CHAPTER 5

# IRRIGATION, ENERGY AND EMISSION EFFICIENCIES

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## 5.0 IRRIGATION, ENERGY AND EMISSIONS

The overall efficiency of the dairy farm operation is a function of what is produced (outputs) from what is used (inputs).

In addition to the milk produced, dairy farming, like other productive activity, creates unintended outputs in the form of by-products and emissions. Some of these are nutrient losses in farm runoff and drainage (refer to Chapters 3 and 4), while others are gaseous losses, including greenhouse gases.

Apart from nutrients (which are addressed in Chapter 3), some of the most important inputs introduced to the farm system come in the form of energy. Fuel and electricity are essential for basic dairy farm operations. Nitrogen fertiliser is an energy-intensive product to manufacture and so can also be considered a type of energy input into the farm system. Similarly, concentrated feed and supplements have an associated energy cost in their production and transport.

For irrigated farms, water is another critical input, which also usually has an energy use associated with it in the form of pumping.

New Zealand dairy production, based on the pastoral system with clover-fixed nitrogen, has gained an international reputation for its efficiency. However, farms with similar production levels can have markedly different levels of input energy intensity and therefore efficiency. This is mainly related to the level of irrigation and fertiliser inputs, with irrigation being the single most important determinant. The efficiency of production in terms of energy used per unit of product declines on irrigated farms since these tend to have higher inputs of both N fertiliser and electricity (refer to Table 5.0-1).

TABLE 5.0-1

**EFFICIENCY INDICATORS OF NON-IRRIGATED AND IRRIGATED DAIRY FARMING IN NEW ZEALAND**

| Indicators of Production and Efficiency | Average Non-Irrigated Dairy Farm | Average Irrigated Dairy Farm |
|---|---|---|
| Per cow milk production (kgMS/cow) | 304 | 346 |
| Nitrogen application rate (kgN/ha) | 68 | 135 |
| Electrical energy intensity (GJ/ha) | 3.4 | 12.2 |
| Total energy intensity (GJ/ha) | 16.9 | 30.6 |
| Total energy input (MJ/kgMS) | 21.6 | 33.6 |
| Gross $CO_2$ emission ($kgCO_2/kgMS$) | 1.4 | 2.0 |

*Wells, 2001*

Efficient dairying also means making the best use of all inputs for maximum production with minimum losses.

Management should aim to convert as much of the nutrients and feed inputs as possible into useful product and lose as little as possible to the environment.

Where irrigation is used, accurate scheduling and efficient application will make best use of the limited water resource and can also significantly reduce energy consumption.

The wise use of machinery fuel and electricity in the farm dairy will cut farm costs, place less demand on national energy resources and reduce greenhouse gas emissions.

Strategies to reduce methane and nitrous oxide emissions from agriculture are still being researched. However, there are some promising avenues to allow farmers to cut back on these emissions while maximising the efficiency of production. These focus on alternative feeds, genetic breeding and soil and effluent management.

## 5.1 IRRIGATION

In the drier climate zones of New Zealand irrigation has dramatically increased production on dairy farms. Water is becoming increasingly important component of farming in New Zealand and its rural economy. Irrigation which was once regarded as an insurance policy type tool has now become an integral part of farming especially in summer dry areas. Irrigation has had a key role in revolutionising farming practices in many parts of New Zealand.

For irrigation to be economic, the increase in production must create enough extra income to cover the cost of purchasing, installing, operating and maintaining the system while still providing an acceptable return on investment. This is most likely in sites with less reliable rainfall and free-draining soils with low water storage capacity.

Irrigation also offers other benefits:

- decreased personal stress associated with climatic variability
- better pasture cover which may decrease the risk of erosion and weed invasion
- a build-up of organic matter in the soil, which can improve water holding capacity and nutrient retention.
- an increase in earthworm activity in the soil.

However, with the increased production from irrigation come other costs and considerations, as irrigation may require:

- a large rise in energy use and associated cost to the farm business and the environment
- changes to farm layout and shade and shelter plantings (depending on the equipment used)
- increased fertiliser use and effluent disposal due to an overall rise in farm production
- increased labour involved in shifting and maintaining the irrigation system
- servicing of debt for the capital cost of the system.

While irrigation reduces the risk from climatic factors, it may expose the farm to higher financial risks or the risk of losing access to the water supply. On-farm storage is one way to reduce the risk of losing access to water and also to lessen the impact on other users.

Increasing demand for water has put some water supplies under stress and has fuelled debate among competing users as to how limited supplies of water should be allocated. Efficient and responsible use will enable dairy farmers to make the best case for ongoing access to the resource. Irrigation technologies and techniques have been developed to minimise nutrient loss and improve irrigation efficiency (refer to 5.1.1.1 Monitoring soil mositure).

Water extraction can have a number of impacts on surface waterways. The waterway may have a reduction in flow rate, depth and area, giving lower water volume. This can affect the physical waterway by reducing the surface area, amount of braiding and frequency and duration of river mouth closure in some cases. Sediment patterns and gravel transport may also change if flushing of the waterway does not take place, impacting on flood scheme users.

Water quality changes can result from lower flows, including warmer temperatures, higher pH and higher nutrient concentrations. The consequent increase in algae and water weeds can decrease oxygen levels in the water.

Table 5.1-1 lists a range of possible consequences of these changes.

TABLE 5.1-1

| SURFACE WATER EXTRACTION CAUSING STREAM DEPLETION - POSSIBLE IMPACTS TO WILDLIFE AND TO RESOURCE USERS | |
|---|---|
| **What/ Who Is Affected** | **Impact** |
| Bird life | Habitat quality decreased, predation increased and higher incidence of nesting failures |
| Aquatic insects and invertebrates | Lower diversity of species and reduced populations, habitat area and quality decreased |
| Fisheries | Temperature range may exceed tolerance of some species, habitat area and quality decreased, food sources restricted, spawning access and success decreased, predation increased |
| Recreational users | Fewer opportunities, aesthetic values impacted on, less suitable water quality for contact recreation |
| Flood control schemes | Lower flows mean less sediment is flushed from the system, which can raise bed levels, flood risks and pumping costs |
| Other users | Less water available, water treatment costs increased, stock water availability and suitability decreased |
| Māori | Spiritual values impacted on (mauri), less access to some culturally important foods |

Groundwater takes can also impact on other users, either in the immediate vicinity of a bore, or over the extent of a whole aquifer if abstractions exceed recharge rates and lower the water table. This can also affect the springs that feed waterways.

Runoff or leaching may also be increased where water is over-applied, with consequent effects on water quality. Poorly operating irrigation systems will apply too much water, saturating the soil. This will waste water and power, and increase the risk of pasture or soil damage and nutrient loss.

As the effects of managing the water resource extend beyond the farm boundary, in most cases a water take for irrigation will require a resource consent from the Regional Council. Complying fully with the conditions and achieving efficient irrigation will ensure that the above potential effects are minimised.

To achieve efficient irrigation and maximise the benefits, a sound understanding of the soil-water balance is required. Based on this, decisions must be made about design and operation, including these aspects:

- new system design
- planning of applications
- efficient operation of the system during the season
- reviewing performance at the end of the season.

Note that issues with irrigating effluent and reducing water use in the farm dairy are discussed in detail in the Dairying and the Environment Committee manual Managing Farm Dairy Effluent.

### 5.1.1 The soil-water balance

The basic objective of any irrigation system is to supply water to overcome a soil moisture deficit, which would otherwise limit plant growth.

A simple analogy for soil under irrigation is an ordinary dishwashing sponge. If you soak a sponge in the kitchen sink it becomes saturated. Lift it out and the free draining water keeps dripping until the field capacity is reached. Then start squeezing the sponge, the first half of the water comes out fairly easily; however you have to squeeze tighter and tighter until eventually reaching permanent wilting point where no more water comes out.

