National Agricultural Energy Optimisation Tool

User Manual 1.1

(As of 15/06/2020)

Contents

Introduction

In order to facilitate users with the proper use of the Agricultural Energy Optimisation Platform (AEOP), the following user manual has been developed.

AEOP is a web-based application offering:

1) decision support for farmers, researchers and policy makers the ability to investigate the economic, electrical and environmental impact of installing new energy efficient and/or renewable technologies on Irish farms using state-of-the-art mathematical modelling.
2) optimisation functionality whereby the optimal solar PV system, water heating system and management practices for either maximizing return on investment or minimizing electricity related CO_2 emissions on a dairy farm can be easily identified.
3) a summary of electricity consumption (Wh/litre), cost (€ cent/litre) and related CO_2 emissions (gCO2/litre) data for a cohort of Irish dairy farms in annual and monthly resolutions.
4) a summary of electricity consumption, cost and related CO_2 emissions data (relative to herd size, land use or overall consumption, cost or emissions) for a cohort of Ireland's beef, sheep and dairy farms between 2014 and 2017, as well as the ability to compare and contrast user's farm costs with Irish averages.

When utilized to its full potential, AEOP will assist with minimizing payback on investments for farmers, maximizing the effectiveness of grant aid for technologies on dairy farms and reduce the agricultural sector's contribution to overall GHG emissions.

This user manual consists of four primary sections. 1) a getting started section which shows users how to access AEOP, 2) a using AEOP section which incorporates step by step guides to the correct functionality of AEOP, 3) a summary and explanation of frequently asked questions, and 4) a glossary of common terms and abbreviations.

AEOP has been developed in collaboration between the Cork Institute of Technology, Bord Bia, Met Éireann, the SEAI and Teagasc. For further information please contact us.

1 Getting Started

1.1 Accessing AEOP

Step 1: Open any browser and go to the following URL: https://messo.cit.ie/dairy
Step 2: Scroll to the *Dairy Energy Decision Support Tool* icon and click *Enter*.

