FEEDLOT DESIGN AND CONSTRUCTION

6. Energy sources and supply

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Introduction

The feedlot production system is highly dependent on energy for equipment used to provide feed and water to livestock, manage waste (including pen cleaning, manure treatment and effluent disposal) and for administration and operation of the facility.

Energy sources are predominantly petroleum-based liquid and gas fuels and electricity from fossil or renewable sources. Energy prices are volatile but, as they generally rise over time, energy usage is an increasing input cost.

Infrastructure for energy storage and supply involve large capital and investment costs, and are long life assets. It must satisfy certain requirements that include an adequate storage volume, reliable and robust enough to resist disruptions (natural or human) and ideally, it should impose minimal environmental costs and security and safety risks.

Design objectives

Energy sources and supply systems should be designed and constructed to

- provide an adequate supply of energy for the feedlot's requirements
- have a redundancy supply capability in the event of loss or interruption
- be energy efficient
- comply with relevant acts and regulations
- protect against any environmental harm
- provide a safe working environment for all people.

Mandatory requirements

The installation and services for electrical and liquid fuel and gas must conform with the requirements of the latest issue of

- the local electricity supply utility's conditions of supply
- the local building regulations and the Building Code of Australia
- respective state and territory electrical safety acts and regulations
- respective state and territory acts and regulations for storage of flammable or combustible substances
- current Australian standards on electrical installations, services and cabling
- current Australian standards on storage of flammable or combustible substances.

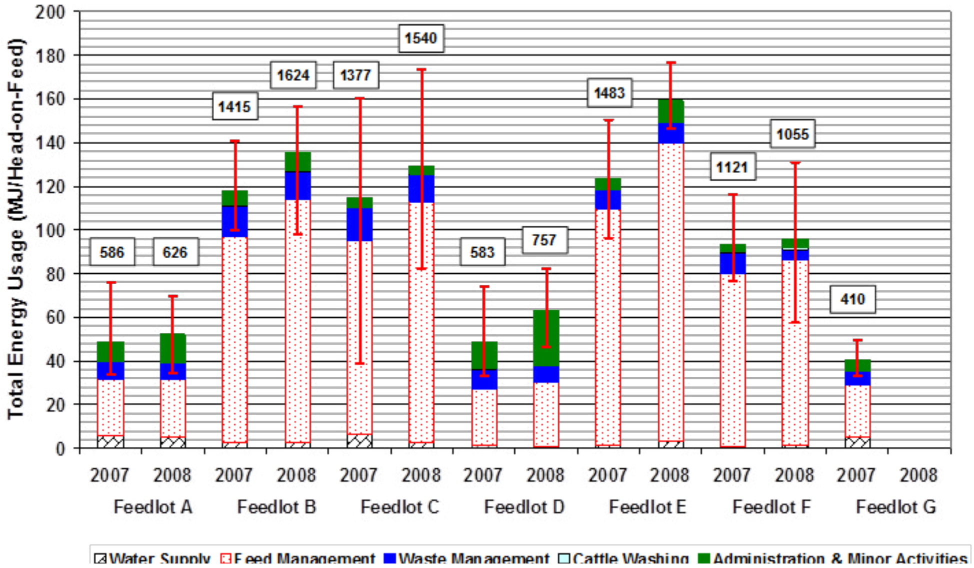


Figure 1. Average monthly total energy usage (MJ/head-on-feed/month).
Source: Davis et al. 2009

Design choices

Energy consumption

Energy consumption varies between feedlots depending on their size and levels of operational efficiency (Figure 1).

Total energy

Total energy usage within a sample group of Australian feedlots was measured from March 2007 to February 2008 (Davis and Watts 2006, 2009), along with the individual usage by water supply, feed management, waste management, cattle washing, administration and minor activities (cattle management and repairs and maintenance).

The average monthly total energy usage ranged from 40 MJ/month/head-on-feed to 124 MJ/month/head-on-feed. Feedlots with steam flaking averaged 100 MJ/month; those with grain tempering or reconstitution processing averaged 45 MJ/month/head-on-feed.

Energy for water

The energy usage for supplying water to the feedlot and for reticulation is a direct function of the system design (gravity or pumped), the pumping requirements (source of water and pumping head, distance), efficiency of the pumping system and power source (diesel or electric). The average monthly energy usage for water across all feedlots was 2.5 MJ/month/head-on-feed (0.04 MJ/month to 6.6 MJ/month). The total annual energy usage for water supply ranged from 12.3 MJ/year/head-on-feed to 77.7 MJ/year/head-on-feed.

