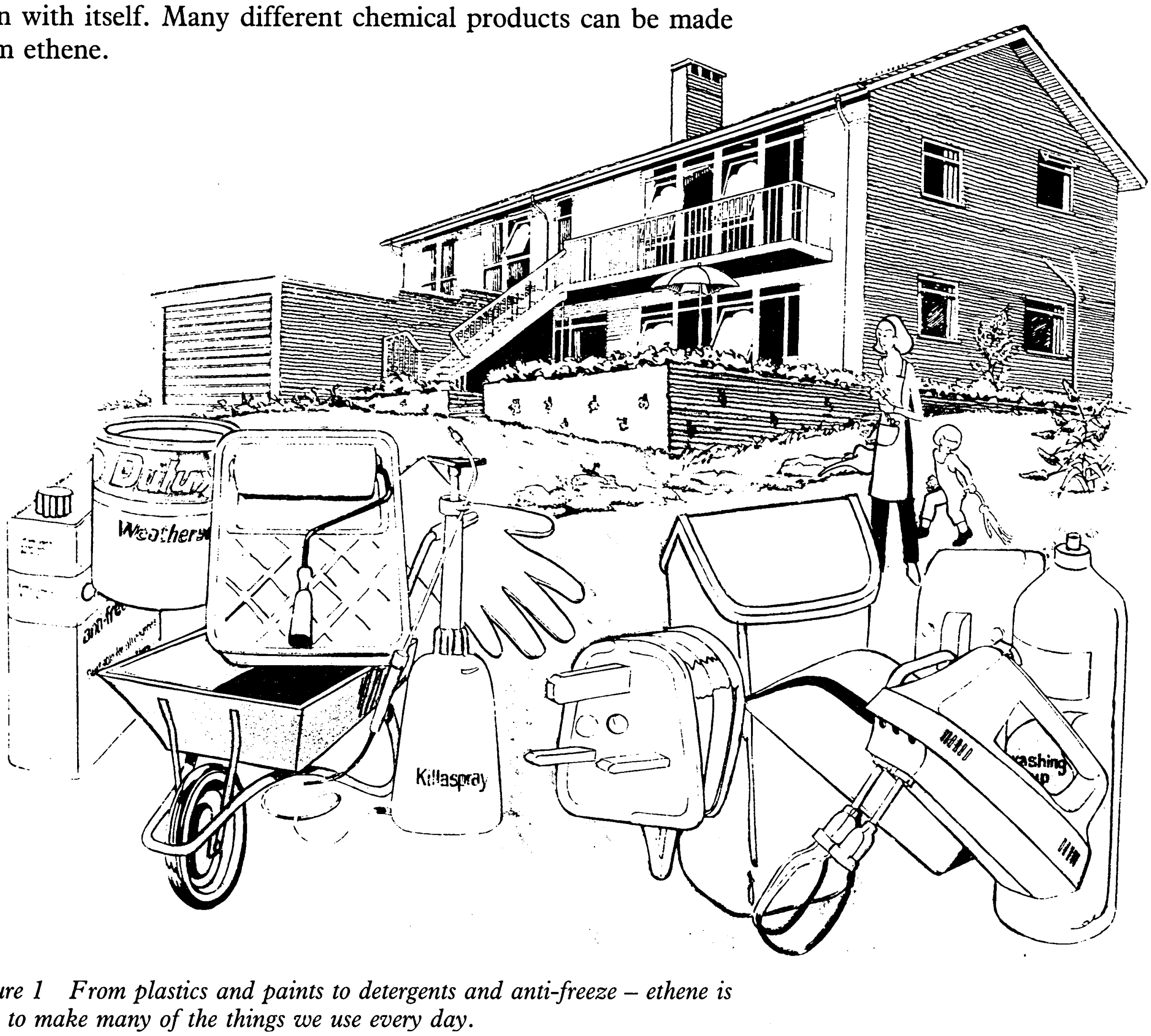


Figure 1 From plastics and paints to detergents and anti-freeze – ethene is used to make many of the things we use every day.

