# Efficient Energy Use in Pig Feed Production

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# Contents



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# Summary


## 85.6% of the Quality Meat Scotland (QMS) assured Scottish sow herd and 83.6% of all the finished pigs are fed from feed prepared on the home farms and from feed mostly sourced from the home farm or locally.

74.2% of sow feed (30,500 tonnes p.a.) on QMS-assured Scottish pig units is home mill and mixed, along with 69.5% (73,800 tonnes p.a.) of weaning to finishing diets.

More than 17,000 tonnes p.a. are prepared on QMS-assured Scottish pig farms by mobile mill and mix units, providing feed for 8.7% of the sow herd and 12.6% of the wean to finish herd.

There is a 3.19p/unit difference in daytime tariff rates paid by producers with >100,000 units p.a. consumption.

Energy brokers are not consistently used. Whether they are used or not, researching tariffs prior to contract end date is highly recommended.

Automation of milling so that it is done at night may reduce related energy costs by up to around 38%.

Farm feed mill and mix is consuming from between 10% to 38% of whole farm annual electricity consumption.

Monitored farm feed mills were using on average 15.3 kWh/t of feed produced, with between 66% and 90% of the power used by the mill, dependant on all the equipment in each mill.

Power factors on the monitored mills varied, but for the amount of power used in the mills any power factor correction is unlikely to be economic. The same is correct for investment in Voltage Optimisation, unless a producer is using large amounts of electrical power elsewhere on the unit.

Renewing the hammers and screen on a mill reduced the energy used per kilogram of grain by 3% and increased milling rate (kg/m) by 5%. Feed grist size distribution was improved.



**Acknowledgements**

Many thanks to the producers who took the time to respond, contributors from the trade, and in particular to the five businesses that gave access for detailed monitoring. The project was funded by Scottish Government as part of the QMS Pig Resource Use Efficiency Programme.




# Introduction

## Scottish pig production operates in a very tight commercial environment.

Production is costly due to location and climate, but there are a number of areas that can be developed to promote Scottish production.

The first is the number of producers who work a cycle that includes growing much of their own feed, home mill and mixing, pig production, and the re-use of pig slurries and manures back on to the ground. The wider impact of this is being investigated in another project. A further aspect of the Scottish industry is the high degree of self-help and co-operation, whereby producers have a track record of working together on projects and sharing their experiences.

The current report is based on information gathered at farm level to ascertain the efficiency of home-based production of feed, and seeks to promote good practice and study any further information on energy efficiency practices.

The report covers a questionnaire sent to relevant QMS-assured pig producers, dialogue with equipment manufacturers, monitoring on selected farms, and output on best practice including guidance documents.

# Questionnaire

**A questionnaire was created, piloted through a selected group of mill owners and then sent to all units identified by QMS as having home mill and mix, or using mobile mill and mix. A covering letter outlined the aims of the project and highlighted the benefits of group participation.**

Twenty responses were received out of forty five businesses approached, including one no longer with pigs and another two who did not wish to provide information. A further thirty six units are supplied from their own central feed mill producing a full range of diets. All non-responders were contacted by phone and email and the questionnaire resent.

## On-farm feed production

74.2% of sow feed on QMS-assured Scottish pig units is home mill and mixed, along with a further 69.5% of weaning to finishing diets. Using the latest 2013 QMS Agrosoft pig production data, the quantity of Scottish home mill and mixed feed is around 30,500 tonnes of sow feed and 73,800 tonnes of grower finisher diet, based on 1.293 tonnes per sow per year and 0.242 kg per finished pig.

In addition to home mill and mixing, a further 17,000 tonnes per year are mill and mixed on QMS-assured Scottish pig units by mobile feed mills, and represent almost 40% of the remaining pig feed that is not mixed by the home farm. The majority of the feed produced by the mobile units will be sourced from the home farm or locally. This mobile on-farm mill and mix represents an additional 8.7% of the sow herd and 12.6% of the wean to finish herd.

Just under 3% of the QMS-assured Scottish sow herd (2.7%) and finishing herd (2.5%) is fed on locally sourced food by-products in central Scotland.

The best estimate is that 85.6% of the QMS-assured Scottish sow herd and 83.6% of all the finished pigs are fed from feed prepared on the home farms and from feed mostly sourced from the home farm or locally.

There will be a high proportion of the pig feed sourced direct from compounders that uses locally sourced grain.

Nearly all farms purchase specialist compound diets, with an average of 20 tonnes per year and 45 tonnes per year for creep and weaner diets respectively.

## Feed Type

*Table 1: Feed type QMS-assured Pig Units % questionnaire respondents*

| Diets | Meal | Pellets | Liquid | Mixed/ other |
|---|---|---|---|---|
| Farrowing | 70% | 5% | 0% | 25% |
| Weaner | 40%* | 40%* | 10% | 40% |
| Grower | 55% | 5% | 15% | 25% |
| Finisher | 85% | 0% | 10% | 5% |

*More than 85% of diet.

## Feed constituents

The main ingredient of most diets is barley, and to a lesser extent wheat. The diet is balanced with varying proportions of soya, full fat soya, whey powder, fish replacer, fishmeal, soya oil and minerals. The main imported ingredient is soya, which is included at rates varying from 2.5% to 20% of ingredients by weight.

## Equipment

A variety of feed mills are used on Scottish units of 5.5 kW to 40 kW power rating. Mills are mainly hammer mills from Christie & Norris, Scotmec and Skiold. Some units use disc mills alone or in parallel with the hammer mills.

Vertical and horizontal feed mixers are used, mainly of 1 or 2 tonne capacity with one rated at 4 tonnes, typically fitted with 4 or 5.5 kW motors. Wet feed mixers are rated at 5.5 kW and 2 tonnes capacity. Feed is moved between weighers, mills, mixers and feed bins by a variety of augers and elevators running mostly around 1 kW capacity motors, with a few larger (150 mm diameter) augers with 4 – 5 kW motors. Ancillary equipment includes dust extractors, baggers and weighers, mostly running with small motors of 0.75 to 1.5 kW.



