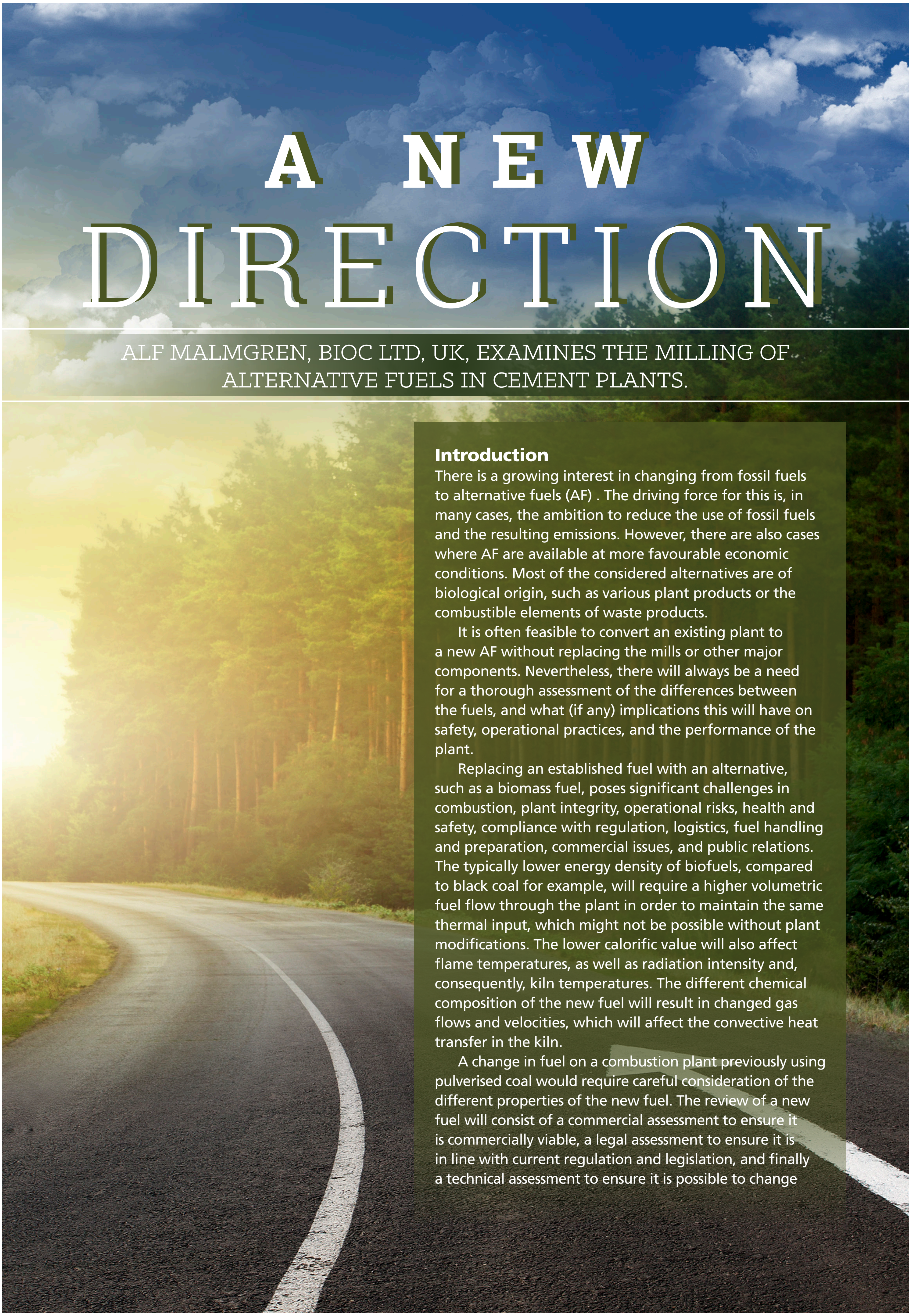

A NEW DIRECTION

ALF MALMGREN, BIOC LTD, UK, EXAMINES THE MILLING OF ALTERNATIVE FUELS IN CEMENT PLANTS.

Introduction

There is a growing interest in changing from fossil fuels to alternative fuels (AF) . The driving force for this is, in many cases, the ambition to reduce the use of fossil fuels and the resulting emissions. However, there are also cases where AF are available at more favourable economic conditions. Most of the considered alternatives are of biological origin, such as various plant products or the combustible elements of waste products.

It is often feasible to convert an existing plant to a new AF without replacing the mills or other major components. Nevertheless, there will always be a need for a thorough assessment of the differences between the fuels, and what (if any) implications this will have on safety, operational practices, and the performance of the plant.