Energy for water

Energy for feed processing

Energy for feed delivery

Energy for waste management

Overhead supply direct to on-site feed processing facility. This is located to avoid accidental contact with high machinery.

Energy for feed processing

The average electricity energy used for feed processing (excluding steam flaking) ranged from 20 to 50 MJ/tonne grain processed for seven feedlots. Variation in electricity energy usage may be attributed to monthly variation in grain delivery, movement, storage and milling efficiency (tonnes per mill). For steam flaking systems, the average gas energy usage ranged from 240 to 315 MJ/t grain processed, with some variation attributed to heating efficiency during winter months. Gas types included LPG, butane and natural gas.

Energy for feed delivery

At most feedlots, the energy usage for feed delivery totalled that for loading and for delivery.

The average monthly energy usage by loaders ranged from 7 to 22 MJ/t ration delivered, and depended on factors such as size of loader, bucket capacity, number of ingredients loaded and the other feed-related activities that the loaders may need to undertake. This may include transporting hay/straw from storage areas to tub grinders, silage from silage pits and high-moisture grain from storage areas.

The average monthly energy usage by feed delivery equipment ranged from 19 to 39 MJ/t ration delivered, and depended on factors including the number of trucks, volumetric capacity, engine capacity, commodity loading positions and pen layout.

Different feed mixing and delivery systems included stationary mixing, mixer/feed out trucks, bunker system, batch boxes and varying combinations in mobile equipment. Mobile equipment combinations included tractor/trailer mixer units, trucks with mounted mixers (various capacities and number, vertical, paddle and screw mixers), and varying loader sizes and number of ingredients loaded.

Energy for waste management

Typically, waste management contributes an average 14% of total energy usage (from 7% to 24%). Energy usage for waste management ranged from 6 MJ/head-on-feed/month to 15 MJ/head-on-feed/month with variation between feedlots attributed to the frequency of cleaning, equipment used and the volume of manure removed at each clean.

Energy sources

Electricity

Electricity is used to operate the various equipment, machinery and production processes.

The infrastructure associated with the electric power system includes supply side infrastructure such as overhead lines and transformers, equipment at the point of supply such as metering, switchgear and earthing, underground cable networks, feeder circuits, and switchgear associated with individual pieces of equipment.

Electric power is generally provided from overhead supply, but where there is no utility supply or the grid is not accessible, a prime power generator may be used. Power generators used as a primary power source (and not just for standby or backup power) can be defined as having an ‘unlimited run time’. Prime generators are usually expensive in terms of capital and running costs.

Point of supply – overhead supply

One of the first determinations in the planning of a feedlot is the nearest point of supply from the local power authority. The local power authority will be able to provide information on supply options and costs, but will require information regarding on-site electrical demands.

Specialist advice regarding on-site electrical demands should be obtained from a designer (electrical engineer) suitably qualified and experienced in this area. Some of the variables can be single-phase or three-phase supply, peak demand versus average loading, and high voltage versus low voltage metering.

In a single-phase distribution system, all the voltages of the supply vary in unison. Single-phase distribution is used when loads are mostly lighting and heating, with few large electric motors. Single-phase motors need additional circuits for starting and are rarely larger than 10 or 20 kW in rating. Single phase line connections are generally available for small domestic requirements.

Three-phase electric power is used to power large motors and other heavy loads and is the most common requirement for feedlots. A three-phase system is usually more economical than an equivalent single-phase at the same voltage because it uses less conductor material to transmit electrical power.

In many country areas, a single-wire, earth-return (SWER) line may be the connection. SWER delivers single phase power and is an economical way of distributing power because it needs only one transmission line (active). There is no neutral — instead, the earth is employed as the 'return' conductor. If three-phase motors have to be used, a single-phase to three-phase power converter has to be installed.

The location of the supply metering dictates the way in which the feedlot will be charged for its electric power usage. With high-voltage metering, the power usage is measured on the input side of the step-down transformer (usually at 11,000V). The feedlot will have to purchase and own the step-down transformer but this form of metering generally results in cheaper power costs. Low-voltage metering is carried out after the transformer (usually at 415 volts) and in this case the transformer is supplied and owned by the supply authority.

Electrical meters and metering

All sites that use electric power will have power authority electricity meters. The most common unit of measurement on the electricity meter is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules (3.6 MJ).

The most common type of electricity meter is the Thomson, or electromechanical induction watt-hour, meter.

Some newer electricity meters are solid state and display the power used on an LCD or can be read automatically. The solid state electricity meter may be able to display several different measurements, including voltage or current in the circuit and display the energy usage in each of the three phases separately or as a total.