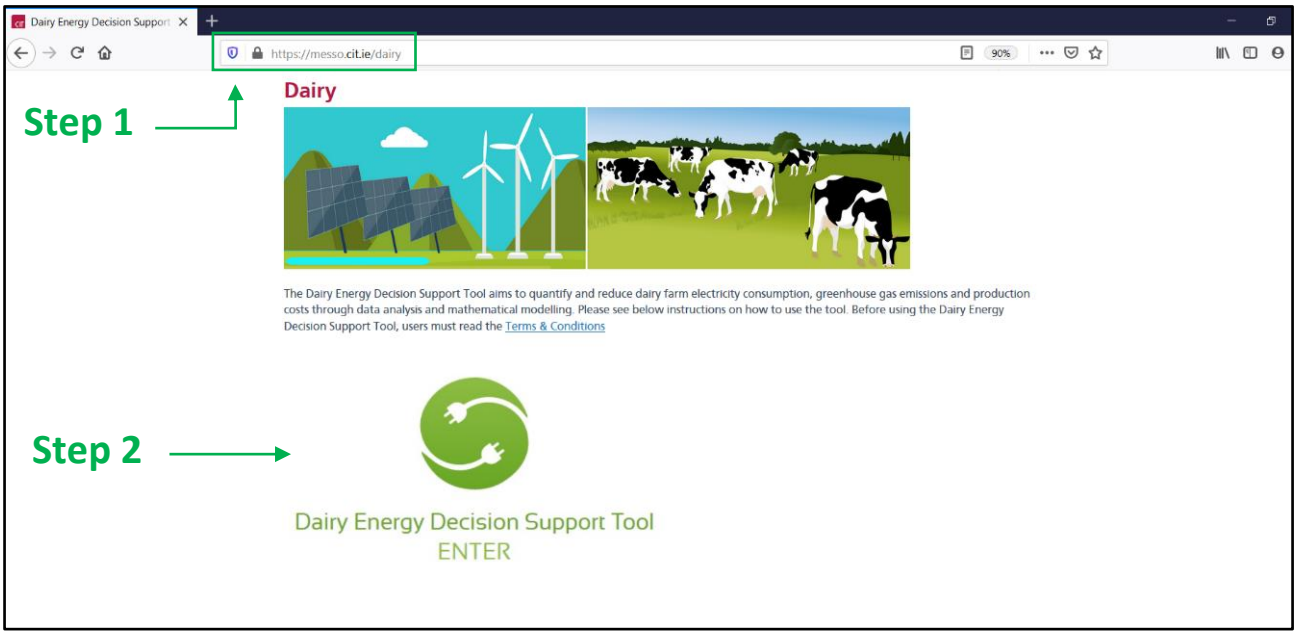

Figure 1 Dairy Energy Decision Support Tool web page

Note: This is the preferred method of accessing AEOP, as the portal URL is subject to change during periods of maintenance. The most recent AEOP version can always be accessed by following Step 1 and Step 2.

Step 3: Read and agree to the terms and conditions prior to using AEOP (see Figure 2).

Figure 2 AEOP terms and conditions

1.2 System overview

Figure 3 AEOP homepage

Once the T&C's have been accepted, the above homepage appears, as in Figure 3. AEOP consists of the following four subsections:

1. About

This section provides a summary of each sub-section with AEOP, including a glossary of dairy energy related terms.

2. Technology Calculator

The *Technology Calculator* allows for the calculation of potential payback periods, cost and CO_2 savings attributed to the installation of energy technologies such as variable speed drives (VSD) for milking machines, solar PV panels, solar thermal, heat recovery and wind turbines.

3. Energy Optimisation

The *Energy Optimisation* tool was added optimisation functionality to the *Technology Calculator*, allowing the optimal technology setup and management practices for either maximizing return on investment (ROI) or minimizing electricity related CO_2 emissions to be established, for a specific dairy farm.

4. Dairy Energy Statistics

This section offers a comprehensive summary of electricity consumption data from an exhaustive audit of Irish dairy farms where remote data recording commenced in 2008.

5. Beef, Sheep and Dairy Statistics

This section provides a summary of historical electricity cost data collected on a selection of Ireland's dairy, beef and sheep farms.

6. Help

This section offers users information related to the proper utilisation of AEOP, including an instructional video (in development), and user manual.