## Maintenance

The requirement for maintenance is dependent on throughput and, to a small degree, the type of grain handled. There were a number of comments on the degree of difficulty at times in processing soya. Most of the respondents were running a monthly maintenance routine of turning hammers, screens and checking mixer screws, with most of the variation of frequency related to throughput. The same applies to replacement of parts. One unit has two mills with monthly servicing, one of which is sent away every year for a full service. Some parts that influence throughput, such as fans, are not always readily available and may cause inefficiency of throughput.

## Duration of use

Most feed mills are operated every day for 5 – 8 hours, mostly during the day. One farm operates the mill twice per week for 8 hours each, while farm mills for wet feeding systems work on and off 24 hours per day. Operation at night was limited.

## Energy supply

All of the respondent farms are operating on three phase, apart from one on split phase. Only 7/20 units provided information on timing of power supply contract expiry dates. Whilst the remainder may feel that such information is confidential, it is highly relevant to point out that when contracts expire without renewal/replacement the user will normally end up paying standard electricity tariffs. Current standard tariff for a one year fixed price supply in postcode AB is 12.53p/unit; in postcode DG 10.90p/unit. The range of actual power use and unit charges for whole farm use are shown in Table 2.

*Table 2: Whole farm electricity consumption and supply price per unit*

| | Power supply – day | | Power supply – night | |
|---|---|---|---|---|
| | Annual consumption | Price per unit | Annual consumption | Price per unit |
| max | 423,000 | 14.28 | 141,936 | 8.31 |
| min | 19,186 | 10.31 | 19,608 | 6.58 |
| mean | 160,079 | 11.99 | 83,874 | 7.07 |
| median | 108,831 | 11.75 | 87,622 | 6.94 |

The dataset is small but reveals the following:

3.97 p/unit difference in tariffs paid for daytime supply. The lowest unit consumer was paying the highest price per unit, but thereafter the range of prices paid for >100,000 unit consumption was 10.31p to 13.5p/unit. The price per unit spread is worth £3,190 per 100,000 unit consumption.

1.65p difference in tariffs paid for night-time supply. The lowest unit consumer was again paying the highest price per unit, but thereafter the range of prices paid for >20,000 unit consumption was 6.66p to 7.35p/unit. The price per unit spread is worth £69 per 10,000 unit consumption. One producer had no night rate.

The typical night tariff rate applies from 2400 hrs to 0700 hrs; as mentioned above, there is limited use of night time tariffs for mill and mixing on the responding units. Maximum power ratings were limited to 70 kVA on a couple of units, and more typically 200 – 250 kVA.

Energy brokers are used by some, but not all, producers.

The estimated proportion of power on the pig units that is used for feed milling and mixing is small but significant, ranging from 10% to 38% based on an average 14.5 kWh required per tonne of home mill and mixed feed. There are a few opportunities for improvements in efficiency, as well as significant potential to look for improved energy supply prices.

# Monitoring of energy use

## Feed mills were monitored on five farms to assess their energy usage.

This was done for a duration of at least one week. Energy loggers (TinyTag TGE-0001, Gemini Data Loggers UK) were connected and set to record a range of energy parameters (current, power and power factor in each phase, and voltage) for the mill and mixing equipment. The equipment in the mills studied is described below:

### Farm 1

One energy logger was connected to the supply for the hammer mill and a second connected to the supply for the mixers and ancilliary equipment. The second logger was not powered so recorded only the phase current. The power was later calculated with the assumption that the voltage matched that measured in the first logger and the power factors in each phase equalled 0.9. The power factor is defined and discussed below.

During the monitored period (14 days) the feedstock milled was predominantly barley (77%), with some soya (12%) and the remainder rape. The hammer mill is rated at 45 kW, the biggest of the monitored mills, processing the greatest quantity of feed. There is no duct extraction system in use.

### Farm 2

A relatively new mill, the 30 kW Tiesan VL 4 hammer mill is two years old and connected to a Robbon 1 tonne mixer (28.5 kW). There are 43 motors on augers, conveyors, agitators and elevators plus a dust extraction system. Not all of these will operate at the same time.

One logger was connected to the hammermill and the other to the mixer and ancilliaries. Monitoring duration was nine days. The standard feed mix ingredients are barley 59%, soya 21%, maize 16% and wheat 4%.

### Farm 3

The feed mill at Farm 3 is a Skiold 15 kW hammer mill more than seven years old, connected to two vertical 1-tonne mixers each of 5.5 kW power rating. One energy logger was connected to the hammer mill's power supply, the other was connected to the power supply to the whole feedmill. The power used by the other equipment in the mill was the difference between the two logger readings. Logging duration was eight days. A separate hammer mill, powered within the whole feedmill supply, was used during the monitoring period.

The feed proportions milled during logging were reported as 70% barley, 19% Soya and 11% wheat.

### Farm 4

There are different mills used for wheat and barley at Farm 4. In the past a disc mill was installed, as this was considered to be more energy efficient. There has been a catalogue of problems getting the disc mill to grind the barley to a consistency that suits the feed-handling system. A new 15 kW hammer mill has just been purchased to process barley, but the 7.5 kW disc mill is still used for the wheat. The feed is mixed in a Skiold 1 tonne mixer, which is thought to be rated at 4 kW. There are 24 additional motors totalling 28 kW.

The first logger was connected to the main consumer unit in the mill so monitored all power used. The second logger recorded the power used by the mixer and ancilliary equipment. The power for the mills was obtained by calculating the difference between the two logger outputs.

The predominant feed processed during the seven-day logging period was 70 – 85% barley/wheat, 12.5% soya.

### Farm 5

The mill has two old hammer mills, both rated at 11 kW, feeding in to either a 1 tonne horizontal mixer or a 2 tonne liquid feed mixer. The mills operate in parallel. Access to electrical connections was not easy at this site, and an assumption has been made that both mills were working in a similar manner and that each milled half of the total quantity of feed produced during the test period.

The predominant feed processed during the seven-day logging period was 80% barley, 17.5% soya.