Electrical energy can be metered by direct metering or current transformation metering.

Overhead electricity – supply with aerial transformer and sub-board

Overhead electricity – supply pole and transformer

Power Authority meter – solid state with LCD display

Power authority meters: electromechanical induction-rotating disc meter, with one meter for each phase

Typically, direct metering will be used in applications requiring less than 100 amps. Electromechanical or digital power meters are installed at the switch board with a separate meter for each phase. Hence, three-phase applications will have three meters.

In many feedlots, line currents may range from small to relatively large, such as in 150 A, so that the size of the conductor to measure the range and to produce an appropriately scaled output becomes prohibitive. In such instances, a current transformer is typically employed in conjunction with the electrical meter and the internal current sensing device of the meter. Conventional current transformers create a scaled output current, proportional to the line current which is supplied to the electrical load. The output current is sensed by the electrical meter and the power consumption of the associated electrical load is measured. Therefore, the transformation ratio (e.g. 80/5, 100/5) needs to be known to calculate the actual power usage.

Metering electricity at various points across the site is strongly recommended to provide data for energy efficiency assessments and management.

Network tariffs

Network tariffs are currently regulated by the Australian Energy Regulator. There are two main tariff components to an electricity bill

- retail component – to recover the purchase cost of energy from the generator
- network component – to recover the network costs (both distribution and transmission) of delivering energy to the site. This is a regulated charge levied by the distribution businesses to which the customer is connected, and by the transmission company that owns the transmission assets.

Retailers and transmission companies vary with each state and territory. In all except Victoria, electricity prices - the ‘standing offer’ tariff - are fixed by independent regulators. The WA and NT Governments directly regulate retail electricity prices while the Queensland Government can vary the regulator’s pricing decisions.

Each retailer has various network tariff classes to which all customers are assigned. The type of network tariff class will depend on facility location, power consumption, use and time of use.

Victoria, Tasmania, NSW and Western Australia have introduced some form of kVa or power factor network tariff. The power factor is a measure of how effectively electrical power is being used by a system. A poor power factor indicates ineffective utilisation of electricity; a good power factor indicates effective electricity and asset utilisation. Enterprises should understand the implications of their power factor and power factor correction when negotiating supply contracts. Power factor correction devices can be installed next to large electricity consumption plant such as feedmills, and these devices will improve the power factor and hence the efficiency of power usage.

It is recommended that specialist advice on network tariffs should be obtained from a suitably qualified and experienced person.

Safety

Unsafe use of electricity and accidental contact with overhead powerlines are common causes of injuries and death. Electricity can jump gaps so a person or piece of machinery may be some distance from a powerline and still be in danger.

Safe clearance distances should be maintained from overhead powerlines for structures (buildings, and stacked farm material), machinery (spray equipment, mobile elevators and mobile machinery) and vegetation. Safe clearance distances depend on the voltage and the type of powerline conductors (wires and cables). As overhead powerlines swing in wind and sag when hot, this movement must be considered in any clearance distance. The various state electricity acts prescribe a range of safe clearance distances.

Photovoltaic systems (Solar energy)

The installation of a photovoltaic (PV) system (either stand-alone or grid-connected) may be used to meet all or part of the electric power demand of a facility. Whether a PV system will be viable depends on the power demand and cost of supply of more conventional sources of energy. PV systems can be used in a wide variety of applications and are commonly suited for stand-alone applications at relatively isolated sites e.g. water pumping.

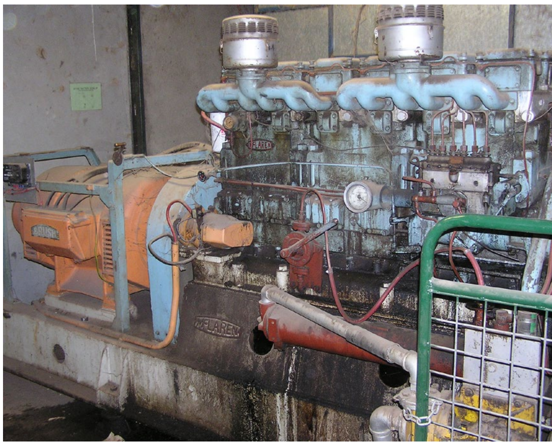
The design of a PV system needs to be realistic and flexible, and not be over-designed or the energy requirements overestimated (e.g. overestimating water pumping requirements). This will increase the cost of the system while not all the power available can be used. Dust and heat can be a problem with PV units located at feedlots. PV systems operate at their peak efficiency at 25°C, and their generation efficiency decreases as the temperature of the unit rises above this. In hot climates it may be necessary to cool the units with water sprays. Similarly dust from feedlot activities can coat PV cells and reduce their ability to generate electricity. If the PV cells have been installed at the correct angle to the horizontal, regular washing with water will remove the dust, and permanently installed water sprays operating on a timer can resolve both heat and dust problems. However, the water used must be free from salts that can coat the surface of the panels and reduce their productive capacity.