Adding value to oil

Most of the ethene produced in Britain is made from oil, although some is also made from natural gas. By distilling crude oil, a substance called **naphtha** can be produced. Naptha is similar to petrol. However, it is not used as a fuel but as a source of chemicals – **petrochemicals.**

Naphtha is a mixture of many different hydrocarbons. Most of them are alkanes, with between five and nine carbon atoms in their molecules. By heating naphtha vapour under the right conditions, its molecules can be made to break up into smaller molecules. This is called **cracking**. If the right conditions are chosen, a lot of ethene is formed when naphtha is cracked. This ethene can be separated off from other products and used to make many useful things. So, beginning with oil, we have a sequence of changes (Figure 2).

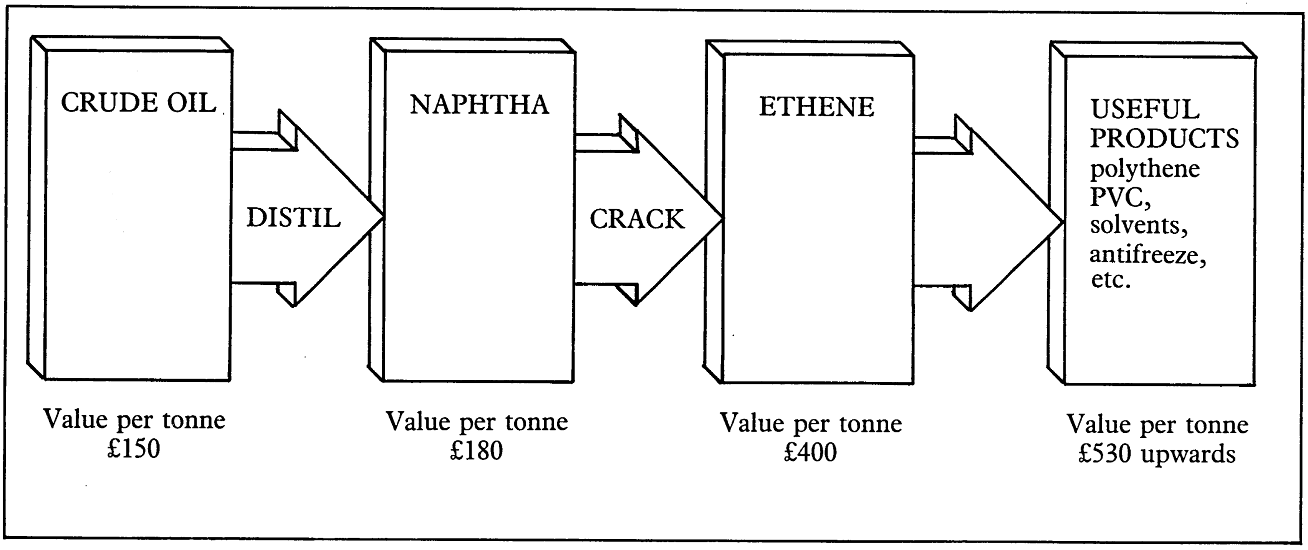


Figure 2 Adding value to crude oil

At each stage in this sequence, *value is added to the starting material*. This added value is needed to pay the wages of employees, run the plant and make enough profit to build new plants.

How big?

We will concentrate on the naphtha → ethene stage. This process is carried out in chemical plants called crackers. Crackers are very complicated, and often huge, as Figure 3 on the next page shows.

What is the best size for a cracker? In this section we will try to find out.

The balance sheet for a cracker

There are many different costs involved in running a cracker. Table 1 on the next page shows the main items.

Table 1 Income and costs of running a cracker

Income	*Costs*
Sale of ethene Ethene sells for £400 per tonne. *Sale of by-products* Cracking produces many by-products as well as ethene. These can be sold as fuel, or, better still, as raw materials for other chemical processes. For each tonne of ethene, 2.5 tonnes of by-products are produced. These can be sold at an average price of £220 per tonne.	*Cost of naphtha* To make a tonne of ethene needs 3.5 tonnes of naphtha. Naphtha costs £170 per tonne. *Energy costs* These are the costs of fuel, steam, electricity, etc., to run the plant. For each tonne of ethene produced, the energy costs are £110. *Fixed costs* These are the costs which are fixed, however much ethene is made in the plant. They include wages, maintenance and the cost of the plant itself. Fixed costs per year can be roughly calculated as 30% of the total cost of building the plant.