2 Using AEOP

2.1 Technology calculator

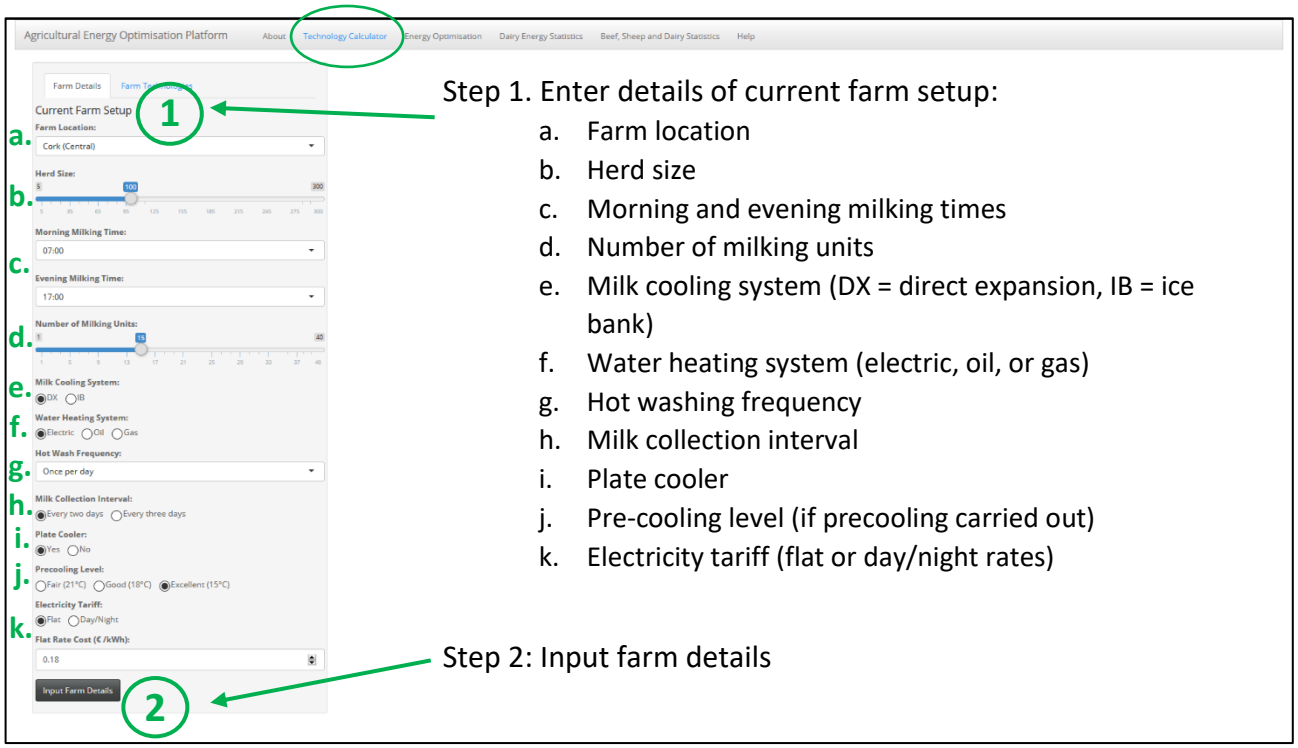

Figure 4 Enter farm details page of technology calculator

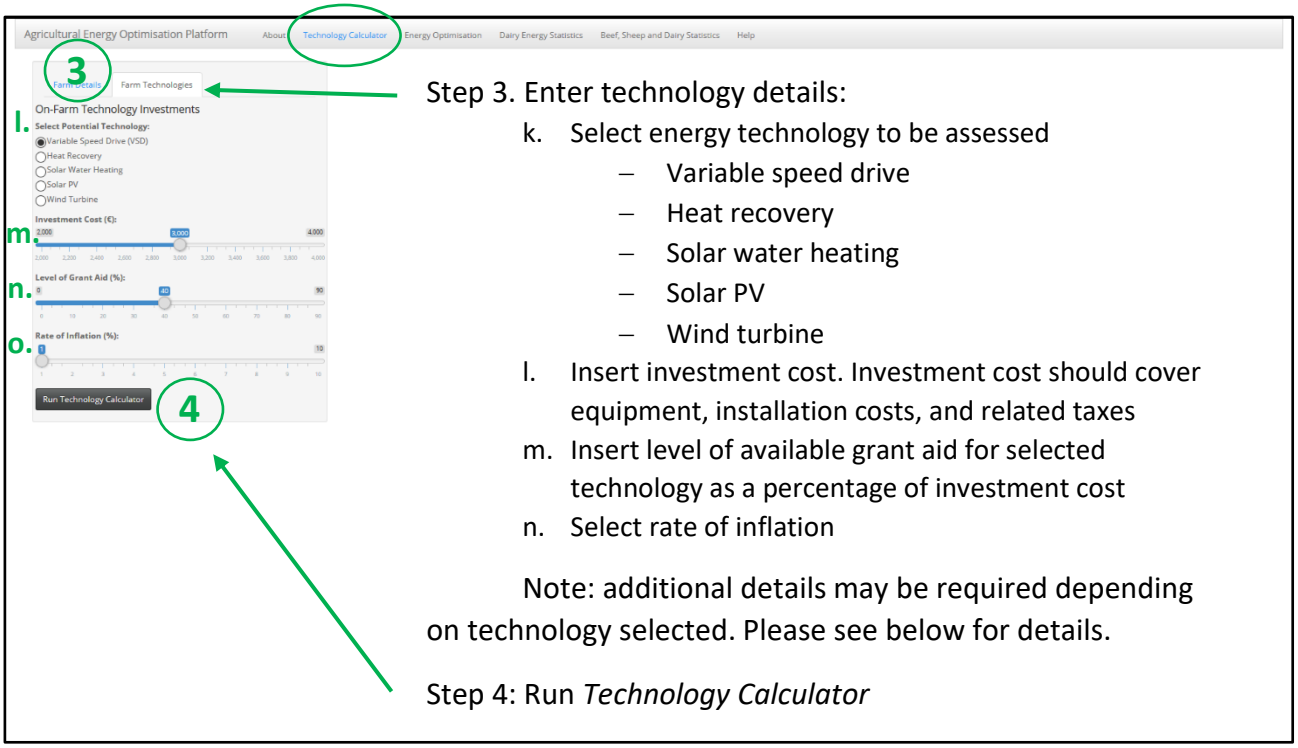

Figure 5 Enter energy technology details page

Additional technology details may include:

- Feed-in-Tariff

The impact of various Feed-in-Tariff (FIT) rates on overall ROI may also be assessed. A FIT is a monetary payment to owners of energy generation technologies such as solar PV or wind turbines, for exporting excess electricity to the electricity grid.