Since a PV system can generate electricity only when the sun is shining, some provision (e.g. battery bank or grid connection) must be made to have electricity supply during cloudy weather and at night, if required.

Every installation must be carried out by an accredited installer to meet the relevant Australian standards.

Backup electric power supply

Backup generators are a common and effective way of protecting a feedlot against the economic, social and animal welfare consequences of electric power disruptions. Most backup generators run on diesel but gas (natural, liquid propane)-driven generators are also available. The ability of a backup generator to provide continuous power, as long as it has a supply of fuel, makes it well-suited for providing both long- and short-term power. As backup power generators typically



Diesel engine-powered backup generator housed inside shed

Self-contained backup generator on skid-mount

work for short durations and do not heat up as much as prime generators, they are generally fitted with smaller cooling systems. Some small-capacity standby power generators can be air-cooled, eliminating the need for water circulation.

The purpose of the generator must be clear before purchase, and it must be adequately designed and sized to cover the power needs of designated loads. Initially, a generator may be chosen for standby usage only. However, if power outages occur frequently or for long periods, it might be worth the extra investment in a prime or continuous-rated power generator to ensure uninterrupted supply of backup power for extended periods of time.

Operating standby generators for longer than the prescribed number of hours at one time is likely to lead to more frequent breakdowns and malfunctions.

All standby generators are designed to automatically provide power to designated loads in the event of an interruption in service. When power is lost, the generator automatically starts and the load is automatically transferred from utility company power to the generator. Once utility company power is restored the load is transferred back and the generator shuts down.

While generator systems are reliable, they are not maintenance-free and require regularly scheduled maintenance to perform as and when needed. The specific testing and maintenance procedures for generator units will vary in accordance with the make, size and operating conditions; however as a guide, generators should be tested at least once a week. The most important maintenance task is the regular exercising of the entire system. The generator should be run under the load that it would normally power for at least 30 minutes at each test. By operating the system under load, the generator is tested along with its starting system, cooling system, and all switchgear required to supply power to the loads.

Main power supply - switchboard arrangement with switchover to backup generator

In addition to the program of regular exercising, other routine maintenance tasks must be performed. The batteries used to start the generator should be checked monthly. Each time the generator is run or exercised, the fuel supply should be inspected to determine how much is present and to ensure that it is free of contamination. The cooling and exhaust systems should be inspected monthly.

Sizing

Proper sizing of the generator is crucial to the success of any installation. This requires a good working knowledge of electricity and its characteristics as well as the varying requirements of the electrical equipment comprising the load.

The electrical load must be analysed to determine total starting and running requirements in terms of watts, amps and voltage. It may be cost effective to have more than one generator, either in a bank or located alongside various power-using operations.

Typically, kVa is used as the primary value when referencing the output power of generator sets. The primary difference between kW (kilowatt) and kVA (kilovolt-ampere) is the power factor. kW is the unit of real power and kVA is a unit of apparent power (or real power plus re-active power). The power factor, unless it is defined and known, is therefore an approximate value (typically 0.8) and the kVA value will always be higher than the value for kW. The standard power factor for a 3-phase generator is 0.8.

Generators with higher power factors transfer energy more efficiently to the connected load, whereas those with a lower power factor result in increased power costs.

Typically, the generator output for industrial applications should be selected at approximately 25% higher than the peak load. For example, if the load is about 40 kVa, select a 50 kVa generator. A higher-rated generator will operate comfortably at approximately 80% of its full capacity, and will provide a margin of flexibility if the load increases in the future.

Before installing a generator check for local authority codes that may dictate requirements regarding placement of the unit e.g. set back from building, electrical wiring, gas piping, fuel storage for gas or diesel tanks, sound and exhaust emissions.

For compliance with various state and national electrical regulations and for safety reasons, the backup power system must be installed, serviced and repaired by a qualified electrician who is familiar with applicable codes, standards and regulations.