# Energy monitoring results


## A graphical representation of the data collected is shown for each farm in Appendix II, Figs 1 – 5.

*Table 3: Recorded power use for the farm feed mills studied*

| Site | Power per tonne feed milled | Proportion of average | Power per tonne feed produced | Proportion of average | Screen size (mm) |
|---|---|---|---|---|---|
| Farm 1 | 11.7 | 106% | 12.9 | 84% | 3.5 |
| Farm 2 | 9.1* | 83% | 13.1 | 85% | 6 |
| Farm 3 | 12.3 | 112% | 18.6 | 121% | 5 |
| Farm 4 | 14.9 | 135% | 16.8 | 110% | 3.5 |
| Farm 5 | 7.1 | 64% | NR | NR | 5 |
| Average | 11.0 | kWh/t | 15.3 | kWh/t | |

*estimated value

The results in Table 3 show that the average power used to produce each tonne of feed was 11.0 kW. This reasonably concurs with the range reported by K. B. Koch[1] of 7.5 to 10.8 kWh/tonne. Whilst Koch's work used a 2.7mm screen, it would be normal – locally – for a larger screen size to be used which would use less power. The data from this small study seems to confirm that more power is used with smaller screen size.

There are many other factors involved though. Energy use on Farm 4 was relatively high for the size of screen used. However, since the test the fan within the hammer mill has been replaced and the throughput has reportedly increased markedly. A separate soya mill with 3.2 mm screen was included with the power used by the mixer at Farm 3. The screen has since been replaced by a 6mm screen.

[1] http://en.engormix.com/MA-feed-machinery/manufacturing/articles/feed-mill-effeciency-t2192/801-p0.htm

## Power factors

The power factor indicates the relationship between each of the three phases of the power supply, specifying which phase leads or lags. The power is calculated by multiplying the voltage x current x power factor. The power factor in electrical motors will be less than 1; the more it falls below 1, the more power (VA) will be required for each kilowatt of power needed by the motor. Power supply companies do not like low power factors and will charge extra if the usage is high, and the power factor is low. For this reason, larger users install banks of capacitors which increase the power factor.

As correcting systems are expensive and the amount of power used in a feed mill is relatively low, it is unlikely that users will be penalised for low power factors, so expenditure on correcting equipment is unlikely to be justified. The power factors measured are shown in Table 4. It is seen that at some sites the power factors are quite low, whilst at others they are close to unity.

*Table 4: Power factors at the test feed mills*

| | Mill | | | Mixer | | |
|---|---|---|---|---|---|---|
| | PF1 | PF2 | PF3 | PF1 | PF2 | PF3 |
| Farm 1 | 0.80 | 0.79 | 0.77 | NR | NR | NR |
| Farm 2 | 0.88 | 0.79 | 0.81 | 0.71 | 0.68 | 0.59 |
| Farm 3 | 0.87 | 0.93 | 0.92 | 0.95 | 0.95 | 0.96 |
| Farm 4 | 0.98 | 0.98 | 0.98 | 1.00 | 0.99 | 0.98 |
| Farm 5 | 0.91 | 0.75 | 0.91 | NR | NR | NR |

## Voltage optimisation

Voltage optimisation is often touted as a way to reduce power costs. It involves reducing the voltage when this is higher than necessary. Considerable savings are quoted but for these to be realised there needs to be a large usage of power, and the power has to be used by equipment that is relatively voltage independent. For example, the supply voltage to florescent lights can be significantly reduced without affecting the light output significantly. On the other hand, electrical motors will have less power if the voltage is reduced.

On a farm that has a large usage from equipment that maintains output when the voltage is reduced, there may be some scope for reducing the voltage and so reducing energy costs. The scope for voltage reduction is approximately 10% below the standard voltage of 240 v. Table 5 shows that at some of the farms the voltage is already slightly reduced. Depending on the usage pattern of other electrical energy on a farm, the voltage reduction may be worth considering – even if it does not improve performance of the mill.

*Table 5: Voltage at tested pig farms*

| Site | Mixer | |
|---|---|---|
| Farm 1 | 240 | v |
| Farm 2 | 236 | v |
| Farm 3 | 241 | v |
| Farm 4 | 245 | v |
| Farm 5 | 234 | v |



## Total energy spend and carbon equivalent

The total energy spend on feed milling throughout the year is indicated in Table 6. This is partly a reflection of the energy used as stated above but also due to the varying price paid for energy.

Not all sites had a split tariff which gives a cheaper rate at night compared to daytime, but those who have this arranged are paying about 40% less for their night rate power than for their daytime power. In many cases the daytime rate obtained using a split tariff is more than a single tariff, but from this study this does not appear to be the case. However, where this does apply it is necessary to compare the proportion of power used by the whole farm during the day, compared to during reduced rate night hours, to see whether a split tariff is worthwhile.

*Table 6: Power costs and carbon equivalents*

| | Day rate (p/kWh) | Night rate (p/kWh) | Carbon tonnes/annum | Tonnes milled/ annum | Tonnes feed/ annum | Energy cost [1] |
|---|---|---|---|---|---|---|
| Farm 1 | 11.26 | 6.87 | 28 | 4,056 | 4,836 | £7,273.06 |
| Farm 2 | 12.63 | 11.27 | 11 | 2,522 | 2,748 | £3,201.16 |
| Farm 3 | 11.53 | 7.20 | 24 | 2,524 | 3,317 | £4,491.96 |
| Farm 4 | 13.5 | - | 22 | 2,326 | 2,964 | £6,716.17 |
| Farm 5 (Mills only) | 11.7 | 6.7 | 6 | 2,008 | 3,146 | £1,679.14 |

[1] Assuming milling and mixing done during day time

There are many factors affecting the price that will be obtained for power, including:

- **Start date and length of contract** – Power has been becoming more expensive, so if a contract was taken out some time ago then the tariff may be low until the contract expires. Subsequent contracts may be significantly more expensive.
- **Amount of power used by the farm** – high power users may get a lower tariff.
- **Energy broker used**

In this study the highest energy user (per tonne) also had the highest unit tariff, and as the contract is due to expire soon it is strongly recommended that a better deal is negotiated in advance of the expiry date. Missing the expiry date of a contract will mean that the standard (expensive) tariff will be charged until an alternative arrangement can be made.

