The chemical industry has existed as a major component of the UK manufacturing sector for nearly 200 years. It continues to be a major part today, with an annual turnover of over £60 billion and employing 600,000 workers.

In this topic guide, you will look at the general principles that determine a suitable location for a chemical plant – physical, human, environmental and economic – and apply these principles to several case studies and to a plant familiar to you or within your locality.

On successful completion of this topic you will:
- understand factors affecting the location of a chemical plant (LO1).

To achieve a Pass in this unit you need to show that you can:
- explain how factors influence the choice of location (1.1)
- assess the relevance of transportation costs and explain the importance of available resources (1.2)
- review the effect of an environmental audit on the planning process (1.3)
- explain the relevance of socio-economic issues (1.4).
1 Location factors

The distribution of chemical plants across the country is far from even, with many plants clustered in regions where the industry has always been strong, for example, Scotland and the north of England. The reasons these locations are favoured remain broadly similar to those that first gave rise to the industry in these areas – access to ports, large-scale labour force and availability of raw materials.

Across the country new manufacturing facilities are still being created, although now decisions about location are driven by access to imported crude oil, availability of a workforce with specialised skills and government grants for use of brownfield sites.

Traditionally, many of the heavy chemical manufacturing plants in the north of England and Scotland have been located near ports. Examples include the petrochemical works at Grangemouth on the Firth of Forth near Edinburgh and the Runcorn cluster of industries close to the port of Liverpool, as well as those based in Teeside and the Humber estuary. The locations of these are shown in Figure 13.1.1.

The significance of the port location for importation of raw materials and exportation of products will be discussed later in this section, but for a site to be suitable for any kind of chemical plant, it must fulfil a number of criteria that are inherent to that specific location.

*Figure 13.1.1: Much of the UK’s chemical industry is clustered in four key regions.*
Take it further

UK Trade & Investment (UKTI), a government organisation that helps businesses develop their markets, published a helpful and accessible report on the UK chemical industry in 2009 (available at http://www.cia.org.uk/Portals/0/downloads_pdf_1_Chemicals-Brochure-FINAL-JAN-09.pdf). This is an excellent source of background information about the chemical industry, as well as providing useful case studies of a number of new and developing aspects of the industry.

Activity

To enable you to complete the activities in these topic guides, you will need to select a particular chemical process to research. Your tutor will be able to advise you on your choice, but it should be a process with which you are familiar and for which you have access to information and data. Your place of employment may provide a suitable example, or it may be better to investigate a process in a local company that is willing to allow you to make contact with suitable employees to help you access the type of information you need. If you do this, it will be important to try to arrange a site visit to the relevant company.

As you work through the topic guides, you will find that some of the activities ask you to find out specific information about your chosen process. At the end of each section of the guide, there are instructions to enable you to produce the portfolio evidence you will need to meet the assessment criteria.

- Select a particular process to research and discuss it with your tutor. Arrange a site visit if necessary.

Geological factors

Many of the sites associated with the chemical industry have in the past been associated with large amounts of highly toxic waste materials, for example:

- heavy metals tailings from extraction of metals from ores
- sludges containing organic residues from oil refining.

The modern chemical industry in the UK now minimises the production and environmental impact of these residues, but in the past these residues may have been contained on site for long periods of time. The risk of leakage and contamination of surrounding soil was very significant, and the fate of the toxic materials depended largely on the underlying geology.

The key geological feature of a site concerns the hydrogeology (movement of water through rocks):

- soil particles can adsorb metal or organic contaminants
- this is enhanced by the presence of organic matter or clay content in soils; sandy or gravel-based soils allow more mobility of contaminants
- high density hydrocarbons that meet groundwater will sink through it until they meet an impermeable layer; at this point they will spread out
- low density hydrocarbons will float on top of groundwater.

Drainage

Chemical plants often occupy large flat sites as it is clear that building on hilly terrain will add additional construction costs to the building process. Such sites are likely to be found on flood plains or coastal sites and therefore may be prone to flooding. This has potentially disastrous implications for damage to the chemical
plant and the spreading of contaminants through the soil and into water courses. Good drainage is therefore essential; unfortunately the clay-based soils that restrict mobility of contaminants drain poorly. Sites built on such soils may need additional drainage.

In any case, flood defences may well be necessary for coastal or flood-plain sites.

**Activity**

For your chosen site, find out the underlying soil type – clay, gravel, sand or other type (for example, sedimentary rock).
- What implications does this have for the dispersion of metal or organic contaminants?