Replacing an established fuel with an alternative, such as a biomass fuel, poses significant challenges in combustion, plant integrity, operational risks, health and safety, compliance with regulation, logistics, fuel handling and preparation, commercial issues, and public relations. The typically lower energy density of biofuels, compared to black coal for example, will require a higher volumetric fuel flow through the plant in order to maintain the same thermal input, which might not be possible without plant modifications. The lower calorific value will also affect flame temperatures, as well as radiation intensity and, consequently, kiln temperatures. The different chemical composition of the new fuel will result in changed gas flows and velocities, which will affect the convective heat transfer in the kiln.

A change in fuel on a combustion plant previously using pulverised coal would require careful consideration of the different properties of the new fuel. The review of a new fuel will consist of a commercial assessment to ensure it is commercially viable, a legal assessment to ensure it is in line with current regulation and legislation, and finally a technical assessment to ensure it is possible to change fuel safely, while maintaining reliable operation without compromising the plant's integrity. An assessment of the risk for negative public attention is often performed as well. A brief discussion of some aspects of a fuel change that need a proper assessment follows.

Alternative fuels examples

Many AF are biofuels. These are very different from fossil fuels, particularly when comparing solid biomass fuels to coal. Although coal is originally also biomass, the geological process it has undergone has altered its physical properties profoundly. Black coal is hard and brittle, while biomass fuels are typically soft and fibrous. Chemically, coal is at least 50% carbon and just a few percent oxygen, whereas biomass fuels often contain 30 – 40% oxygen and much less carbon. Biomass has much lower bulk density and also a lower calorific value, which means that it is less economical to transport longer distances, unless it has been processed in a way to increase the bulk density, for example the pelletising process. The production of biomass tends to be on a smaller scale than the large mines where coal is extracted.

Examples of AF that have been used in large combustion plants include: wood, forest residues, thermally-treated wood (torrefied or steam exploded), agricultural residues (cereal husks), byproducts from food industries (olive residue), and palm kernel expeller cakes. There are also numerous varieties and qualities of fuels produced from both municipal and industrial waste, which must be individually assessed for the specific process and plant they are intended for.

Commercial aspects

Any commercial activity is only feasible long term if it is profitable, or at least not loss making. The change from fossil fuels to alternatives must therefore be commercially viable by costing less, producing a higher income or ensuring valuable positive publicity in the form of a green image for the company.

The existence of a fuels trading infrastructure is an important commercial consideration. Many biomass fuels are byproducts of agricultural or forestry activities, and are produced on a small scale. Large users of fuels do not usually have an organisation suited to deal with small transactions, but are rather used to buying coal in hundreds of thousands of tonnes. The solution can be to introduce an intermediary organisation but this comes at a cost and makes the fuel more expensive. While an established trading infrastructure does imply that there are multiple suppliers in the market, access to alternative suppliers is important in reducing supply risk.

Legal requirements

Examples of legal frameworks that must be met are environmental legislation (Industrial Emissions Directive in the EU), waste legislation (Waste Incineration Directive in the EU), renewable fuels legislation, health and safety legislation, and dangerous substances and explosive atmospheres regulations in the EU (DSEAR). This is a complicated, but nevertheless critical, area of focus.

Health and safety aspects

Risk assessments related to the fuels need to be reassessed, taking the properties of the new fuel into account. Three areas that must be considered follow.

Fire and explosion

Dust explosions can occur if dust is released in explosive concentrations in the presence of an ignition source, such as a hot surface or spark. Some equipment is designed to contain explosions, for example in coal mills. An AF must be assessed to ensure there is no risk that the pressure containment capacity of such equipment is exceeded. When explosion suppressors are used, these will be dimensioned for a maximum rate of pressure rise during an explosion, and this will vary for different fuels and must be part of the assessment.

Many solid fuels can self-ignite. This is true for coal and a coal stockpile is routinely compressed to reduce the amount of oxygen that is present in the space between coal particles. This reduces the potential for oxidation of coal, which can lead to increased temperatures and auto-ignition. Biomass materials contain much higher oxygen concentrations and tend to self-heat by microbiological mechanisms rather than by oxidation. The risk mitigation will therefore need to be different. Exposure to water is also a significant risk in a wood pellets store. Different explosion and fire properties of the new fuel will require DSEAR zoning to be reconsidered.

Dust accumulating on ledges and other horizontal surfaces can self ignite if the layer is thick, and can form an explosive atmosphere if suddenly dispersed, such as during cleaning using pressurised air. Good housekeeping is therefore essential.

Handling properties

Biomass materials tend to be fibrous and difficult to feed because the fibres interlock and cause blockages much more readily than coal. A screw feeder or pneumatic transport line working reliably with ground coal might not work at all with ground wood pellets, even if the particle size distribution is the same, due to the fibrous structure.