- Use renewable system for household electricity

This input is required when assessing solar PV and wind turbine energy technologies. This input is required to consider a planned situation when generated electricity would also provide energy to the farmhouse. If true, an annual electricity consumption figure of the farmhouse is required as an input.

- Start water heating after morning milking

This input represents the demand side management functionality of the technology calculator. By default, water heating is set to be carried out during night hours (beginning at 12 midnight), to avail of cheaper electricity of a day/night pricing system. However, users can assess potential ROI improvements of solar PV and wind turbine technologies due to shifting water heating to daytime hours.

Step 5. Wait a few moments while calculations are being carried out. Note: figures may take a few moments to appear after loading bar has complete. See Figure 6.

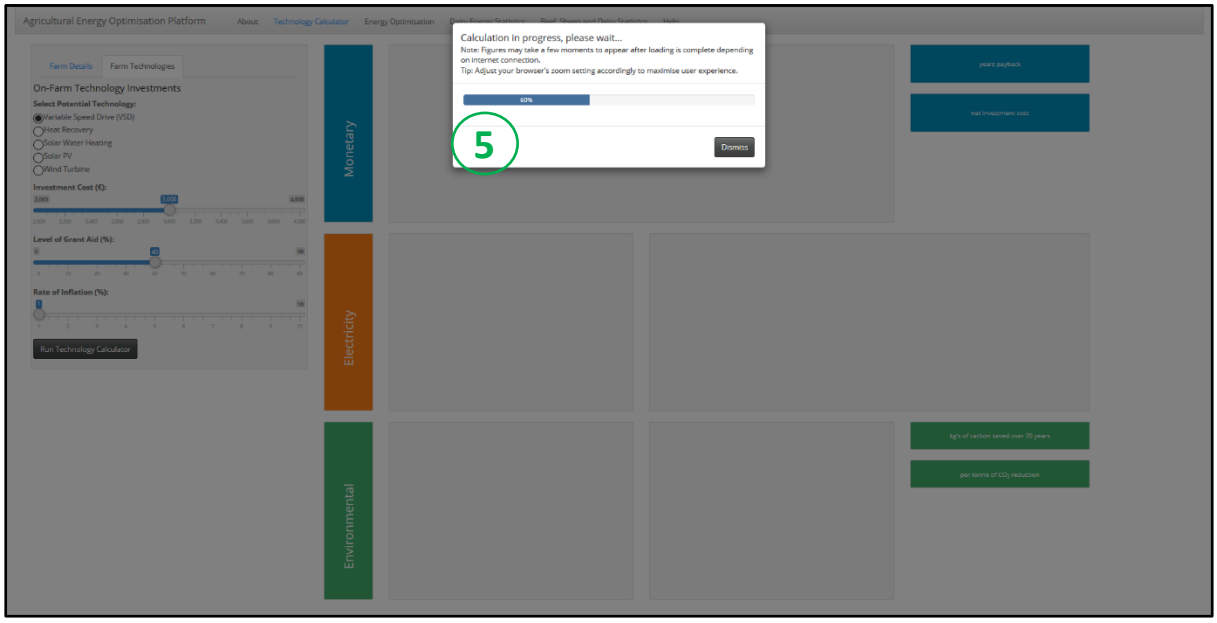

Figure 6 Loading bar demonstration

Step 6: Assess the monetary, electrical and environmental impact of installing the selected energy technology on the user's farm.

Figure 7 Technology calculator results page

Note: Figure 7 charts a, d, e, f, and g can be downloaded (as a .png file) by hovering the cursor over the required chart, and clicking the camera symbol.

Monetary

Figure 7a. Return on investment

The technology return on investment (ROI) bar chart demonstrates the annual performance of the selected technology in terms of its ROI. When the technology is first purchased (year 0), the ROI is -100%, with this value changing over time to reflect the savings incurred using the selected technology. Black bars signify years of investment deficit, while blue bars signify an investment surplus.