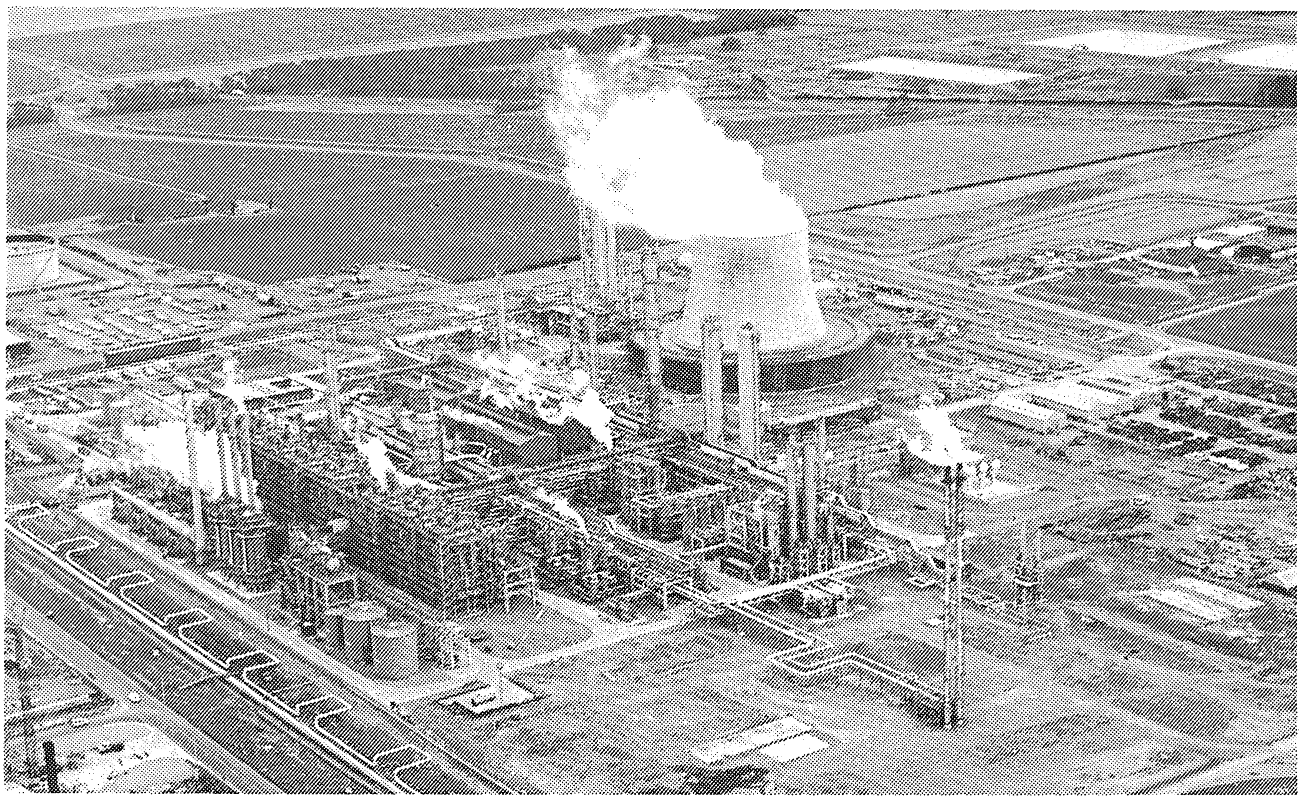


Figure 3 An example of a large cracker

The costs for three different-sized crackers

You are going to do some calculations to compare the costs of three crackers of different sizes. Table 2 gives the details.

Table 2 The costs of three crackers of different sizes

Size of cracker	*Tonnes of ethene made per year*	*Cost of building cracker plant*
Large	500 000	£330 million
Medium	300 000	£230 million
Small	100 000	£110 million

Draw up a table like Table 3. You are going to put the answers to questions 1 to 12 in the table.

Table 3

	large cracker	medium cracker	small cracker
Q.1	tonnes	3.5 tonnes	tonnes
Q.2 Naphtha cost	£	£595	£
Q.3 Energy cost	£	£110	£
Q.4	£ million	£230 million	£ million
Q.5	£ million	£ 69 million	£ million
Q.6	tonnes	300 000 tonnes	tonnes
Q.7 Fixed cost	£	£230	£
Q.8 Total costs	£	£935	£
Q.9	tonnes	2.5 tonnes	tonnes
Q.10 Income	£	£550	£
Q.11 Net cost	£	£385	£
Q.12 Profit	£	£ 15	£

Questions 1 to 12 help you work out the cost of ethene per tonne. Do all twelve questions for the large cracker first, then for the small one. The answers for the medium cracker have been worked out for you already, to help you with your own answers.