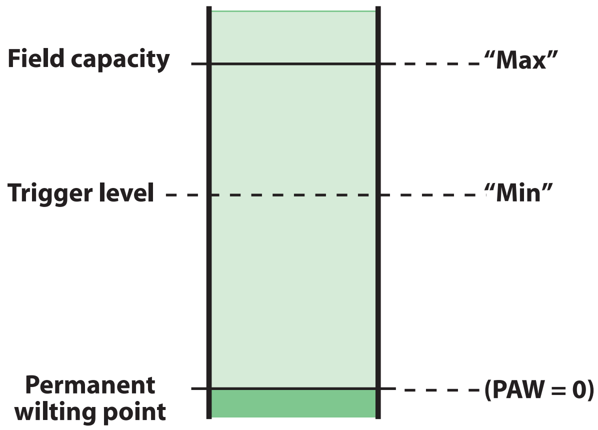
The following concepts are useful when planning the correct application and timing of irrigation events (refer to Figure 5.1-1):

- saturation point is when the soil is completely full of water. At saturation point, the water table is at the soil surface. Any additional irrigation or rainfall will be wasted as surface runoff or drainage below the root zone

- field capacity is the soil moisture content after the soil has been fully saturated and excess water has drained freely from the soil for 24 hours. At field capacity, plant roots can readily draw water from the soil
- permanent wilting point is the soil moisture content at which plants can no longer draw water out of the soil. At the permanent wilting point, plants will be so short of water that they will not recover, even if water is subsequently applied
- available water capacity is the amount of water held in the soil between permanent wilting point and field capacity. Available water capacity varies with soil type (refer to Table 5.1-2)
- evapotranspiration is the combination of water evaporated from the soil surface and the water transpired by plants. It indicates soil water loss that can only be replaced by either rainfall or irrigation
- soil moisture deficit is the difference between field capacity and current soil moisture levels. It indicates how much water has been lost through evapotranspiration and drainage
- the critical deficit is the soil moisture deficit after which drought stress will be experienced by the plant.

FIGURE 5.1-1

**IRRIGATION TERMS**




Note: Field capacity, permanent wilting point, and available water capacity are all specific to a given type and depth of soil; as such these properties do not vary over time (they are the same year to year). The critical deficit will vary according to the type and stage of the crop. The critical deficit for pasture is typically 50% of the available water capacity of the soil profile.

In summary, irrigation aims to keep soil moistures between the critical deficit (stress point) and field capacity, so that growth is not limited, and water is not wasted (refer to 5.1.4.1 Irrigation scheduling).

TABLE 5.1-2

**AVERAGE AVAILABLE WATER CAPACITY OF VARIOUS PASTORAL SOILS**

| Soil type | Available water capacity (mm water / 100 mm depth of soil) To a depth of 0.3 m | Available water capacity (mm water / 100 mm depth of soil) Depths below 0.3 m |
|---|---|---|
| Sand | 15 | 5 |
| Loamy sand | 18 | 11 |
| Sandy loam | 23 | 15 |
| Fine sandy loam | 22 | 15 |
| Silt loam | 22 | 15 |
| Clay loam | 18 | 11 |
| Clay | 17.5 | 11 |
| Peat | 20 to 25 | at least 20-25 |

#### 5.1.1.1 Monitoring soil moisture

Being aware of soil moisture levels throughout the season is critical to making sound decisions for optimum water use.

Soil moisture measurements should be taken from a variety of places over the property as single site observations are not likely to be representative. There are a number of options available to monitor soil moisture, including the following:

- observation is the most basic method, by digging holes to check soil moisture on the surface and subsurface. This requires experience for accurate interpretation
- tensiometers indicate soil moisture indirectly by measuring soil moisture tension (how freely water is available to the plant). Tensiometers work best at the 'wet end' of the range
- devices are available such as Aquaflex cables, TDR, resistance meters and neutron probes. These can be accurate and reliable, and are able to measure soil moisture throughout the soil profile to allow precise scheduling. However, the equipment is expensive and most likely to be used by consultants or advisors rather than farmers. Each type of equipment has advantages and disadvantages, which should be discussed with an advisor
- water budgets and water balances track soil moisture. From a known start point of soil moisture - usually field capacity at the start of the irrigation season - expected changes in soil moisture are estimated by adding rainfall and irrigation, and subtracting evapotranspiration (refer to 5.1.1.2 Monitoring evapotranspiration). A water budget is inexpensive and reasonably accurate if it is done carefully. However, errors do accumulate to a point where soil moisture estimates can be inaccurate towards the end of the season.

#### 5.1.1.2 Monitoring evapotranspiration

Evapotranspiration (ET) is the total water lost by direct evaporation from plant/ soil surfaces and water transpired from plants. This is water lost from the soil that needs to be replaced by irrigation or rainfall.

ET figures calculated from weather station data are commonly presented in local newspapers or on Regional Council websites during the irrigation season. Kits may also be purchased to measure ET on the farm.

#### 5.1.1.3 Monitoring water applied

Knowing how much water an irrigation system actually uses is an important precursor to effective and efficient management. It is also important in order to demonstrate that resource consent conditions have been met.

A recommended method for measuring water flow rates or volumes through the pump is to use a water meter. Look for a meter that meets ISO or similar standards.

Electricity use is only a good proxy for direct measurement of water use if the operating conditions of the pump or irrigation system do not change significantly (e.g. groundwater level variation, pump wear, different flow rates). A water meter is preferable.

Where irrigation systems are applying water at more than one location of the farm at the same time, a water meter on each irrigator is recommended for management precision.

While a water meter indicates how much water has passed through the pump it may not be an accurate measure of water applied due to factors such as wind, leaking noses or blocked nozzles therefore it should be used in combination with techniques to determine actual application rates (refer to 5.1.5.1 Testing irrigator efficiency).

### 5.1.2 Irrigation application variables

When determining irrigation applications, and when purchasing new equipment, the key variables of irrigation application must be taken into account:

- application depth (mm)
- application rate (mm/hr)
- return period (days)
- uniformity of application.

#### 5.1.2.1 Application depth

The application depth (mm) is the amount of water applied at any one time (i.e. in a single pass, run or application).

The optimum amount of water applied per application depends on the available water capacity of the specific soil type and the current water volume held in the root zone. The prevailing weather conditions and predictions should also be taken into account.

The application depth is calculated by first determining the Available Water Capacity (AWC) for a known soil profile, either by using Table 5.1-2 or other published data on the particular soil type.

For example, based on Table 5.1-2, for pasture with a rooting depth of 70 cm in a loamy sand soil, the AWC would be:

18 mm AWC / 100 mm soil depth X 300 mm soil depth = 54 mm in the top 300 mm

\+

11 mm AWC / 100 mm soil depth X 400 mm soil = 44 mm in the next 400 mm

= a total of 98 mm AWC in the top 700 mm of soil.

The application depth is then given by: AWC (mm) X critical deficit (%) / 100

The application depth for this example is 50% of the AWC (based on a critical deficit of 50%), therefore the application depth is 49 mm.

This is referred to as the net application depth, however allowances should be made for irrigation inefficiencies of the equipment (refer to Table 5.1-3).

The gross application depth (to account for application efficiency) is:

$$\frac{\text{net application depth (mm) X 100}}{\text{application efficiency (\%)}}$$

Therefore based on Table 5.1-3 using a spray irrigator to apply a net application depth of

49 mm, the gross application depth would be 61 mm (49/80 x 100).

TABLE 5.1-3

**EFFICIENCY OF APPLICATION FOR VARIOUS IRRIGATION METHODS**

| Method of application | Application efficiency (%) | |
|---|---|---|
| Trickle | | 100 |
| Spray | Night watering<br>Average day watering<br>Day watering in hot, windy weather | 90<br>80<br>60 |
| Control flooding | Border dyke | 70 |
| Semi-controlled flooding | Wild flooding, little or no prepartion and no spreader banks | 50 |

### 5.1.2.2 Application rate

The application rate (mm/h) is the speed at which water can be applied. If water is applied at a greater rate than the infiltration rate of the soil, runoff can occur and water and nutrients will be lost and may pollute waterways.

Application rate depends on the depth of water applied relative to the area it is applied on and the watering time of the system. The smaller the 'footprint' or 'wetted width' in relation to the total water flow through the irrigator, the higher will be the instantaneous application rate (the amount of water actually applied to that spot at that time).

Different types of irrigation systems have varying capacity to adjust the application rate. Travelling and rotating irrigators can be set so that their speed and application rate is appropriate for the soil type. However, these systems may not have a high uniformity of application, with a high variation in the instantaneous application rate at different points across the irrigator's path (refer to 5.1.2.4 Uniformity of application).

The maximum application rates given in Table 5.1-4 are for soils on pastoral land of up to 8° slope. Note that these are maximum figures and the input to the soil will be less, depending on the weather conditions.