**Geographical factors**

**Greenfield and brownfield sites**

If a chemical plant is to be built in a new location then the land on which it will be built is likely to fall into the category of either a **greenfield site** or **brownfield site**.
- Planning regulations encourage the use of brownfield sites and discourage the use of greenfield sites; there may be subsidies available for developing brownfield sites.
- Brownfield sites may be of sizes or shapes that do not lend themselves to the design of a chemical plant.
- Brownfield sites may be already contaminated with industrial waste.
- Brownfield sites may already have access to infrastructure and local workforce; that may be less true for greenfield sites.
- Greenfield sites, as undeveloped areas of open countryside, offer greater scope for the large areas of land required for chemical plants.

**Take it further**

Although few completely new sites for chemical plants are being developed in the UK, countries such as India have a rapidly growing chemical industry and provide some interesting case studies highlighting the factors affecting the location of new chemical plants.


**Other geographical factors**

Other geographical factors that may need to be taken into account include:
- access to raw materials
- availability of a suitable energy supply (such as hydroelectric power, local coal mines or natural gas pipelines)
- the existence of infrastructure such as water and sewage supplies
- transport links
- access to a workforce with suitable skill levels.

These factors will be discussed further in Sections 2 and 3 of this topic guide.
Activity

Find out whether the chemical site you are studying is likely to need to expand the area of the site at some point in the future.

- Would the expansion involve the utilisation of brownfield or greenfield land?
- How likely would it be that planning permission would be granted for the use of this land?

Economic factors

Investment in new industry set-up became increasingly difficult to attract during the recession which began in 2008.

Some subsidies are available from government (regional or national) and from European sources. Examples of such sources include:

- support from the Department for Business, Innovation and Skills, which was formed in 2009 to replace the Department for Business, Enterprise and Regulatory Reform (particular help is given to innovative projects or projects with proven environmental benefits)
- support from Local Enterprise Partnerships (which replaced Regional Development Agencies in 2012), or Devolved Administrations in Scotland, Wales and Northern Ireland
- European support from, for example, the European Social Fund, which helps create employment opportunities in disadvantaged areas.

Take it further

The Chemical Industries Association (CIA) publishes pamphlets and reports providing an up-to-date picture of the UK chemical industry. Several useful case studies of the setting up of new chemical facilities are detailed in their 2009 report for the UK Trade and Investment organisation, available online at [http://www.cia.org.uk/Portals/0/downloads_pdf_1_Chemicals-Brochure-FINAL-JAN-09.pdf](http://www.cia.org.uk/Portals/0/downloads_pdf_1_Chemicals-Brochure-FINAL-JAN-09.pdf).

Environmental impact

Historically, chemical plants have had a considerable environmental impact:

- they occupy large areas of land, often near the coast, and can be highly visually intrusive
- there can be effluent emissions of vapour or waste liquids into the air or sea/rivers
- solid waste may need to be stored on site in waste lagoons
- hot water from coolant systems may be released into rivers or the sea.

Modern chemical plants are covered by strict environmental management regulations, which ensure the control of waste and emissions.

Take it further

In England and Wales, businesses are required to apply for an environmental permit to ensure that they comply with the Environmental Permitting Regulation (2010).

The Environment Agency website provides guidance on the application of these regulations ([http://www.environment-agency.gov.uk/business/topics/permitting/default.aspx](http://www.environment-agency.gov.uk/business/topics/permitting/default.aspx)).
Sustainability

Modern chemical plants aim to be as sustainable as possible.

In order to increase sustainability, increasingly the chemical industry is applying the principles of green chemistry to the design and operation of plants:

- processes are designed to maximise the mass of raw material that ends up in the desired product (the atom economy)
- substances used in the process (including solvents) should be chosen to have as little environmental impact as possible
- energy should be used as efficiently as possible in the process
- the amount of waste created should be kept as low as possible.

Take it further

Case studies of the application of green chemistry can be found at http://www.york.ac.uk/chemistry/research/green/.

Waste disposal

There are four main options for the disposal of waste:

- waste release: waste is released into the environment but is treated or contained to reduce the environmental impact. For example, solids may be contained by encapsulation, and liquid waste may be diluted to levels that are not environmentally damaging before release into the environment. There are now strict controls on such releases of waste.
- recovery recycling: waste is recovered and recycled back into the process.
- reuse: waste is recovered and reused in some other way (for example, sold to other industries).
- waste reduction at source: strategies are used that reduce the production of waste during the process. Examples of these strategies include the choice of reactions with high atom economy, use of green solvents such as supercritical CO₂, increased reclaiming of catalysts by using new zeolite-based processes, and so on.
Activity
For your chosen process, find out any of the environmental effects of the process on the local environment. You should consider what waste products are created by the process and how they are treated or disposed of.