Figure 7b. Investment payback period

The payback period signifies the number of years required to cover the initial net investment cost. This is linked to the ROI bar chart, whereby the payback period represents the time when ROI switches from a deficit to a surplus.

Figure 7c. Net investment cost

Net investment cost equals the total investment cost minus grand aid.

Electricity

Figure 7d. Energy use

The energy use bar chart demonstrates the impact the selected on-farm technology has on the annual energy use of the farm. The *before* bar illustrates the farm's energy use prior to the addition of the on-farm technology. If a plate cooler is selected as the on-farm technology, the milk cooling energy is displayed. If VSD is selected, the milking machine energy use is

shown. If solar water heating or heat recovery are selected, the water heating energy is shown. If solar PV or wind turbine are selected, the overall farm energy is shown.

If plate cooler, VSD, solar water heating or heat recovery are selected, the *offset* bar displays the amount of energy which is provided by the selected technology. If solar PV or wind turbine are selected, the *generation* bar displays the amount of energy which is provided by said technology, in addition to the amount of energy exported to the grid.

Figure 7e. Farm load profile

The farm load profile displays hourly electrical energy consumption (kWh) of the farm with the energy technology installed, averaged across a typical year. If solar PV is selected, the electricity generated by the PV system is also displayed. This allows for parallels (or lack thereof) between farm energy use and PV energy generation to be identified.

Environmental

Figure 7f. CO_2 emissions

The CO_2 emissions bar chart demonstrates the environmental impact which the use of the selected on-farm technology has on the farm. The *before* bar illustrates the annual CO_2 emissions of the farm prior to the addition of on-farm technologies, while the *after* bar illustrates the annual CO_2 emissions of the farm when and on-farm technology is used.

Figure 7g. Grid vs Renewable energy penetration

A breakdown of the total annual energy purchased from the grid versus the total annual energy provided by renewable energy systems after the addition of an on-farm technology is displayed in this donut chart.

Figure 7h. CO_2 saved

The CO_2 emissions savings over the lifetime of the selected on-farm technology (20 years) is displayed here.

Figure 7i. Cost / tonne CO_2 reduction

This displays the net cost (minus grand aid) per tonne of CO_2 reduction over the lifetime (20 years) of the energy technology.

Step 7: The impact changes to herd size, infrastructural equipment, milking times, electricity tariff, or energy technology details will have on ROI and payback period can be easily calculated by following Step 1, Step 3, and Step 4.