# Mill maintenance

## A test was run at Farm 3 to measure the impact of changing the hammers and screens on the feed mill (Skiold 15 kW hammer mill).

Gemini data loggers were used to measure the exact current and voltage used to mill a measured quantity of consecutive whole barley samples.

## Comparison of energy used before and after hammer replacement

A quantity of grain was milled at Farm 3 using hammers that were considered to be due for replacement. These were then replaced with new hammers and a new screen (5mm) and a similar quantity of grain was milled. The results are shown in Table 7.

*Table 7: Energy monitoring before and after hammer/screen replacement in a feed mill*

| | Quantity milled (kg) | Average power during milling (kW) | Power used (kWh/kg) | Time to mill (min) | Milling rate (kg/min) |
|---|---|---|---|---|---|
| Before hammer replacement | 803 | 10.9 | 91.0 | 52 | 15.4 |
| After hammer replacement | 873 | 11.7 | 88.1 | 54 | 16.2 |
| % change | +9% | +7% | -3% | +4% | +5% |

Table 7 shows that replacing the hammers and screen on this mill reduced the energy used to mill each kilogram of grain by 3% and increased milling rate (kg/m) by 5%. The mill used a 5 mm screen. The impact on feed particle size distribution after milling is shown in Table 8. There was a reduction (15.9% to 11.7%) in the proportion of whole/part grains larger than 2mm (2000 μm) passing through the mill after new hammers and screen were fitted. Particles above 2 mm diameter are less likely to be efficiently digested than smaller particles.

## Grist size before and after

*Table 8: Percentage by weight of milled feed at different grist sizes (n=3)*

| Sieve size | % Feed by weight | | | Coefficient of variation | |
|---|---|---|---|---|---|
| μm | Worn | New | P value | Worn | New |
| <500 | 15.1 | 19.6 | 0.248 | 31.8 | 16.4 |
| 500 | 23.7 | 28.2 | 0.066 | 11.6 | 4.9 |
| 1,000 | 17.9 | 20.6 | 0.084 | 8.6 | 6.3 |
| 1,400 | 27.7 | 20.0 | 0.059 | 18.0 | 5.5 |
| 2,000 | 10.3 | 7.2* | 0.036 | 14.7 | 12.5 |
| 2,800 | 2.7 | 2.0 | 0.238 | 31.4 | 2.4 |
| 3,350 | 2.9 | 2.5 | 0.630 | 47.6 | 24.8 |

The proportion of feed milled to a size less than 1 mm diameter (1000 μm) increased from 38.8% to 47.8% after changing hammers and screens. This will, in general, improve feed digestibility although very fine particles less than 100 μm will tend to increase airborne dust levels and increase the risk of ulceration of the stomach lining. The variability of the results is high, which reduces the probability of significant differences (P<0.05) between grist sizes before and after changing the hammers and screens. However, it is clear that the variability of particle sizes, expressed as the coefficient of variation in Table 2, was greatly reduced after new hammers and screens were fitted.



Grist size has an influence on gut health and efficiency of feed utilisation. A target grist size distribution for grower/finisher pigs is 35% <1 mm, 50% at 1 – 2 mm, and 15% above 2 mm.

Screen design has a significant impact on energy efficiency. In tests comparing 2.80 mm drilled screens with conventional 2.78 mm punched screens, 26% savings in energy and 33% increase in production rates were achieved. However, the increased cost of the screen offset the financial gains on energy saving (Rothwell, Vigneault and Southwell, 1991. Hammermill drilled screen evaluation on an energy and economic basis. Can J Agr Eng 315-320).

Different mill types have different power efficiencies per unit of feed produced, as shown in Table 9 below. Whilst opportunities exist to improve energy efficiency by changing from hammer to disc mills, a number of QMS-assured producers have found the disc mills to be less versatile than hammer mills for the variety of feed ingredients used.

*Table 9: Comparative energy use of hammer and disc mills*

| Description | |
|---|---|
| Feed consumption/day | 5 tons |
| Feed consumption/year – 5 tonnes x 365 days | 1,825 tonnes |
| Hammer mill energy consumption/year – 1,825 tonnes x 11kWh | 20,075kWh |
| Disc mill energy consumption/year – 1,825 tonnes x 6 kWh | 10,950 kWh |
| Hammer mill energy price/year – 20,075 kWh x £0.12 | £2,409 |
| Disc mill energy price/year – 10,950 kWh x £0.12 | £1,314 |

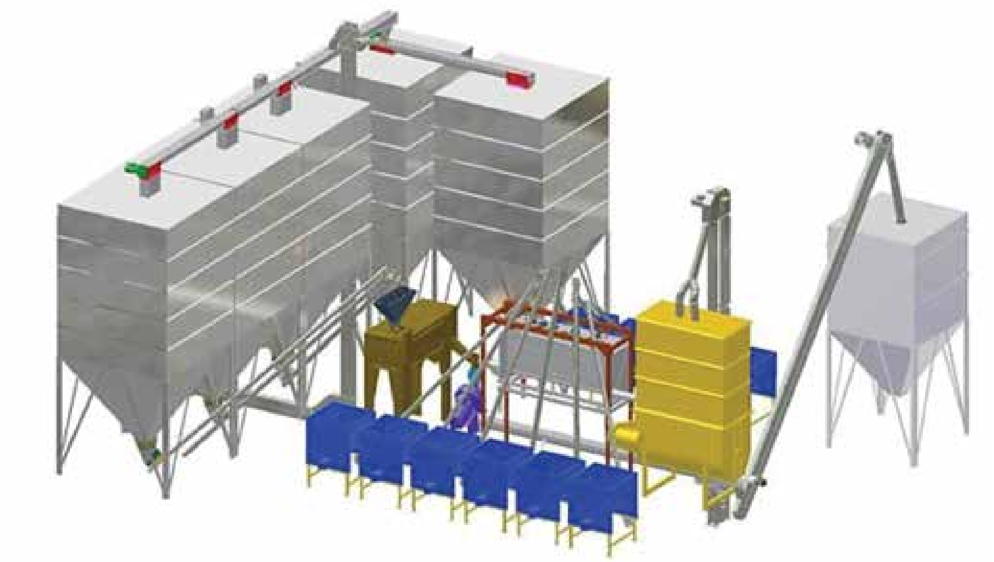
# Mill maintenance guidance
## Appendix I