Electrical services and cabling

Electrically powered equipment needs an appropriate power supply with switchboards, distribution boards, associated switchgear and cabling. Each control, switch, main switchboard and distribution board should be clearly labelled. All switchboards and distribution boards should be designed to be vermin proof with lockable doors.

All the cables should be installed on a cable ladder, in conduits or internal to walls or structure. Cables themselves must not be supported from roof structures nor left unsupported. Relevant standards must be put in practice in relation to cable supports.

All underground electrical services must be installed in accordance with the requirements of AS 3000. Layouts of underground services with quantity and size of cables and conduits should be marked and recorded accurately. Underground cable routes are to be marked with manufactured cable markers indicating the presence of underground cables.

Distribution boards should be located near electricity usage points so that the length of connection cable is kept as short as possible to reduce line losses.

All electrical installations must be carried out by an appropriately licensed electrical contractor.

Liquid fuels

Liquid fuel (diesel, petrol or gas) is required for mobile machinery and for some stationary plant. *Section 38 – Fuel and gas storage* details requirements for storage of these various fuel types.

Banked LPG storage tanks – with bollard protection

Diesel and petrol fuel storage with bowsers. Bunding behind and to each side of the facility is effective against spills; however it could fill with water after rain and has to be drained.

Renewable (bio) energy

There are four potential processes of energy recovery from biomasses such as feedlot manure. These include

Combustion

Combustion is the thermal reaction of oxygen with the carbon, hydrogen and sulphur in a fuel or solid waste yielding heat energy with the principal products of combustion being carbon dioxide, water and sulphur dioxide. When combusting sludge or manure, the amount of water (moisture content) and combustible material (volatile solids) present in the waste will significantly influence the quantity of usable energy which can be generated by the combustor or in fact, the amount of auxiliary fuel required to complete the combustion process.

There are currently no commercial facilities combusting feedlot manure in Australia but research and pilot-scale combustion trials have been conducted around the world. Research (Watts et al. 2013) has been conducted by MLA in this area.

Gasification

Gasification is a thermal process where a small portion of the waste (typically 5–15%) is combusted under starved air combustion conditions to raise the waste material to a temperature of about 900°C. The end products of gasification are a syngas comprising mainly carbon monoxide, hydrogen and carbon dioxide and an ash or char product, depending on operating temperature. Typically, gasification processes use air, oxygen and/or steam.

There are currently no commercial facilities gasifying feedlot manure in Australia. The high silica and ash content of feedlot manure means that existing biomass gasification systems may be of limited use. Gasifiers specifically designed to handle feedlot manure need to be developed with turnkey commercialisation if adoption is to occur within the industry.

Conventional gasifiers appear to be of limited use for the processing of feedlot manure.

Pyrolysis

Also called carbonisation, pyrolysis is universally regarded as a process where waste is heated indirectly, in the absence of oxygen, to a temperature of between 350 and 500°C. Under these thermal conditions the waste decomposes and 30–60% of the dry mass is volatilised to produce a crude syngas, with the remaining solids converted to a char product. In essence, pyrolysis is the thermal destructive distillation of organic materials.

Anaerobic digestion (Biogas)

Anaerobic digestion is a process that decomposes organic material (i.e. volatile solids) in the absence of oxygen. The mineralisation process is completed by microbial consortia composed of hydrolytic and fermentative bacteria as well as acetogens and methanogens. Bio-gas (CH_4) and CO_2 are produced as a waste product of digestion.

Research is also currently being conducted by MLA in this area. A few feedlots in the USA have installed anaerobic digestors.

Quick tips

- Determine available connection (e.g. single-phase, three-phase) of electric power from local power authority when planning a new development or upgrading an existing facility.
- Seek professional assistance when negotiating electric power supply contracts.
- Renewable energy systems such as solar or wind may be viable depending on the power demand and cost of supply of more conventional sources of energy. No bioenergy processes have yet been shown to be viable at Australian feedlots.
- Conduct a power supply risk assessment to determine contingency options for interruptions and/or loss of electric power.
- Generators are a common and effective way of protecting a feedlot against the economic, social and animal welfare consequences of electric power disruptions. Most backup generators are powered by diesel engines and should be checked every month.
- Obtain and keep a record of line diagram schematics and ratings of switchgear and cables of the electric power system.
- Record and keep layouts of underground services with quantity and size of cables and conduits.
- Installing meters for electricity and liquid fuel throughout the feedlot allows data to be collected for assessing energy efficiency.

Further reading

Standards Australia, 2009, Electrical Installations – Australian and New Zealand Wiring Rules (AS/NZS3000:2007), Sydney, NSW, Standards Australia.

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