2.2 Energy optimisation

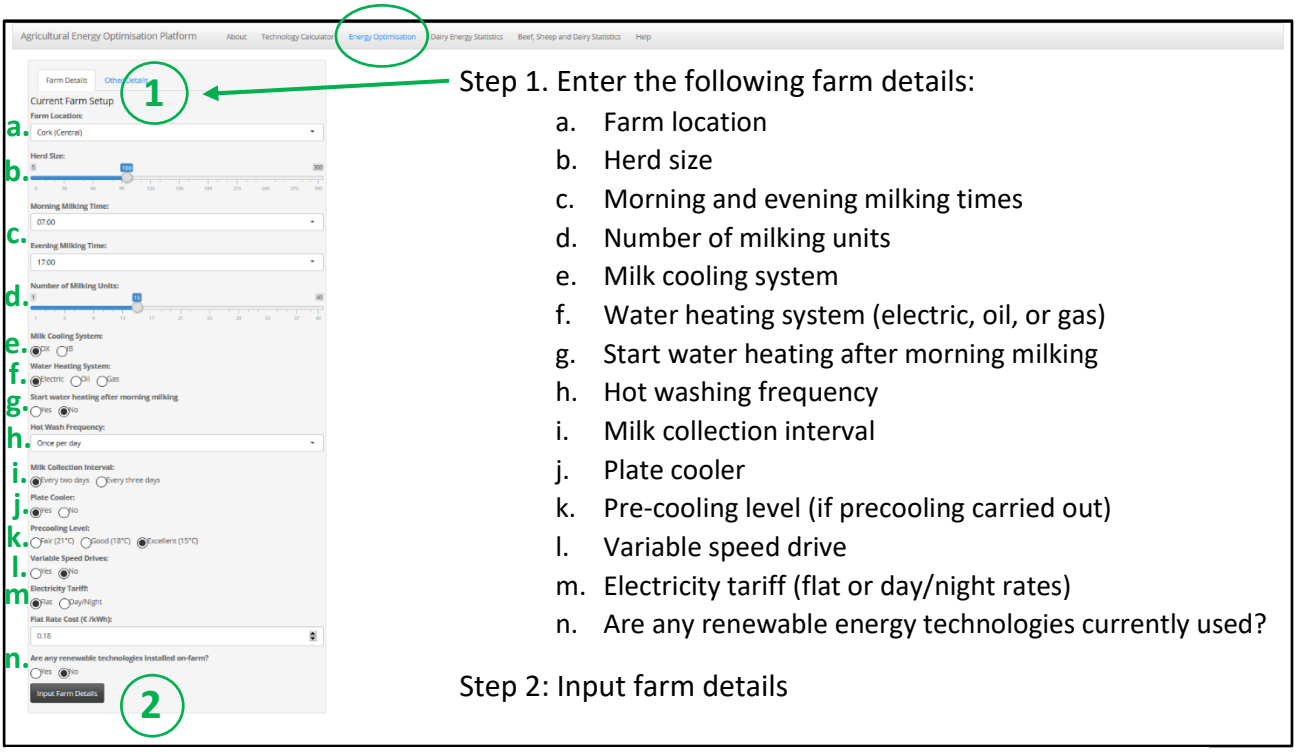

Figure 9 Enter farm details page of energy optimisation portal

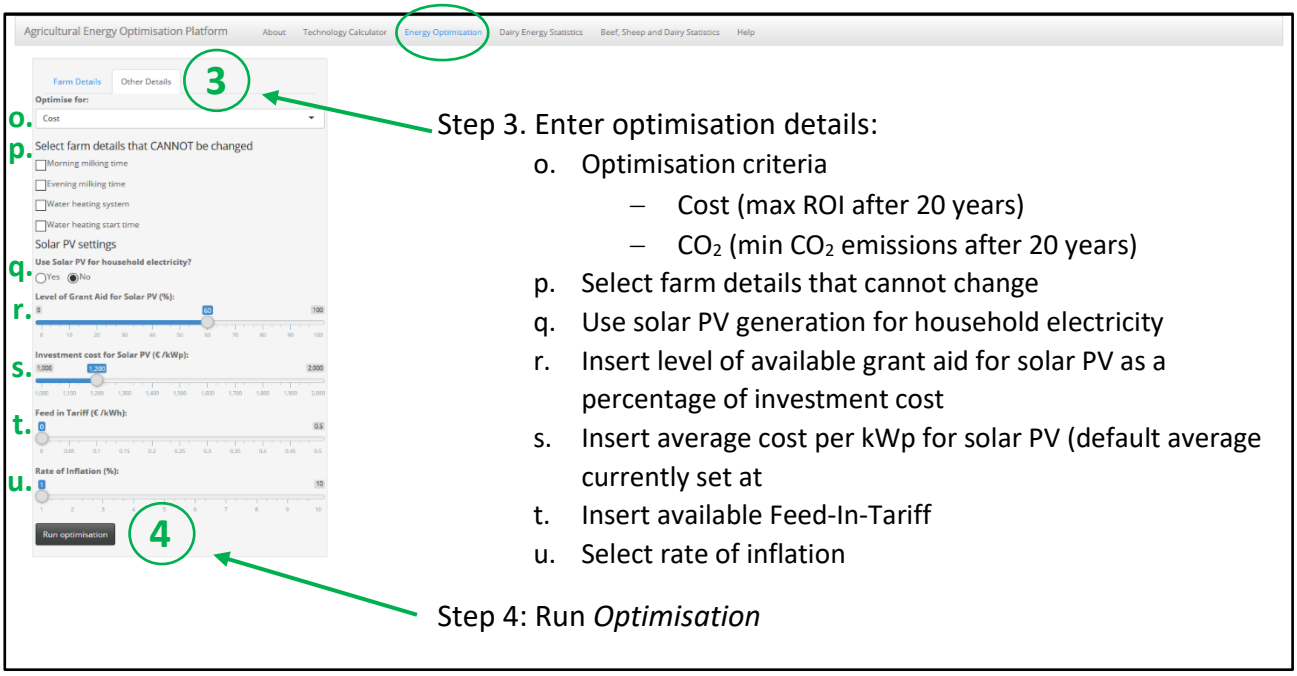

Figure 8 Enter energy optimisation details page

Step 5. Wait a few moments while calculations are being carried out. Note: figures may take a few moments to appear after loading bar has complete. See Figure 6.