### Hammer and disc mill maintenance

Standard operating procedures are available on the QMS website: www.qmscotland.co.uk/environment

Replacing worn hammers for new on feed mill

Mobile mill and mix equipment; fixed plant



# Power data – monitored farms 1 to 5
## Appendix II

*Figure 1: Power recorded at Farm 1 feed mill*

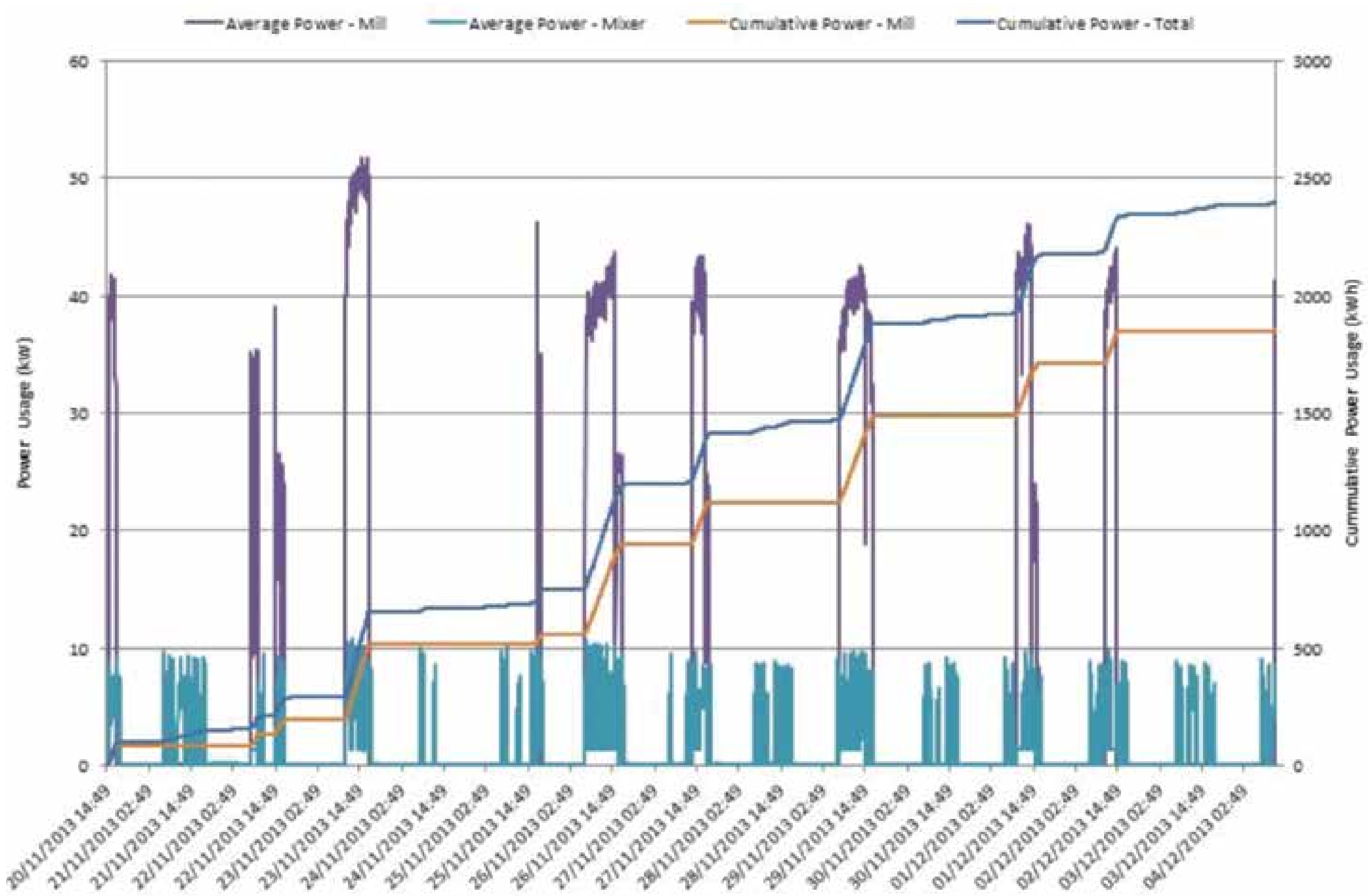


*Figure 2: Power recorded at Farm 2 feed mill*

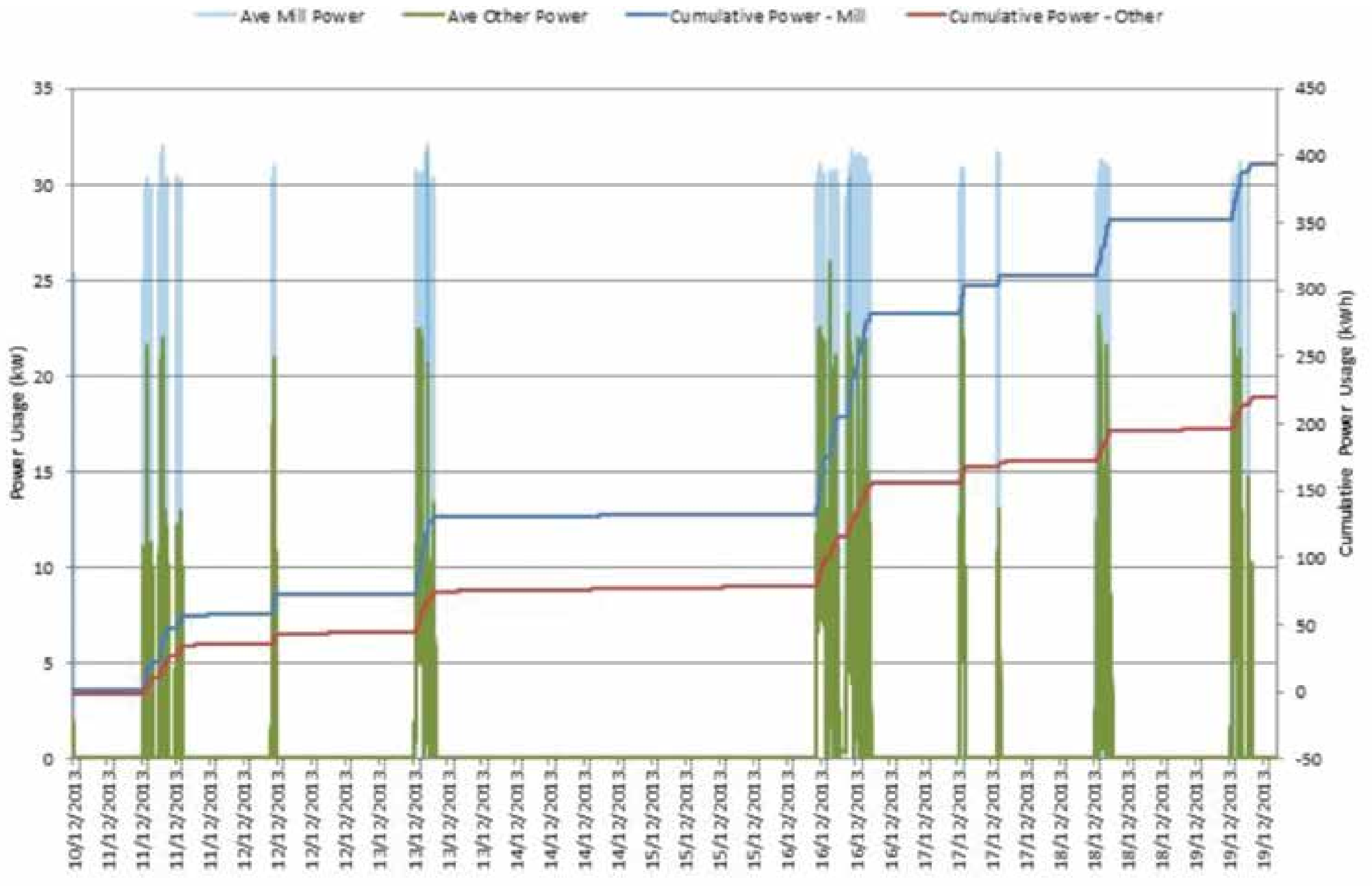