TABLE 5.1-4

**IRRIGATION RECOMMENDATIONS FOR VARIOUS SOIL TYPES UNDER PASTURE COVER**

| Soil type | Maximum application rate (mm/hr) |
|---|---|
| Sand | 32 |
| Pumice | 32 |
| Loamy sand | 32 |
| Sandy loam | 20 |
| Fine sandy loam | 17 |
| Silt loam | 10 |
| Clay loam | 13 |
| Clay | 6 |
| Peat | 17 |

Note1: If figures are available for a specific soil type use them instead
Note 2: Application rates for land slopes up to 8º with low to steep hills refer NZS 1503, 1973
Note 3: Lighter application rates should be used when establishing pastures and crops
Note 4: If peat is very dry, start irrigation by using lower application rates and more frequent applications.

*New Zealand Pastoral Agriculture Research Institute Limited; NZS 5103, 1973; Livingstone, 1992.*

### 5.1.2.3 Return period

The return period (days) is the time that elapses between irrigation applications to allow for infiltration and efficient water use.

The ideal return period corresponds to the number of days required for the soil to reach the critical deficit. This varies, depending on crop water requirements under current weather conditions and evapotranspiration (ET) rates.

The return period is calculated by:

Net application depth (mm)

Evapotranspiration (mm)

For an irrigation system applying 50 mm of water to a soil with a AWC of 100 mm the return period for two different scenarios is shown below:

In the spring, assuming no rain with a spring mean monthly ET of 2 mm/day

The return period is:

- 50 mm/2 mm per day = 25 days

In the summer, assuming no rain with a mean monthly ET of 5 mm/day

The return period is:

- 50 mm/5 mm per day = 10 days

The decision when to reapply water will also be adjusted based on:

- the irrigation system's ability to move around the property
- district scheduling schemes (e.g. for border dyke systems)
- stock rotations
- prevailing weather to obtain the benefits of rainfall.

### 5.1.2.4 Uniformity of application

Any factor that causes uneven watering can heighten the risk of leaching or runoff of nutrients. It also increases the potential for under-watering or over-watering various parts of the paddock. In practice, a number of factors cause uneven watering:

- irrigation system design. Gun systems tend to be the least uniform, whereas travelling systems that can be adjusted, or low-application rate sprinkler systems are more uniform (refer to 5.1.3.3 Application efficiency of different systems)
- physical nature of the farm. A high application rate will give uneven watering on uneven or sloping ground, and ponding may occur. In this situation, particular care should be taken to ensure that application rates are kept low
- prevailing weather conditions. Wind can shift the spray pattern and can also slow down travelling irrigators. In areas frequently exposed to high winds, irrigate in calmer conditions and use boom-type irrigators rather than gun-type irrigators.

All of these factors must be taken into account when determining appropriate irrigation depths and rates and designing the system.

## 5.1.3 Selecting an irrigation system

When selecting and installing an irrigation system, be sure to design for both your current and future needs. Consider:

- capital cost
- running costs/ energy efficiency
- labour requirements
- application efficiency and uniformity
- maximum and minimum application rates, acceptable return periods and total system capacity
- total water needed, and suitability/reliability of the water source
- reliability of the system and maintenance required
- whether any parts of the system will be used to apply dairy shed effluent. (Refer to the Dairying and the Environment Committee manual Managing Farm Dairy Effluent).

Selection of the system to ensure it will meet the needs of the farm operation is vital, as system design sets the platform for all future operations. Before final selection of an irrigation scheme, it will pay to have the proposed scheme checked by an independent advisor or consultant. Once the system is in place, its operation and management during the season then determine its overall success.

Irrigation systems are affected by factors such as fence and race layout, water systems or the siting of farm buildings. It is important to take a long-term view - it may be better to move existing structures to accommodate a better irrigation system, as irrigation is a long-term investment. However, mature trees in the landscape are not so easy to replace, and the choice of system should take into account the benefit of farm trees for shade, shelter and aesthetic and property values. Equipment that can work around trees (such as moveable sprinklers) may entail a greater labour input, but can also be very efficient.

### 5.1.3.1 Designing for peak demand

It is advisable to seek expert advice to calculate the peak demand for your property.

For economic reasons, it is usually advantageous to design irrigation systems to run for 22-24 hours per day to meet peak demand. This is because peak demand only occurs for 1-3 months in the year, and in the shoulders of the season, the system can be operated for fewer days per week or fewer hours per day. Irrigation systems designed to meet peak demand over fewer hours of the day need higher flow rates, larger pumps and pipes, and higher application rates. Therefore they will have higher capital and operating costs.

Some farmers try to aim for night use only (to irrigate in less windy conditions and to use night rate electricity). However, it is rare to find a system designed to operate on 12 hours per day at peak demand that is more cost-effective than one designed with lower capacity that is needed for 24 hours a day at peak demand. For this reason, it is important to choose a system design that minimises losses in windy conditions.

Associated with peak demand planning is a consideration of the water supply. Surface water takes are usually simpler and cheaper than groundwater, but river flows are subject to natural variations and may not provide a reliable supply. Groundwater is often more dependable, but the cost of lifting water to the surface can be a major constraint. If groundwater levels fall, this can change the economics for the irrigator, so it is wise to do some background research into the future reliability of the water supply.

### 5.1.3.2 Types of irrigation systems

There are six main types of irrigation systems:

1. Sprinklers and laterals
2. Soft hose travelling gun irrigators
3. Hard hose travelling gun irrigators
4. Travelling boom irrigators
5. Centre pivot systems
6. Flood irrigation through border dykes.

Sprinklers and laterals are well suited to pasture irrigation on undulating country or paddocks with irregular shapes. Generally, they use 20% less energy than travelling gun irrigators of similar capacity. However, the system requires a high labour input to shift - up to 4 hours per day for a 200-cow herd. The selection and placement of sprinklers gives high potential for water to be applied uniformly, and at low average and instantaneous application rates, assisting efficiency. These systems are least likely to create problems with surface ponding or runoff of water.

Soft-hose travelling guns are the cheapest type of travelling irrigation system to install. They are easy to maintain, readily transportable, suitable for cropping and have good resale value. As gun-type irrigators operate at high pressure, they usually require 20 to 25% more energy to run than a comparable sprinkler and lateral system. A tractor, heavy rollers or permanent fixtures are required as an anchor for the unit and a tractor may be required to move it. Gun irrigators are considerably affected by wind and are not suitable in hilly paddocks. Gun systems provide the least uniformity and even at low average application rates, instantaneous rates can be high due to uneven distribution.

Hard-hose travelling guns use hard pipe as the means not only to deliver the water to the irrigator but also to

FIGURE 5.1-2

SPRINKLERS AND LATERALS

FIGURE 5.1-3

CENTRE PIVOT IRRIGATOR

winch the irrigator in. Hard-hose travelling guns do not require a tractor as an anchor, do not damage crops and can be used for steep runs or irregular shaped paddocks. Hard-hose units take a little more energy to run than soft-hose units of the same capacity.

FIGURE 5.1-4

**BORDER DYKES**

Travelling boom irrigators operate on similar pressure to sprinkler and lateral systems, can be transported between areas, are good for cropping and are available as either fixed or rotary booms. Fixed boom units are powered by a diesel engine whereas the rotary units are driven by water pressure from the system, making them cheaper to operate. They are less affected by wind than travelling gun irrigators. The main disadvantages of travelling boom irrigators are that paddocks must be free from barriers (e.g. trees) and the capital cost is comparatively high. Towable systems generally have higher application rates because of the need to apply more water per irrigation.

Centre pivot systems involve a sprayline revolving around a central hydrant. As with travelling boom irrigators, the capital cost is high and paddocks must be free from barriers so only low shelter can be planted. Pressures and energy requirements are less than for travelling irrigators and they require very low labour inputs. The sprinklers at the edges of the pivot move much faster than the centre sprinklers. In order to compensate for this and achieve a uniform application depth, it is necessary to adjust the application rate and the wetted footprint over the length of the pivot, e.g. by mounting different-sized sprinklers along the pivot.

Flood irrigation relies on slightly sloping land and gravity to transmit the water over the application site. With border dyking, flat land is divided into rectangular sections, with furrows and checkbanks (i.e. borders) that are used to direct flow. Flood irrigation through border dykes has lower running costs and energy use than a spray application system, because the soil conveys the water. However, extensive earthworks are involved in land levelling to allow successful water reticulation. To operate effectively, a land flooding system requires a large volume of liquid to be applied at one time and it is usually a less water-efficient means of irrigating. Water application tends to be uneven, with more water applied at the top end of the gradient. There is also a high risk of polluted runoff entering streams if there is a discharge from the paddock to a waterway.