A related problem is flow in a hopper or bunker. If ground fuel is stored in a hopper, bunker, or silo, this vessel will have been designed for a specific fuel and might not be compatible with the AF.

Dust released from different materials has varying particle sizes, densities, and surface structures, which will affect its tendency to stay airborne. Dust from standard wood pellets tends to become and stay airborne much more readily than coal dust. This means that dust concentrations can grow to levels where there is a risk of an explosive atmosphere forming during prolonged handling operations. This dust will also take

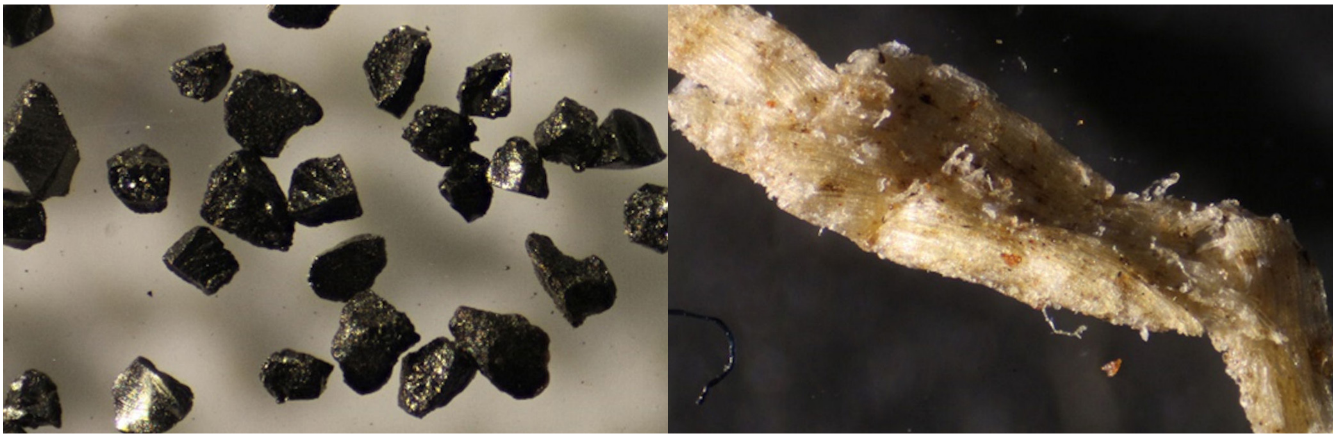

Figure 1. Coal particles to the left and a wood particle to the right. Both from a vertical spindle mill.

significantly longer to settle when the release of new dust stops.

Health risks from handling the fuel

De-gassing and oxygen depletion can be an issue in some biofuels. Wood pellets and wood chips can release significant amounts of CO and CH_4 and deplete the oxygen levels in the air. This can constitute a serious health hazard if the pellets are stored in a confined space such as a silo, a closed shed, or during trans ocean transport by ship. Monitoring equipment and rigorous procedures must be in place to safeguard the well-being of any personnel entering the store.

Fuel produced from biological materials will be subject to biological activities, including mould and rotting. These processes degrade the fuel, constitute a health risk in that hazardous spores can be released, and will also release heat that can lead to auto-ignition. These fuels might also attract the attention of birds and rodents.

Fugitive dust from handling processes can enter the respiratory tract and cause occupational asthma. Direct contact with eyes and skin can also cause irritation and allergic reactions and, as some are toxic, many materials have legal exposure limits that must be observed.

Ethical and PR considerations

It is largely accepted that the use of fossil fuels and emissions of CO_2 need to be reduced and this is even a requirement in many countries. Reducing the need to burn any fuel at all would be a logical method to do this, but if this cannot be conducted, the second-best method is to use a fuel that releases less CO_2 to the atmosphere per unit of heat; hence the industry attraction to biofuels. Converting from fossil to renewable fuels can also improve the green credentials of a company.

There are some potential pitfalls here: the production of the fuel needs to be sustainable, must not result in the displacement of indigenous people or wildlife, and must not have a negative impact upon any water and food supply.

An example of negative publicity surrounds palm oil plantations and the replacement of natural forests, the reduction in biodiversity, and the displacement of orangutans, in Indonesia. This became headline news at the same time as tests of using palm oil to replace fossil oil were conducted at several power plants. Many of the tests were consequently dropped. Some tests, although successful, did not lead to use of palm oil as a biofuel due to the risk of negative publicity.

Table 1. **Energy density of biomass fuel and coal**

	Coal	Fresh sawdust
Bulk density (kg/m^3)	~1000	~400
Net calorific value (MJ/kg)	~25	~8
Energy density (MJ/m^3)	25 000	3200

Technical aspects

Some key technical properties of a fuel that need consideration are discussed below. The assessment is usually conducted on two levels: feasibility and operational risk. One approach that has been used with success is to estimate the economic cost in terms of maintenance, levels of wear and tear of the plant, and staffing requirements.