Questions

1 *How much naphtha do you need per tonne of ethene made? (see Table 1)*

2 *What is the cost of this naphtha? (see Table 1)*

3 *What are your energy costs per tonne of ethene made? (see Table 1)*

4 *What is the total cost of building your plant? (see Table 2)*

5 *The fixed costs* per year *are roughly 30% of the cost of building the plant. What are your fixed costs* per year?

6 *How many tonnes of ethene will you make per year? (see Table 2)*

7 *From your answers to questions 5 and 6, work out your fixed costs* per tonne of ethene made.

8 *From your answers to questions 2, 3 and 7, work out your* total *costs per tonne of ethene made.*

9 *How many tonnes of by-product will you get per tonne of ethene made? (see Table 1)*

10 *What income will you get from selling these by-products? (see Table 1)*

11 *From your answers to questions 8 and 10, work out your* net *costs per tonne, after allowing for income.*

12 *If you sell the ethene at £400 per tonne, what is your profit per tonne of ethene?*

Compare the profit per tonne from the three crackers – small, medium and large.

13 *Which size cracker is most profitable?*

14 *Look back at your figures. Can you explain why this cracker is the most profitable?*

Part 2 Is Bigger always Better?

Your calculations will have shown you that larger plants are more profitable. But this does not mean they are always the best ones to build. Think about these points.

1. *The plant needs to run at full capacity* Suppose a large cracker only produces 300 000 tonnes of ethene a year, instead of 500 000, because demand for ethene is low.

> 15 *What will happen to the cost per tonne of ethene? You can find out by going through the calculations for the large cracker again, using 300 000 tonnes per year instead of 500 000.*

2. *What happens if everyone builds large crackers?* Britain uses just over a million tonnes of ethene a year.

> 16 *How many 500 000 tonne per year crackers does Britain need?*
>
> 17 *ICI, BP, Shell and Esso all run petrochemical plants. What would happen if they* all *built 500 000 tonne per year plants?*
>
> 18 *Oil producing countries like Saudia Arabia are beginning to build their own large crackers so they can produce ethene instead of just crude oil and gas. They can then convert ethene to useful products like polythene for export. What is the advantage to these countries of doing this? What effect might it have on British petrochemical companies?*

3. *Communications and industrial relations* Most of the processes that go on in a cracker are automatic. Gases and liquids are moved around in pipes, often controlled by computer. Not many people are needed to run the plant, but the workers do need to be very skilful.

The area of a large plant is about 15 hectares, which is about the the same as 36 football or hockey pitches.

> 19 *What communication problems might there be within a large cracker plant?*
>
> 20 *Which do you think would be better for good industrial relations – a large plant or a smaller one? Why?*

4. *Distribution* Once ethene has been made, it must be distributed to the factories which use it to make other materials. Sometimes these factories are nearby, but sometimes they are a long distance away.

> 21 *What distribution problems may arise if a small number of very large crackers are built?*

5. *Environmental problems*

> 22 *Which do you think would cause fewer environmental problems – a large cracker, or several small ones? Why?*

Part 3 What about other industries?

In the case of ethene, economies of scale have led to larger and larger plants being built. But even with ethene, bigger is not necessarily always better, as large plants bring their own problems.

In other industries the economies of scale may not be so important as for ethene. It all depends on the type of industry.

Take furniture, for example. Making furniture is **labour-intensive**. This means it needs large numbers of people to make the products – far more than in an ethene cracker. Building an enormous furniture factory would lead to many problems – for example, with industrial relations, communications and quality control. It is difficult to take a pride in your work in an enormous factory where you feel no more than a cog in a huge machine.

23 *It is best to work in small groups on this question.*

(a) *Think of as many examples as you can of* small *industries in your local area or in a nearby town. In each case, say what the industry makes. As far as possible, try to decide why the factory is that size, and whether it could usefully be made bigger.*

(b) *Repeat part (a), but this time for any* large *industries in the locality. Once again, try to decide why the factory is large, and whether it could usefully be broken down into smaller units.*

If you get a chance to visit local industries, try to talk to people working there about what they think is the best size for their factory.