### 5.1.3.3 Application efficiency of different systems

Application efficiency refers to how much of the water applied is held in the soil root zone where it can be used by plants.

Table 5.1-5 shows that efficiency is primarily determined by the uniformity of application and a suitable application rate. The type of system chosen has a strong bearing on achieving both uniformity and a suitable application rate.

TABLE 5.1-5

**TYPICAL WATER LOSSES FROM A PRESSURISED IRRIGATION SYSTEM**

| Loss component | Range | Typical |
|---|---|---|
| Leaking pipes | 0-10% | 0-1% |
| Evaporation in the air | 0-10% | < 3% |
| Wind-drift out of target area | 0-20% | < 5% |
| Interception and evaporation from the crop/pasture | 0-10% | <5% |
| Surface run-off | 0-10% | < 2% |
| Uneven/ excessive application depths and rates | 5-80% | 5-30% |

*McIndoe, 2002*

Farmers often focus on leaks in pipelines or spray drift on windy days, as these factors are visible. However, these losses are often small compared to non-uniform application or excessive rates of application. Systems that cannot apply depths of water appropriate to soil water holding capacities or apply water evenly will be inefficient.

For example, for a system with a uniformity coefficient of 70% (typical of many systems in New Zealand), about 90 mm of water needs to be applied to replace a 50 mm soil moisture deficit over 90% of a field. Improving the uniformity to 90% means that only 60 mm of water needs to be applied to achieve the same result.

In general, the systems with highest efficiency are those that can apply small amounts of water frequently, such as medium-length centre pivots, linear move systems and 'pod' type sprinklers or long lines. Centre pivots, linear move machines and towable pivots can achieve high efficiency if used on the basis of 'little and often'. In the lower band of application efficiency are guns and high application rate booms, particularly when they are applying large, fixed depths of water over longer return intervals. Guns are most affected by wind, and booms with high application rates are most susceptible to surface redistribution and runoff.

Speeding up a travelling irrigator is an easy way of applying less water. However, this can have implications for system capacity, because if an irrigator operated at high speed is not moved after completing its run, the extra down time reduces system capacity. So for all moveable systems, there is generally a trade-off between maintaining system capacity and applying lower depths to increase application efficiency, entailing more shifting and labour.

The choice of system is also influenced by other factors such as availability of local suppliers and service, portability and ease of shifting, and the need to irrigate odd-shaped paddocks or paddocks with trees.

### 5.1.3.4 Energy efficiency of irrigation systems

The energy input into irrigation systems is principally the electricity required for pumping, although centre-pivot and lateral move irrigators also require an additional energy source for propulsion (refer to 5.1.3.2 Types of irrigation systems). Flood systems do not require pumping to distribute water.

Choosing the right pump for the system is vital to minimising energy use. There is significant variation in the maximum pump efficiencies of different pump models. Also, electric motor efficiencies can vary between models. This means that there can be significant differences in energy use between pumps that provide similar duties.

The lowest cost per cubic metre of water pumped generally occurs when the pump is being operated at a flow equal to or higher than the flow at the maximum efficiency point. Choosing a pump with an operating duty above the maximum efficiency flow will also result in less loss of irrigation system performance as the pump wears.

### 5.1.3.5 Labour requirements

The labour required to operate an irrigation system varies greatly. Fully automated systems can reduce the labour for daily operation to a few minutes per day. However, automatically controlled systems cost more, and can have a significant labour requirement for maintenance or require specific technical expertise.

### 5.1.3.6 Reliability and maintenance of the system

When looking into systems, it is useful to find out how much maintenance is required and how many years' service can be expected from them. Ask around and enquire of other farmers who are using these systems. Poor water quality due to sand or silt, organic materials, and iron in the water can also have a major effect on system life.

## 5.1.4 Planning irrigation

Pre-season planning includes mapping out the overall strategy for the season, considering the timing or trigger points of when to start irrigating, and conducting the necessary pre-season checks or maintenance. Ongoing planning involves monitoring conditions and scheduling irrigation accordingly.

### 5.1.4.1 Irrigation scheduling

Irrigation scheduling will help to identify when it is best to start irrigating, how much to irrigate, and when to stop.

The aim of irrigation scheduling is to irrigate before reaching the critical deficit point, and to fill the soil to slightly below field capacity. By not quite filling to field capacity, rain that falls after irrigation is still useful. By not allowing soil moisture to fall to the critical deficit, variations in soil conditions and plant use are allowed for so that no plant suffers drought stress.

The closer soil moisture levels get to field capacity, the more likely it is that subsequent rainfall will be lost to deep drainage or runoff rather than held in the root zone of the plants. The more rainfall that can be used, the less irrigation will be required.

However, there is a cost to irrigating with small applications. Systems have to be designed to operate on shorter cycles, and this involves a labour cost for non-automated systems. Careful consideration is needed of these trade-offs when scheduling.

In theory, the most efficient use of rainfall would occur if soil moistures were retained at a little above the critical deficit by applying very small depths of water. This would leave the soil as dry as possible without causing any yield loss. For large field irrigation systems, it is not realistic to design or operate a system at this level, and there is generally a trade-off between optimum use of rainfall and irrigation system capacity and return intervals. For well-designed systems, the approach of using a trigger level a little above the stress point and irrigating to just under field capacity is a reasonable compromise.

For example, if a soil holds 100 mm of water between the critical deficit point and field capacity, then irrigation could occur when the deficit reaches 80 mm, applying 60 mm of water to finish with a soil moisture deficit of 20 mm.

### 5.1.4.2 Timing of irrigation

The golden rule is to plan ahead. To make the decision as to when to start, it is useful to know your soil's water holding capacity and the critical deficit for the pasture or crop, to keep in mind the capacity of the irrigation system and to measure soil moisture regularly.

Aim to avoid moisture stress, by planning one complete irrigation cycle ahead (i.e. if it takes 20 days to get around your irrigated pastures, then you need to consider how dry it will be in 20 days' time). Using soil moisture measurement and evapotranspiration (ET) predictions is the most reliable way to do this.

This may mean starting while soil moisture levels are still well above the critical deficit. To avoid wasting water, start with light applications and use heavier applications later in the cycle.

### 5.1.4.3 Strategies for working with restricted water

Where there is a shortage of water during the season, the following strategies may be adopted:

- ensure that the irrigation system is operating to a high standard to avoid wastage
- water the paddocks with the highest water holding capacities in preference to paddocks with soils of low water holding capacity
- extend the irrigation interval on less productive pastures - paddocks that do not respond as well to irrigation and those that contain drought tolerant species - and lessen the interval on more productive pastures. For severe water shortages, stop watering paddocks that have species more tolerant to moisture stress and concentrate the water on those paddocks that are less tolerant and more productive
- do not irrigate paddocks that use water less efficiently due to poor design or location. This is particularly significant with border dyke systems
- miss out 25% of borders in any round, leaving a different area out on each round.

#### 5.1.4.4 Pre-season checks

The importance of testing wells and pumps depends on the spare capacity in the system. For systems with high capacity, a small loss of pumping performance may not matter, whereas systems with limited capacity have less room for poor performance.

Properly installed pumps that are pumping clean water can run for many years without problems. However, if there appears to have been a drop in performance (for example the system is not operating at correct pressures) then a pump and well test is recommended.

Possible causes of poor performance include well level changes, pump wear, screen blockages or casing failure.

Travelling irrigators should be maintained according to the manufacturer's specifications, which usually includes attention to lubrication, bearings, seals, tyre pressures, drag hoses, and wire ropes as well as the system structure. Pipes and hoses should be checked for blockages that can cause serious damage to the drive units if they pass through the system.

Leaks in pipes should be repaired and sprinklers, nozzles and jets should be examined.

The system should be test-run to check sprinkler operation, application depths and travel speeds (refer to 5.1.5.1 Testing irrigator efficiency).

### 5.1.5 Improving efficiency of operation

Improving water use efficiency will reduce impacts on the water source and other users, and promote the image of dairy farmers as good stewards of the water resource. For the farmer, significant power savings can be made through increasing water use efficiency, which will also minimise the risk of nutrient loss.

Poor irrigation efficiency depends primarily on four inter-related factors. These are:

- irrigation timing, which is a function of soil moisture before irrigation
- the depth applied, which determines soil moisture after irrigation
- application uniformity, and
- application rate, both of which affect how much of the water will be lost to drainage, or wasted due to surface redistribution, ponding and runoff.