Energy content

Energy density is the combined result of bulk density and calorific value, and is the amount of energy that can be released by burning one volume unit of the fuel.

A fuel with lower energy density will require a much larger store to provide supply for the required time period. Table 1 demonstrates this by showing the bulk density, calorific value and the resulting energy density for coal and fresh sawdust. The conclusion is that a conversion from coal to fresh sawdust (which is an extreme case, but a good illustration) will require almost eight times as high volume flow of fuel to produce the same thermal input.

The moisture content of the fuel is also significant. Biomass fuels with a lower ignition temperature than coal will impose limitations on the mill performance as the lower ignition temperature will necessitate that the maximum temperature in the mill is severely restricted compared to during coal operation. This means that the mill has a lower drying capacity if the outlet temperature of the mill is to be kept at a level that guarantees stable flames, which is required for safe operation of the plant.

Figure 2. Oversized wood particles recovered from the ash bath after passing through a power plant boiler.

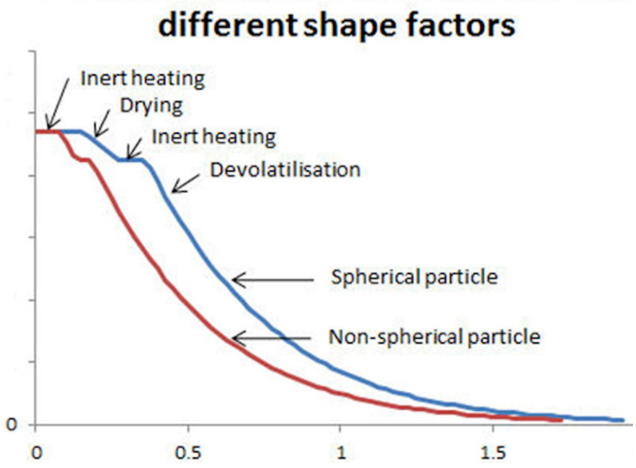

Figure 3. Combustion time for fuel particles of different size.

Mechanical properties

The fibrous nature of most biomass fuels makes them very different to the brittle coal. They are more ductile and the plastic deformation before fracture will require more energy for grinding to the same size. The resulting particles will also have very different shapes (Figure 1). The consequence of this is that they will react differently in the classifier depending on their aerodynamic properties. Dynamic classifiers are considerably less sensitive to this than static ones. The higher power requirement for the grinding of biomass fuels and the fact that they typically burn faster than coal means that it is desirable to grind them to a larger resulting particle size. This requires readjustments and sometimes modifications to the classifier.

Weather resistance

Coal and fresh wood chips are traditionally stored outdoors, exposed to the elements without problems. Wood pellets, on the other hand, will disintegrate and self-ignite if they are exposed to rain and will therefore require storing under dry conditions. This, in combination with the lower energy density, will add significant investment in large under cover storage facilities as part of any conversion from coal to wood pellets.

So-called second generation biofuels, for example torrefied or steam exploded biomass, are more weather proof and can be stored in the open without degradation or self-ignition. It is still preferable to allow them to enter the milling plant without too much surface water from the rain, as this will limit the milling capacity due to the lower temperatures in the mill, which makes it difficult to keep the mill outlet temperature sufficiently high for stable flames.

Combustion performance

Larger fuel particles need longer residence times in the flames to burn out completely. However, some materials are more reactive than others, which means they will burn faster and demand less residence time. Many biomass fuels have a high content of volatile substances that evaporate and burn in gas phase making the particles burn out faster. The optimal size distribution of a pulverised fuel for good combustion in a specific plant varies. Biomass particles can be larger and still burn out well, but there is a limit (Figure 2). It is usually possible to improve burnout by reducing the particle size, but at the cost of increased energy consumption in the milling plant, reduced mill capacity, and even lower output from the whole plant.

The burnout time will also depend on the shape of the particle, with a non-spherical particle burning faster than a spherical, due to its larger surface area in relation to its volume. The result of a simulation can be seen in Figure 3.

The calorific or heat value of the fuel will influence the combustion temperature, which in turn will affect the flame stability and therefore the risk for flame out and interrupted operation.

The behaviour of ash particles during combustion is crucial regarding the risk of slag formation in the furnace, as well as fouling in the convective parts. It is also an important factor in corrosion of metal surfaces that are exposed to the combustion products. AF have extremely varying ash contents, from clean stem wood with less than 0.5% ash to rice husks with more than 15% ash.

Conclusion

There are many factors that need assessing in connection to a fuel change, particularly such a drastic change as from coal to biomass. There is a growing amount of interest in these type of conversions and with proper testing and planning, a fuel switch can be carried out with minimal inconvenience and little risk to plant and staff.