Take it further
The vital issues of green chemistry and clean technology are discussed in detail in the Handbook of Green Chemistry and Clean Technology (Clark and McQuarrie, 2009).

Portfolio activity (1.1)
For your chosen process, describe the location of the plant where the process is carried out. Discuss the factors that may have been important in the selection of this site, or which are important now in ensuring the continued viability of the plant. In your answer:
• discuss the geographical features of the site, such as underlying geology, classification of the site as brownfield or greenfield, access to utilities, etc.
• discuss the economic features of the site, such as the availability of funding from regional, national or European sources
• discuss the environmental features of the site, such as the way in which disposal of waste products may impact on the environment.

2 Transportation and resources
A range of different materials need to be transported into and out of an operating chemical plant:
• starting materials, which may be raw materials, feedstock or commodity chemicals (in cases where seawater or air is the actual raw material used in a plant, this may be directly obtained from the locality of the plant)
• products
• waste materials, including co-products and side-products (see Topic guide 13.2)
• solvents and catalysts, which will usually be recycled within the plant in some way, but may require resupplying unless 100% is recycled
• energy – in the form of fuel or electricity supplied to the plant. In some cases the plant may export excess energy, such as electricity obtained from waste heat. In some cases, plants are deliberately built near sources of energy – for example, in coalfields or near to a source of hydroelectric power.

Transport costs
A range of transport solutions may be used:
• sea transport: crude oil and some other raw materials may arrive in the UK by sea. Many plants that use these materials are sited by the sea in suitable port locations. For many materials that are imported from distant locations, there is no alternative to this form of transport, since air transport would be extremely expensive and unsafe for transporting some materials
• **road transport:** if the product or starting materials are not too bulky they may be most easily transported by road, although the ongoing costs of doing this are high

• **rail:** coal and metal ores are needed in very large amounts by the iron and steel industry. Dedicated rail lines to these industrial sites allow large-scale transport of these raw materials to the site, as well as export of the refined metal from the site. Rail transport is cheaper than road transport, once the infrastructure is built

• **pipelines:** a network of pipelines exists in the UK to allow feedstocks derived from crude oil, such as kerosene and ethene, to be transported from refineries to plants across the country that use these feedstocks. The cost of building the pipeline is high, but ongoing costs are low

• **National Grid:** electricity for chemical plants can obviously be provided by the National Grid. However, some metal extraction processes require very large amounts of electrical energy; electricity supplied by the National Grid would be prohibitively expensive and so local sources of electricity are used, such as coal-fired power stations or hydroelectric power.

In addition, utilities such as gas, water and sewage involve the transportation of materials in and out of the plant. These were dealt with in the previous section.

### Case study

Aluminium extraction uses a vast amount of electrical energy; approximately 5% of the world’s electrical energy is used in this industry. At the beginning of 2009, the UK had three aluminium extraction plants:

- Anglesey, an island off the coast of North Wales
- Lynemouth, near Ashington in north-east England
- Lochaber, near Fort William in the Scottish Highlands.

The Anglesey and Lynemouth plants have closed since 2009.

1. Research the location of these plants and discuss the transport costs involved in the operation of the plant (include raw materials, energy and products).
2. Suggest why the plant at Lochaber has remained operational while the other two have closed.

### Activity

- Find out what resources are required by your chosen process. Explain how each of them is transported into or out of the plant.
- Are there any local resources (for example, energy or raw materials) that are used by the plant and which may help to explain its location?

### Workforce

The availability of labour is often related to transportation issues. Clearly, plants will need to be sited close to centres of population large enough to supply the workforce required for the plant to operate.

This is not simply a question of being located close to centres of population; a high-quality transport infrastructure will enable the workforce to be drawn from a greater distance.
Unit 13: Industrial chemistry

13.1: Factors affecting the location of a chemical plant

Case study
Grangemouth refinery (see Figure 13.1.2), on the Firth of Forth in central Scotland, employs around 2000 workers.
- Use a map to locate the Grangemouth site and comment on the suitability of the site in terms of the availability of workforce in the locality and the suitability of the transportation network to allow these workers to access the site.

Activity
- How many people are employed by the plant which operates your chosen process?
- If possible, find out where the members of the workforce live. For example: how far does a typical worker commute?

3 Environmental audits

Environmental site assessment has become increasingly important for chemical companies. One such type of assessment is an environmental audit. This is particularly important when:
- a company is proposing to introduce a new process or build a new facility
- a company needs to demonstrate compliance with legislation
- a company needs to satisfy its consumers or suppliers that it has good environmental credentials.