The following steps can be taken to increase water use efficiency:

- understand soil and plant characteristics and schedule accordingly (refer to 5.1.4.1 Irrigation scheduling). Get a good understanding of the water-holding capacity of your soils and of plant requirements for optimal production (refer to 5.1.1 The soil-water balance). Monitor soil moisture and evapotranspiration rates to plan your irrigation applications
- irrigate uniformly. Minimise wastage and nutrient losses by applying the correct amount of water evenly. Choose a system with a high uniformity of application, monitor its performance and make improvements for greater uniformity as required
- reduce application depths. The lower the application depth, the less likelihood of saturating the soil and causing runoff or leaching. The demand on the water source is also smaller
- irrigate more frequently. Lowering the return period allows smaller application depths without causing a decrease in crop production. Even if application depths remain constant, a shorter return period could reduce the seasonal water requirement as it enables irrigation to be better planned around rainfall
- check that the irrigation system is working accurately. Test your system regularly and make improvements where necessary (refer to 5.1.5.1 Testing irrigator efficiency). Check for any nozzle blockages from sediment, algae etc
- avoid losses to the air. Minimise above-ground losses by irrigating at night where possible and avoiding hot, windy days.

#### 5.1.5.1 Testing irrigator efficiency

As inefficiency of water application cannot always be seen; it needs to be measured. Many irrigators speed up during their runs and apply a heavier application at the start than at the end of the run. Most irrigators apply water unevenly across their wetted width. Some types of equipment are more prone to creating ponding or runoff.

To test the evenness of water application across the irrigator's run, carry out a uniformity test as follows:

1. Note irrigator pressure and wind direction. Avoid testing on a hot or windy day.
2. Place cans (e.g. plastic ice-cream containers or fruit tin cans) in front of the irrigator and at right angles to the direction of travel. Space cans evenly in both directions from the centre of the irrigator's run. Use at least one can every 10 m, and more near the run edge (e.g. every 5 m). All cans must have the same diameter. Cans may need to be anchored to remain upright.
3. Measure the application rate at each site by emptying each can into a clear calibrated jug. Record each reading.
4. Plot results out on a piece of paper to determine variability from the centre to the edges of the run.

If application is not uniform, adjustments could include changing nozzle size and spacing or changing system operation to reduce pressure variations. Proper maintenance is also important, such as replacing worn sprinklers and nozzles or blocked emitters.

Travelling irrigators can be speeded up if too great a depth is being applied. Another option is to offset the sprayline or irrigator run by up to half a set or run with every alternate irrigation. This ensures that a heavier application is applied to the ground that was under-watered during the last irrigation. Extra lengths to sub-main pipe may be required. The run reversal method can also be used to compensate for travelling irrigators that speed up during their run. Reverse the direction of the irrigator's travel each alternate irrigation. If permanent anchors are installed at the end of each run, additional temporary anchors will have to be used.

Table 5.1-6 lists the common complaints regarding poor irrigator efficiency and suggestions for improving efficiency.

TABLE 5.1-6

| IMPROVING IRRIGATION EFFICIENCY | | | |
|---|---|---|---|
| Irrigator type and problem | | | |
| **Uneven watering** | **Under-watering** | **Uneven travel speeds** | **Ponding and runoff** |
| **Sprinklers and lateral**<br>Check system is operating at proper pressure<br>Check all sprinklers are correctly spaced<br>Check all sprinklers are rotating freely<br>Check all nozzles are the correct size<br>Use offset method<br>Reduce spacing between sprayline sets | Move twice daily | | Check that the water application rate suits the soil type<br>Disconnect hydrant near wet spots |
| **Travelling gun irrigators**<br>Check machine pressure is suitable<br>Alter angle of guns<br>Use offset method | Check machine flow rate and pressure are suitable<br>Use offset method<br>Reduce lane spacing | Adjust turbine settings<br>Use run reversal method<br>Fit speed compensator to turbine | Increase irrigator speed |
| **Travelling boom irrigators**<br>Check machine pressure is suitable<br>Check for blockages in nozzles | | Adjust turbine settings<br>Use run reversal method | Increase irrigator speed<br>Reduce flow rate<br>Change nozzle type to increase wetted footprint |
| **Centre pivot systems**<br>Check machine pressure is suitable<br>Check nozzle size configuration<br>Check for blockages in nozzles | Check machine flow rate and pressure are suitable<br>Fit extension arms<br>Use offset method<br>Reduce lane spacing | Use run reversal method | |

**Note 1:** Seek advice from manufacture when changing nozzles or making other "design" changes

**Note 2:** For wind effects on sprinklers and laterals - check system is operating at the proper pressure/ check all sprinklers are standing upright / change to single not twin nozzles / change to low trajectory sprinklers.

*Adapted from MAF, 1986*

### 5.1.5.2 Energy efficient operation

Reducing energy use is largely achieved by reducing pumping hours. Irrigation scheduling and soil moisture monitoring are important tools for ensuring that the irrigation water is used when needed. The biggest opportunity for reducing pumping is through better use of rainfall (refer to 5.1.4.1 Irrigation scheduling).

In terms of pump operation, major efficiency gains are made when selecting the best motor/ pump combination at the design stage (refer to 5.1.3.4 Energy efficiency of irrigation systems). Operating a pump at a flow at or beyond its maximum efficiency point will reduce the cost per cubic metre of water pumped. Be aware that if you are throttling your pump at the headworks, you will be wasting energy. A means of reducing pump pressure, such as fitting a variable frequency drive, trimming pump impellers or replacing the pump, should be implemented. As pumps wear, they become less efficient. Monitoring performance with pump tests will indicate whether or not loss of performance is significant enough to warrant repairs.

Changing to low pressure spray nozzles will reduce energy consumption, but may not result in significant savings because of the high application rates that occur, causing surface redistribution and runoff. For deep well pumps, most of the energy is used to lift water to the surface, and modifying the system at the surface will have little impact.

### 5.1.6 Performance review and audit

At the end of a season, a review and audit can help to determine weaknesses in the system, solutions and potential benefits from improved water efficiency and reduced power consumption.

The review should look at:

- daily and seasonal water use in relation to climatic conditions and soil moisture
- production
- time used, including for maintenance
- energy use.

This can help to assess the effect of irrigation on productivity, profit, farm labour and the environment. Knowing the cost of water, energy and labour can be helpful in planning for next season. Having accurate records will also help with resource consent compliance.

Monitoring the number of hours lost per season due to system failure will allow the reliability of the system to be assessed and replacements to be made in a timely manner.

### 5.1.7 Minimising impacts on soil and water quality

The main impacts of irrigation on soil and water quality result from poor management and over-watering. In this situation, soils become saturated and susceptible to damage, and nutrients, sediment or faecal material may be lost from the irrigated area to surface or groundwater.

A further risk to water is the spread of unwanted organisms (e.g. didymo) when irrigation equipment is moved between water bodies without cleaning. For further information on didymo control contact Biosecurity New Zealand (0800 809 966 or visit www.biosecurity.govt.nz).

#### 5.1.7.1 Minimising runoff and leaching

As pasture production increases under irrigation, fertiliser requirements increase. The application of extra water and fertiliser to a soil can increase the pool of nutrients available for leaching. There is also a greater risk of spreading unwanted organisms from one water body to another e.g. didymo in runoff. If too much water is applied, or if it is applied unevenly, there is a risk of greater nutrient leaching.

Flood systems are particularly prone to high losses of nutrients and faecal material, especially if runoff water flows directly to streams via drainage channels from the border-dyke system. Reducing the amount of runoff is critical in these situations e.g. by ensuring clock times are appropriately set, headraces and borders are adequately maintained, and bunding is present. Application of soluble P fertiliser should also be delayed until after the last irrigation event in autumn, or less soluble forms (such as RPR) should be used.

Irrigating after intensive grazing or application of effluent should be avoided with all systems to minimise faecal contamination of receiving waters if runoff occurs.

In general, carefully scheduled, light applications of irrigation to suit soil and plant needs will promote active growth and pasture uptake of nutrients, and can therefore reduce leaching losses.

The gradual build-up of organic matter in previously unirrigated soils can also help to increase N-storage in the soil and reduce leaching.

Overall efficiency of nutrient use will help minimise the risk of losses under irrigation (refer to 3.1 Nutrient efficiency). A nutrient budget can provide guidance on appropriate nutrient application rates (refer to 3.1.3 Nutrient budgeting).

N-fertiliser should be used in split applications, at times when the most strategic gain will be made from the nutrients (refer to 3.3 Nitrogen fertiliser). Application should be avoided immediately before irrigating.