*Figure 3: Power recorded at Farm 3 feed mill*

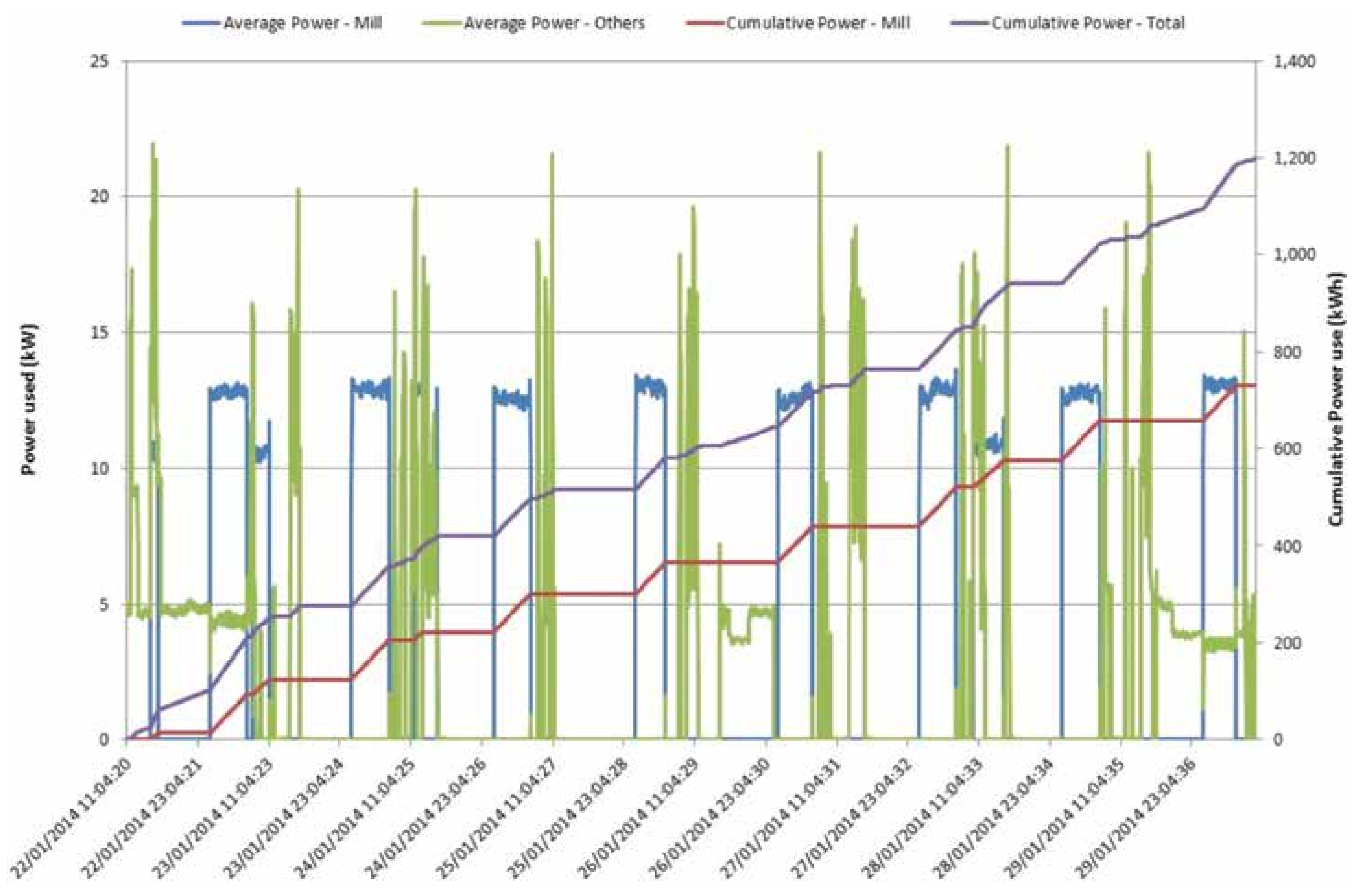





*Figure 4: Power recorded at Farm 4 feed mill*

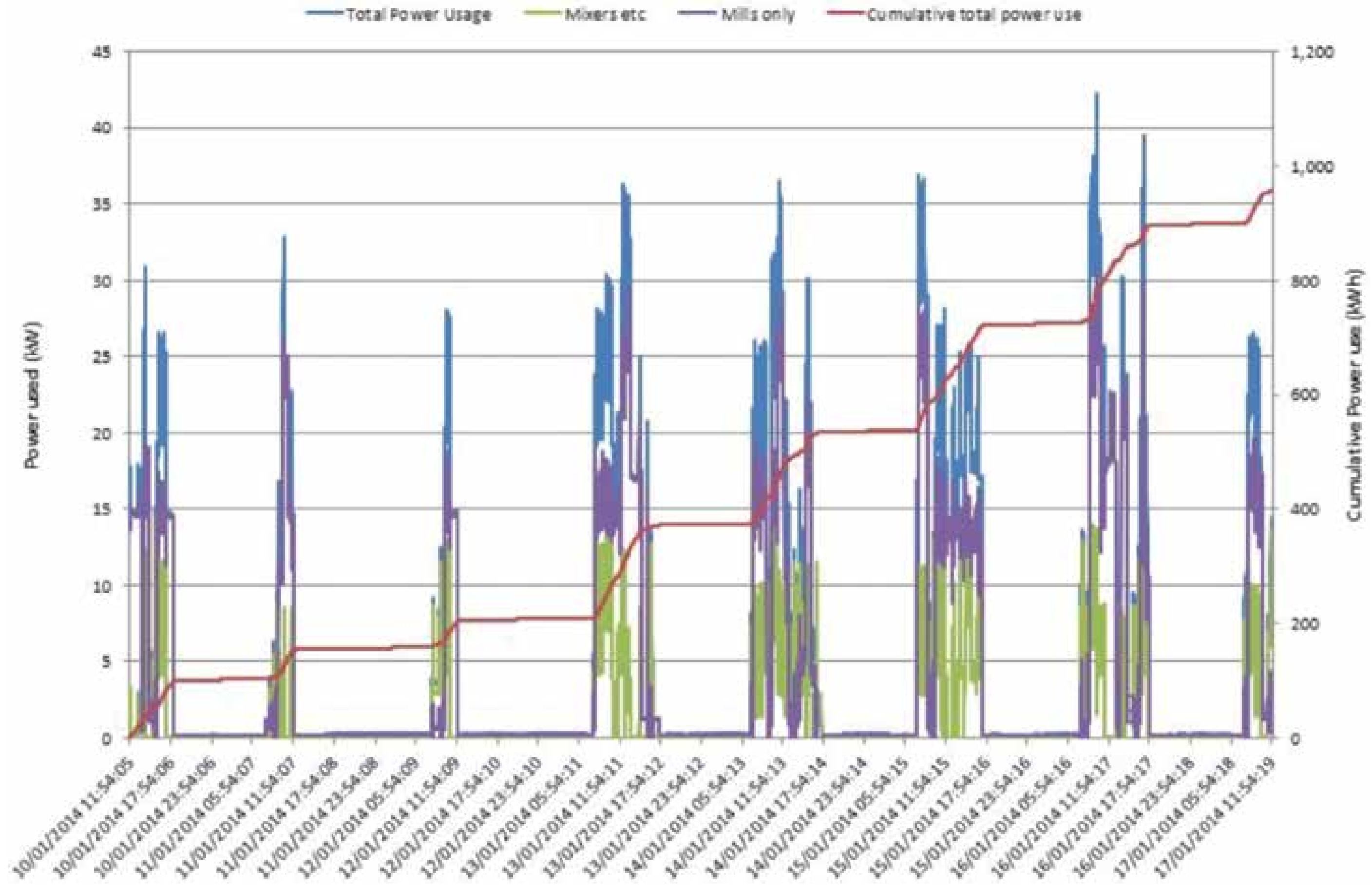
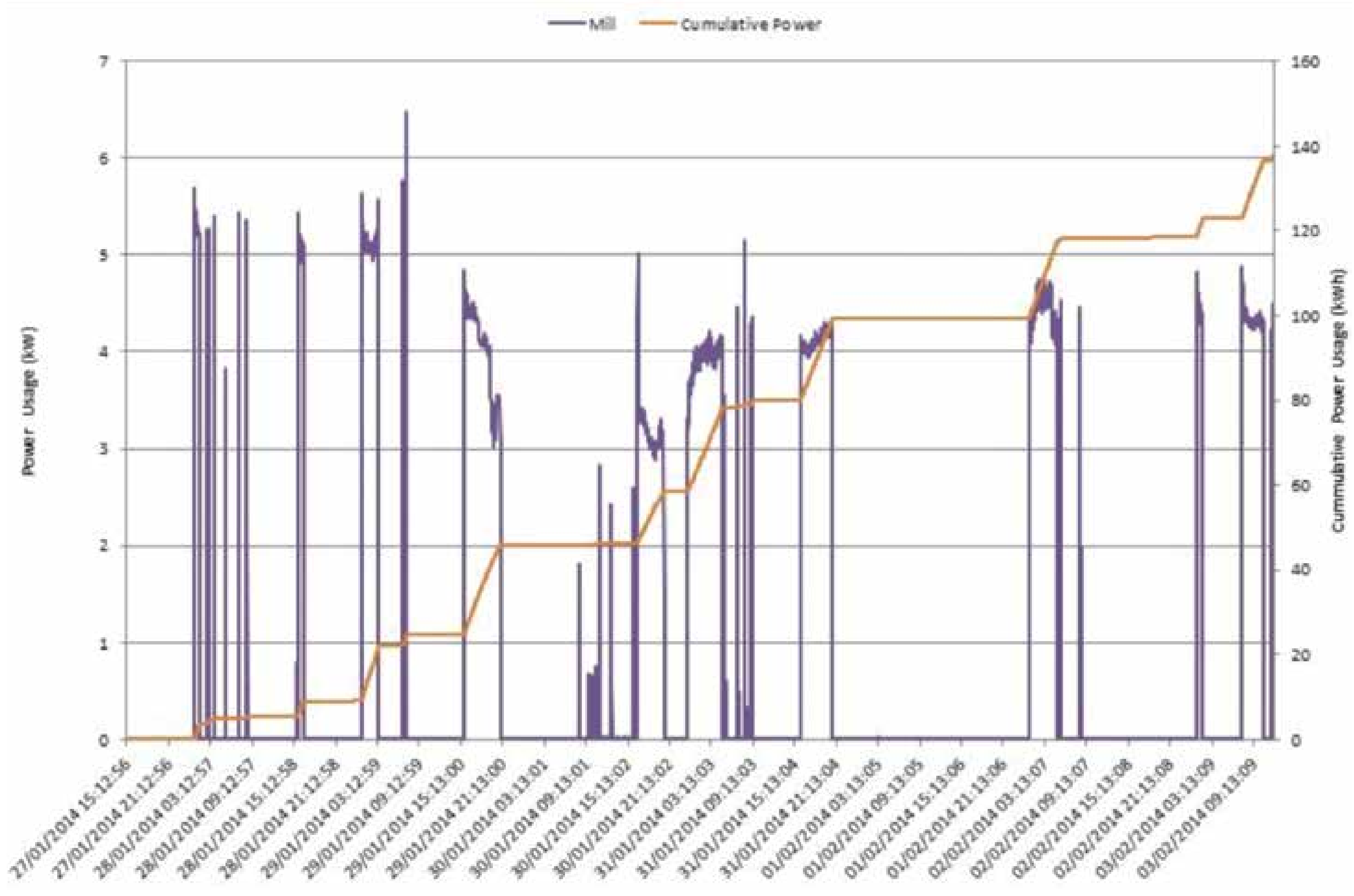