Various types of environmental audit may be carried out. The most significant to the topic of plant location are:
- **compliance audit**: checking that environmental legislation and company policy are being followed
- **health and safety audit**: assessing risks and planning for the possibility of accidents
- **site audit**: examining actual or potential environmental problems specific to the site.

I work for an international environmental assessment organisation, providing consultancy and project management services to a range of clients in the UK and Europe. My particular area of expertise relates to the ISO 14000 series of standards, particularly ISO 14001, which sets out the key criteria for an effective environmental management system.

To evaluate if a client is meeting these criteria, I will spend time in the organisation establishing what legislation is relevant to its operation and looking for evidence of compliance. This will involve examining its current environmental management systems and then observing the systems in action to look for a match with the paperwork. I also interview a ‘diagonal slice’ of personnel within the organisation and find out whether their perceptions of the operation of the systems matches what is written down in the paperwork.

Environmental auditor

Life Cycle assessment
Another very significant type of environmental assessment, which is increasingly being used in the chemical industry, is the Life Cycle assessment (LCA), in which the environmental impact of a product is assessed through every stage of its manufacture, use and disposal.

Link
You will find out more about the environmental and health and safety aspects of chemical processes in Topic guide 13.2.
13.1: Factors affecting the location of a chemical plant

**Site audit**

A site audit will concentrate on the effect of the operation of the plant on the local environment.

- If a plant is being set up from scratch, what is the environment like at present?
- What effect will the operation of the site have on local properties (visual impact of the site, smells from emissions, dust from delivery lorries, noise from operation of the plant and transport, etc.)?
- What effect will the operation of the site have on the natural environment (emissions into groundwater or rivers/seas, potential for contamination of soil, etc.)?
- What effect will the operation of the site have on the local infrastructure (increased traffic congestion, need for increased National Grid capacity, etc.)?

A company will need to be able to demonstrate that it can minimise the impacts identified in the audit.

**Activity**

Obtain access to a site audit for the site of your chosen process. Ideally this should be one that related to a planning application or an internal feasibility study.

- What were the major issues that were covered by the site audit?
- Did the planning application/feasibility study have a successful outcome?
- To what extent do you think the site audit was significant in the outcome of the planning application?

The Environment Agency makes available details of the permits that it issues to industry and businesses that carry out activities that have the potential to pollute the environment. The registers can be accessed at [http://www.environment-agency.gov.uk/research/library/publicregisters/default.aspx](http://www.environment-agency.gov.uk/research/library/publicregisters/default.aspx).

**Portfolio activity (1.3)**

Explain the importance of environmental auditing. In your answer:

- describe why environmental auditing is carried out
- describe an environmental audit that was carried out relating to the operation or siting of your chosen process
- describe the impact of the audit on the planning process.

4 Socio-economic factors

The Chemical Industries Association states that the chemical industry in the UK has a turnover of around £60 billion per year – about 2.5% of the UK Gross Domestic Product (2009 figures) and approximately 600 000 people in the UK workforce depend on chemical businesses. The discrepancy in these figures can be explained by the fact that the chemical industry is not a particularly labour-intensive one. Many of the jobs in the industry are in finance, marketing, R&D, management, etc. rather than directly in production.

As a result, there is a wide range of skills required by the workforce – from laboratory technicians and chemical engineers to accountants and IT personnel.
Many of these jobs will require qualifications at graduate level or equivalent; overall the workforce in the chemical industry earns 40% more on average than in other manufacturing industries.

Grants, including the European Social Fund, may be available to fund training for employees working in the chemical industry, particularly in areas of economic deprivation.

There may therefore be considerable socio-economic benefit to the local economy from the presence of a major chemical firm; not simply from the employment it provides but from the spending power of its relatively well-qualified and well-remunerated workforce.

### Further reading

An excellent introduction to the structure and operation of the UK chemical industry can be found in *The Essential Chemical Industry (5th edition)* (Clements, Dunn et al., University of York, 2010), which is produced by the Chemical Industry Education Centre at York as a resource for level 3 students and their teachers. The first 40 or so pages are a detailed and accessible exposition of the key principles on which the industry is based.


The issues of green chemistry, which underlie much of the way in which the industry is seeking to reduce its environmental burden, are described in a number of case studies on the website: [www.york.ac.uk/chemistry/research/green/](http://www.york.ac.uk/chemistry/research/green/).

A more detailed approach to green chemistry is the *Handbook of Green Chemistry and Clean Technology* (Clark and McQuarrie, 2009).

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