Sulphur should be applied in elemental form rather than sulphate form on irrigated pastures to avoid S leaching.

### 5.1.7.2 Managing soils and grazing under irrigation

Applying irrigation at high rates and/or grazing soon after irrigating raises the risk of pugging (refer to Section 2.1 Compaction and pugging).

Soils at field capacity are most prone to pugging. Pugging may also be worse if the land has been recently cultivated and resown.

Avoid high application rates, particularly in autumn on clay soils (when the water application rates should be reduced, even if moisture deficits persist).

Do not graze immediately after water application.

## 5.1.8 Top tips for irrigation

- **When installing irrigation, consider how to create the most efficient system as high ongoing energy use and cost can result from inefficiencies.**
- **Wherever possible, choose a system that has uniform water application, and is capable of delivering the lowest practicable application depths and rates.**
- **Have the system checked by an independent irrigation design expert.**
- **Choose a pump that suits your requirements and will operate efficiently at the duty required. Correctly match the pump to the system requirements, rather than throttling a system with a gate valve.**
- **Use a reliable irrigation scheduling method to achieve efficient water use. Over-watering is expensive and results in uneven watering and leaching or runoff. Irrigate 'little and often', to the extent that is practicable – do not irrigate below the active root zone.**
- **Use an accurate soil moisture monitoring technique or expert advice to assist with scheduling.**
- **To minimise leaching, do not apply N immediately before irrigation and consider applying N in lower quantities, more frequently (split dressings).**
- **Keep good records including detailed plans and specifications of the system installed, water and energy use and production over the season. Use these to plan improvements and for consent compliance.**

## 5.2 ENERGY EFFICIENCY

Energy used on farms includes fuels (diesel and petrol) and electricity. Products used on the farm also have 'embodied energy' (the energy required for their production, including raw material extraction and manufacturing). Added to this is the energy to transport inputs like race materials and supplements to the farm. Therefore the farm's use of fertilisers, supplements, aggregate and even building materials all factor in its energy efficiency.

Table 5.2-1 shows the average proportion of energy inputs from various sources to irrigated and non-irrigated dairy farms. This demonstrates the importance of fertiliser as an energy input on all farms and the high use of electricity on irrigated farms. Of all fertiliser, N-fertiliser is the most energy intensive (with urea requiring an average of 20GJ of energy per tonne manufactured, compared to superphosphate at only 2GJ of energy per tonne manufactured).

TABLE 5.2-1

**PROPORTION OF ENERGY INPUTS FOR THE AVERAGE NEW ZEALAND DAIRY FARM**

| Type of Energy Input | Non-Irrigated Farm | Irrigated Farm |
|---|---|---|
| Fertilisers | 38% | 34% |
| Fuel (farm and contractor fuel use) | 21% | 13% |
| Electricity | 20% | 40% |
| Capital* | 13% | 7% |
| Other** | 8% | 6% |

*Wells, 2001*

* Capital includes buildings, vehicles, machinery and farm infrastructure improvements.

** Other inputs include bought-in feeds, aggregate, chemicals and off-farm grazing.

Research shows that the average energy intensity on New Zealand dairy farms is similar in all regions except Canterbury, where pumped irrigation makes farming more energy-intensive and nitrogen inputs are also relatively high. The average overall ratio of energy used per unit of production is lower for the New Zealand dairy industry than reported overseas, however individual farms with pumped irrigation or high nitrogen fertiliser use may have higher energy ratios than some dairy farms in Europe.

While around two thirds of our grid power is from renewable sources (largely hydro-electricity), the potential for major new hydro dams and wind farms is limited, so further increases in electricity use are likely to come from fossil fuels such as coal and gas.

Farm businesses have a high degree of oil dependency - for liquid fuel, for the generation of electricity used on the farm and for the production of inputs, particularly nitrogenous fertilisers. This is a concern on three fronts:

- exposure to cost increases as oil prices rise
- use of a non-renewable energy source
- release of carbon dioxide to the atmosphere.

Firewood and biofuels (e.g. 'biogas' from organic material such as manure, or 'biodiesel' made from vegetable oil or animal fat) also release carbon upon combustion, but this is carbon that has been trapped from the air and stored in that material by the growing tree or pasture. Therefore these are termed 'carbon-neutral' fuels.

### 5.2.1 Electricity savings

On a farm with pumped irrigation, irrigation efficiencies are likely to offer the most potential for electricity savings (refer to 5.1 Irrigation).

The other use of energy, and therefore source of potential savings, is the farm dairy. The typical electricity consumption in a farm dairy is shown in Table 5.2-2.

TABLE 5.2-2

| ELECTRICITY CONSUMPTION IN A TYPICAL FARM DAIRY | |
|---|---|
| **Activity** | **Proportion of electricity used** |
| Water heating | 32% |
| Milking system | 26% |
| Milk chilling | 21% |
| Water pumping | 10% |
| Other (shed lighting, effluent pump, etc.) | 11% |

Energy audits of working dairy farms suggest that an average saving of 25%, and in some cases as much as 38%, can be achieved. Table 5.2-3 shows the typical proportion of energy use that could be saved for various activities.

TABLE 5.2-3

| POTENTIAL ENERGY SAVINGS FOR VARIOUS ACTIVITIES | | |
|---|---|---|
| **Activity** | **Main opportunity to save electricity** | **Typical saving for that activity** |
| Water heating | Heat recovery system | 69% |
| Milking system | Vacuum pump variable speed drive | 47% |
| Milk chilling | Milk vat insulation | 23% |
| Efficient lighting | Energy efficient lighting | 66% |

*Genesis Energy (website data)*

Many energy supply companies offer advice on how to reduce electricity use on the farm. Check your local supply company's website or ring for advice. Some websites offer energy savings calculators that can estimate the payback time for investing in different energy saving technologies.

On large farms, major savings in electricity use can also be achieved if methane digestion is used to process effluent and produce biogas that can meet farm energy needs.

### 5.2.1.1 Water heating

Immediate savings for very little cost can be made by:

- insulating all hot water cylinders and pipes
- repairing any leaks and/or dripping taps in the hot water system
- regularly checking thermostat settings to ensure you are not over-heating water (80ºC).

More significant reductions can be achieved through:

- utilising the warm water from the pre-cooler heat exchanger (plate cooler) as a supply for the hot water cylinders
- installing a heat recovery system that uses waste heat from the refrigeration system to heat water.

Wood burners and solar heaters are also alternatives. Wood burning technology can be a relatively inexpensive option for a small farm dairy if sufficient firewood is grown on the farm and you are prepared to put in the work to keep up the firewood supply. Food Safety regulations require that any wood burning heater be installed so that the firebox opens outside the milking area and storage rooms, as smoke can lead to milk contamination.

Solar heating can be used as a pre-heating option for your electrical cylinder. Solar is a clean source of energy that does not produce greenhouse gas emissions. The investment in solar heating is less cost-effective if night-rate electricity charges are available and electrical hot water cylinders are timer-controlled. However, if the dairy requires hot wash after morning and afternoon milking year-round, solar can be cost-effective.

### 5.2.1.2 Milking system

Within the milking system, the vacuum pump is the key component. The vacuum pump should be maintained regularly for efficient operation.

More substantial savings can be made by:

- installing a variable speed drive to the vacuum pump
- when replacing the pump, choosing the correct size for its function and selecting a high efficiency pump.

Vacuum pumps run continuously during milking and cleaning, independent of the amount of air to be removed from the system at any one time. Variable speed drives allow for changes in the vacuum to meet demand. For example, when fewer cows are being milked at one time, the variable speed drive automatically compensates for this.

In addition to the significant energy savings that can be made by installing a variable speed drive (reducing energy use by up to half), there are other potential benefits:

- an improvement in milk quality (cell counts) due to less stress on cows through application of a desirable, constant vacuum
- reduced noise in the shed
- less maintenance on the vacuum pump due to the soft starts and slower, smoother running
- reduced use of grid power at peak times (morning and early evening, and over summer when hydro-lake levels are low).

Not all farm systems are suitable for this technology – consult suppliers to enquire.

### 5.2.1.3 Milk chilling

Milk leaves a cow at approximately 38.6°C and needs to be cooled to below 7°C within three hours of milking and to remain chilled until it is collected.

Immediate savings can be made by:

- insulating refrigeration pipes going to the milk vat
- carrying out regular maintenance e.g. cleaning air condensers and/or replacing filter fans
- maintaining the correct refrigerant charge.