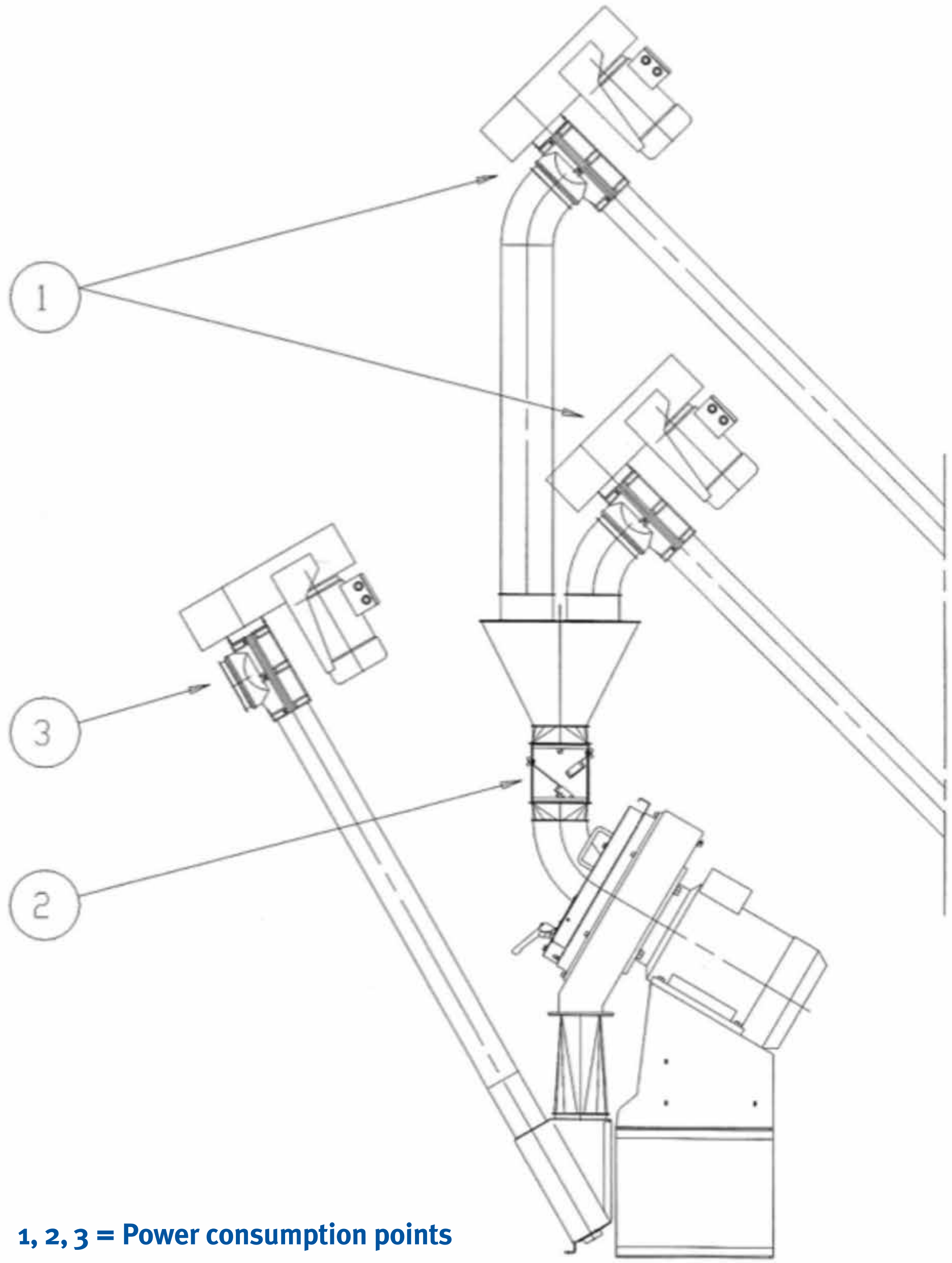



*Figure 5: Power recorded at Farm 5 feed mill*



# Efficient energy use in pig feed production
## Appendix III




**1, 2, 3 = Power consumption points**

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