More substantial reductions are achieved by:

- directing the warm water from the plate cooler outlet to the hot water cylinders
- insulating the milk vat
- for outside vats, ensuring that they are sheltered from hot winds and mostly in the shade during the day.

Plate coolers need to be properly cleaned and maintained to provide efficient cooling and prevent milk contamination.

In some areas, farm water supplies may have higher temperatures, so other options may need to be considered, such as ice banks and chilled water storage.

Milk vat insulation products differ in price, durability and effectiveness – check with suppliers.

### 5.2.1.4 Energy efficient lighting and appliances

While lighting is only usually 1-2% of a dairy farm's electricity consumption, savings can be made by turning off lights when not in use, and by switching to fluorescent bulbs or energy saving light tubes.

Also consider the purchase of appliances for the farm and staff housing – look for a high rating for energy efficiency.

Electric fence maintenance is important to reduce power wastage, ensure efficient use of the system and to ensure phone lines are not the recipient of interference. Phone line interruptions are a major problem in rural areas as the effects are usually felt by neighbouring phone users.

Regular maintenance of electric fence units should include:

- clearing fence lines of long grass and weeds regularly
- clearing away broken branches or other debris which may have fallen across the wires
- checking for any broken wires or loose wires
- checking fence unit batteries or solar units
- testing voltage along fence to identify any faults or shorts circuits. Walking along fence line with a portable radio which is un-tuned and on high volume will locate the source of any electrical leakage.

### 5.2.1.5 Biogas production

Biogas is naturally generated by the anaerobic digestion of animal waste (e.g. dairy shed effluent). Typically it contains 70% methane and 30% carbon dioxide, although high concentrations of odorous gases such as hydrogen sulphide are produced if anaerobic digestion is incomplete. Both methane and carbon dioxide are greenhouse gases. If effluent is left to decompose anaerobically outside (e.g. in an effluent pond), methane will be released into the atmosphere. However, capturing the biogas and burning it as fuel is an alternative that will generate 'carbon-neutral' energy for the farm.

Biogas can be used directly for gas heating or refrigeration, or it can be converted to electricity with a generator. If a retrofitted petrol or diesel engine is used, typically there will be a 30% efficiency of conversion to electricity with a further 40-60% of the energy converted to heat. This heat can then be harvested by drawing the hot water from the engine's cooling system and by fitting a heat exchanger to the exhaust of the generator. The resulting hot water can be circulated either through pipes inside the digester or through a water jacket around it to warm the digestion chamber, speeding up the rate of anaerobic digestion and reducing the size of digester required to process the effluent.

In New Zealand, where only 10-20% of a cow's daily waste production is deposited in the farm dairy, the minimum size for economical biogas production is around 1000 cows. The technology is more cost-effective for larger herds or where other surfaces capture effluent (e.g. feed pads or stand-off areas).

Plug-flow digesters have been specifically designed for New Zealand dairy farms. A plug-flow digester is a trench, (e.g. 3 m deep by 3 m wide by 20 m long) which is either constructed of concrete or dug into the ground and lined with a heavy plastic liner. It is a 'constant volume digester', where manure feeding in at one end displaces an equal amount of digested effluent at the other end. A solids concentration of more than 9% is required, so this digester is appropriate for effluent slurry that has been scraped, rather than washed, from the farm dairy or feed pad. There is no mixing in the plug-flow digester but effluent is pre-treated in a mix tank before entering the digester.

Another simple option currently being researched in New Zealand is to cover the anaerobic pond in a conventional pond treatment system and collect the biogas being released from the pond surface. While the technology to do this is simple, covers cost between \$20-50 per $m^2$.

With all biogas generation technology, the cost-effectiveness for a particular farm situation will depend on the relative cost of other fuels and will become more attractive with rising fossil fuel prices. In addition to potential economic benefits, biogas avoids the use of limited fuel reserves by converting what otherwise is a farm waste product into energy, while releasing no more carbon into the atmosphere than would otherwise have been produced by the natural breakdown process.

### 5.2.2 Fuel savings

Fuel efficiencies can be made on dairy farms by:

- adopting no-till or minimum tillage practices in cropping and regrassing
- minimising the growing and feeding out of supplements
- using lighter vehicles where possible. However the use of ballast to avoid tractor wheel slippage can be beneficial where traction is poor.

Like road vehicles, farm vehicles will be most fuel-efficient when they are regularly tuned and when tyres are inflated to the correct pressure.

### 5.2.3 Savings on energy-intensive inputs

While their energy consumption is not directly visible, inputs to the farm system have an energy cost associated with their production and transport. High amongst these is the energy required to create nitrogen fertiliser. Therefore any efficiency in N-fertiliser use has a corresponding energy benefit (refer to 3.3 Nitrogen fertiliser.)

Supplements bought onto the farm also require energy to grow and manufacture, and to transport onto the farm.

Energy efficiencies and cost savings can often be made by using local materials for farm purposes such as aggregate for tracks and races from a suitable local source.

### 5.2.4 Top tips for saving energy

- **Don't forget N-fertiliser management as a means to decrease the farm's overall energy use – urea is an energy intensive product to manufacture and fertilisers account for more than a third of a farm's total energy use.**
- **Use pumped irrigation carefully (see 5.1 Irrigation) to reduce electricity consumption.**
- **Install a variable speed drive on the farm dairy vacuum pump.**
- **Use heat exchangers to capture waste heat from refrigeration and use it for water heating.**
- **Insulate hot water cylinders and milk vats in the farm dairy.**
- **Cut back on cultivation or use no-till techniques.**
- **Consider strategies to minimise the use of supplements or maximise the efficiency of supplement use.**
- **Select and operate farm vehicles to reduce use of diesel and petrol.**
- **Regularly service and tune all farm vehicles and machinery.**
- **Correctly ballast the tractor to optimise wheel slip.**
- **Radial ply tyres properly inflated to low pressure values can achieve better fuel efficiency.**

**Check out these useful websites on saving energy:**

**www.dairysavings.co.nz (Genesis Energy tips to save power and savings calculator)**

**www.meridianenergy.co.nz/yourfarm (Meridian Energy power saving ideas)**

**www.climatechange.govt.nz (case studies on energy efficiencies on dairy farms)**

**www.ruralenergy.co.nz/dairyaudit/index (technology for energy saving on dairy farms)**

**www.energywise.org.nz (general tips on energy efficiency)**

**www.emprove.org.nz (tips for reducing business energy use)**

**www.eeca.govt.nz (the Energy Efficiency and Conservation Authority)**

**www.4million.org.nz (the "4 million careful owners campaign" - how individuals can cut energy use)**

**www.agrilink.co.nz (energy reports and tools)**

## 5.3 GREENHOUSE GAS EMISSIONS

There are three principal greenhouse gases produced from agricultural activity that help create a 'blanket' effect around the planet and speed global climate change: methane, nitrous oxide and carbon dioxide. Their sources and importance are shown in Table 5.3-1

TABLE 5.3-1

| GREENHOUSE GASES | | | | |
|---|---|---|---|---|
| **Greenhouse Gas** | **Greenhouse Effectiveness (compared to same amount of $CO_2$)** | **% of Average Dairy Farm Emissions** | **% of Total NZ Emissions** | **Main Source on Dairy Farms** |
| Methane $CH_4$ | 21 | 58% | 45% | Result of ruminant digestion. Breathed out by cows |
| Nitrous oxide $N_2O$ | 300 | 38% | 16% | Released from soils Influenced by wetness and compaction, and N content in urine, effluent and fertiliser |
| Carbon dioxide $CO_2$ | 1 | 4% | 37% | Fuel and electricity use |

Two very potent greenhouse gases – methane and nitrous oxide, representing well over half of the national emissions profile – are sourced mainly from pastoral agriculture.

In ratifying the Kyoto Protocol, New Zealand committed to reducing its total greenhouse gas emissions to 1990 levels by 2008-2012, or purchasing carbon credits for the difference.

Many of the steps farmers can take to reduce greenhouse gas emissions will also bring benefits to the farm in terms of efficiencies and cost savings.

The nutrient budget package OVERSEER® can be used to predict the effect of different farm management practices on greenhouse gas emissions. The package can produce a greenhouse report for different scenarios showing the effect of changing practices on overall emissions or emissions of specific gases.

### 5.3.1 Reducing carbon dioxide emissions

The gross carbon dioxide emissions from energy use on dairy farms are estimated at 1.4 kilograms of $CO_2$ per kilogram of milk solids.

Reduced carbon dioxide emissions will mainly result from saving fuel and electricity (refer to 5.2 Energy efficiency).

In addition, farmers may choose to plant trees as carbon sinks (where the trees are to be permanent cover) or carbon-neutral fuel (where firewood or biogas is used in place of fossil fuels such as oil, coal or gas).

Owners of new forests planted since 1990 have the option of owning the credits from those forests, which could then be traded on the carbon market. However, these forests cannot then be clear-felled, as permanent forest canopy must be retained. For further information visit www.maf.govt.nz/forestry/pfsi

There has been debate as to whether increasing pasture production will build up organic matter and hence the carbon content of soils, making soils an effective 'carbon sink'. However, research shows that overall, soil carbon levels in New Zealand's grazing lands are at or near steady state. Relatively little unimproved grassland is being broken in for intensive pastoral farming, resulting in a dramatic increase in soil carbon. Adding more nitrogen fertiliser to already fertile pasture not only produces more pasture and therefore carbon addition to the soil, but it also increases the rate of decomposition and carbon release, and therefore has no overall effect on carbon storage. In addition, there is a carbon cost in the fossil fuels used to produce nitrogen fertiliser, and increased nitrous oxide emissions may result from the nitrogen-enriched soils.

There may be potential for improvements in soil organic matter levels in soils that have been under continued cultivation and are then returned to pasture or a no-till regime. No-till has been shown to increase soil organic matter by up to 50% in some cases. However, the area of these soils is not considered to be significant enough for soil carbon sinks to have a major effect in New Zealand.

Farmers wishing to increase organic matter and carbon in cultivated soils can:

- adopt minimum tillage
- retain crop residues
- grow winter cover crops or green manure
- include a long pasture spell in the crop rotation.

### 5.3.2 Reducing methane emissions

Methane is New Zealand's major greenhouse gas, and our methane production per capita is 10 times the world average. This is because methane is a natural by-product of a ruminant's digestive system and New Zealand has a large amount of agricultural stock. Unlike carbon dioxide, which can be sequestered by growing plants, there is no major sink for methane on earth. Recent measurements indicate its concentration is growing at about 0.6% per year. It is 21 times as efficient as carbon dioxide as a greenhouse gas (i.e. 1 kg of methane has 21 times the effect of 1 kg of $CO_2$ when calculated over 100 years).

Reducing methane emissions is likely to benefit farmers directly, since less methane production means a cow will have more energy available to produce milk.

#### 5.3.2.1 How methane is produced

A cow's rumen contains about 80 kg of fermenting feed that is broken down by large numbers of bacteria, fungi and protozoa. The main products of feed digestion are acetic acid (used by the cow for energy and production), and the waste product hydrogen which the cow must get rid of to allow digestion to continue. Some of the cow's available energy is used to convert the hydrogen into methane ($CH_4$) through another microbial process. The methane is then expelled through the cow's nose and mouth.

The less methane produced, the more energy the cow will have to produce milk. A cow wastes between 4% and 9% of its gross energy intake producing methane.

#### 5.3.2.2 How methane production can be minimised

Research into lower methane production centres on variations in feed and the potential for breeding programmes to influence methane outputs.

Studies have shown that feeding high quality legume forages containing condensed tannins, or feeding concentrated feeds (total mixed ration) can reduce methane output per unit of milk when compared with a pasture-only diet. Conversely, high-fibre diets will result in increased methane outputs.

In trials, cows fed with sulla or birdsfoot trefoil (condensed, tannin-containing legumes) in late lactation produced the same amount of methane as cows fed ryegrass, but the sulla-fed cows had higher dry matter intakes and were higher producing. This means that the methane output was less for the same amount of intake or milk output. Tannins also have other benefits such as increasing milk solids production and preventing bloat.

The use of high concentration feeds (total mixed rations) is an option for methane reduction but is costly. The production of grain-based feeds also has a high energy input for cultivation, processing and transport that releases carbon dioxide, another greenhouse gas, and cropping practices can impact on soil and water quality.

Cows show a high degree of variation in the amounts of methane they produce on similar dietary intake. Research is ongoing into the potential to make the most of this genetic variation to reduce methane emissions through breeding programmes.

### 5.3.3 Reducing nitrous oxide emissions

Nitrous oxide is the most potent of the three main agricultural greenhouse gases, being 300 times as effective as carbon dioxide in its greenhouse effect. It is thought to account for over a third of total agricultural greenhouse emissions in New Zealand, although there is uncertainty in determining actual emissions.

The release of nitrous oxide to the air through natural soil processes also represents a loss of N from the farm system, so there can be benefits to farmers from managing N-sources to reduce nitrous oxide losses. However, the conversion of N in wetlands to gaseous forms, which includes a proportion of nitrous oxide, is often encouraged as a way to prevent soluble N from reaching waterways. Swamps and wetlands are a key source of nitrous oxide emissions. Therefore the greatest benefit to the farmer and the environment will come from keeping N within the pasture root zone and not allowing it to leach into groundwater.

#### 5.3.3.1 How nitrous oxide emissions occur

The greatest proportion of nitrous oxide from agricultural sources is emitted from animal urine deposited during grazing. A further amount is released when ammonium-N in excreta or fertiliser is converted to nitrate through nitrification, since nitrous oxide is a by-product of the nitrification process. It is also produced when the nitrate in animal urine or in N-fertiliser is released back to the air from wet soils through denitrification.

The process of denitrification which occurs in wetlands and swampy soils releases a suite of gases. By far the greatest proportion is inert $N_2$ gas. However the greenhouse gases methane and nitrous oxide can also be produced in varying proportions depending on conditions. While minimal field research has been done on this topic, in theory the process is likely to be most 'efficient' (minimal $N_2O$ production) under highly carbon-rich and anaerobic conditions and when nitrate loadings are not excessive. While ongoing research is needed to optimise wetland design and management for minimal $N_2O$ production, in general the benefits of nitrate reduction in wetlands are still likely to outweigh the negatives of greenhouse gas release.

#### 5.3.3.2 How nitrous oxide emissions can be reduced

The greatest emissions occur after grazing events, particularly on poorly drained soils during winter. Therefore avoiding pugging and using on-off grazing in wet conditions will reduce emissions (refer to 2.1.1 Limiting pugging damage). The effluent from a stand-off area can be captured and spread back onto soils when they are drier.

Other good management practices for effluent capture and treatment will also help make the most of its fertiliser value while minimising emissions of nitrous oxide. Effluent applied to land at rates that exceed soil water holding capacity and pasture uptake of N will create the greatest potential loss of N loss to the atmosphere as nitrous oxide. The Dairying and the Environment Committee manual Managing Farm Dairy Effluent outlines good practice for effluent management.

Efficient use of N-fertiliser, and avoiding its use in cold, wet conditions is also helpful to ensure that N is taken up by actively growing pasture and not lost to leaching, and then potentially to the atmosphere through denitrification in wetlands (refer to 3.3 Nitrogen fertiliser and 3.1 Nutrient efficiency). A nutrient budget can be used to predict the loss of nitrous oxide resulting from different farm management practices and to increase the efficiency of N use on the farm (refer to 3.1.3 Nutrient budgeting).

The use of nitrification inhibitors has been shown to reduce nitrous oxide emissions by between 50 to 75% in field trials, by slowing the conversion of ammonium to nitrate and thus slowing the release of nitrous oxide from this process (refer to 3.3.3 Nitrification and urease inhibitors). There are also benefits for production as N is more likely to be held in the soil over winter and remain available for pasture uptake in spring.

The use of feeds with a low concentration of N (high carbon : nitrogen ratio) such as maize, is also a way to reduce the amount of N excreted and therefore available for leaching or loss as nitrous oxide.

Maintaining anaerobic conditions in wetlands (i.e. saturated soils) and a carbon-rich environment (e.g. through the use of wood chips in a constructed wetland or establishing raupo in a natural wetland) may decrease the proportion of N released as nitrous oxide.

### 5.3.4 Top tips to reduce greenhouse gas emissions

- **Use nitrogen fertiliser (including effluent) efficiently and only when pasture is actively growing.**
- **Investigate alternative feeds with lower methane output and more efficient N utilisation.**
- **Use nitrification inhibitors to retain nitrogen in the soil profile where it can benefit pasture production and reduce the release of nitrous oxide gas.**
- **Make energy savings through efficient irrigation and farm dairy technology.**
- **Cut back on farm fuel use with lighter vehicles and less tillage.**

## 5.4 FURTHER READING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