Step 6: Assess the monetary, electrical and environmental impact of installing a solar PV system on the user's farm with optimum milking times, water heating system, water heating start time and solar PV system size under the given constraints to either maximise ROI or minimise CO_2 emissions.

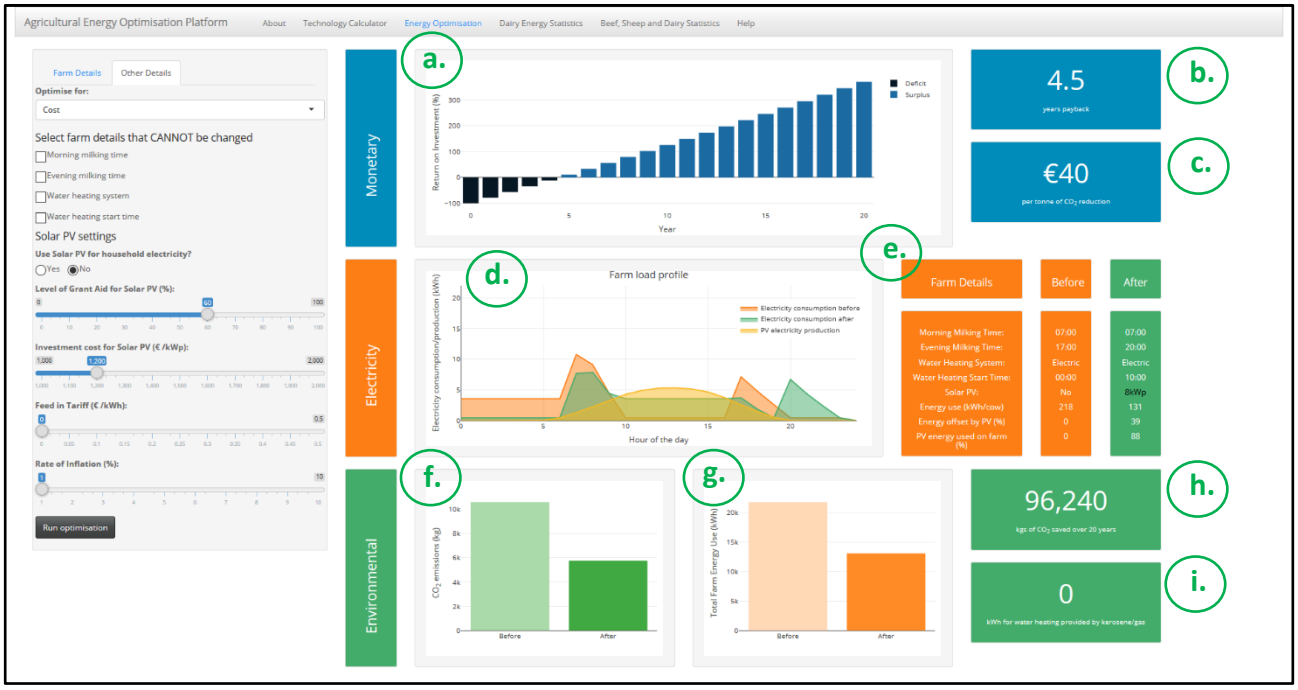

Figure 10 Energy optimisation results page

Monetary

Figure 10a. Return on investment

See page 8 for explanation.

Figure 10b. Investment payback period

See page 8 for explanation.

Figure 10c. Cost / tonne CO2 reduction

See page 9 for explanation.

Electricity

Figure 10d. Farm load profile

The farm load profile displays hourly electrical energy consumption (kWh) of the farm with the energy technology installed, averaged across a typical year. The electricity generated by the PV system is also displayed. This allows for parallels between PV energy generation, current energy use, and energy use after changes to managerial practices are carried out to be identified.

Figure 10e. Current and optimum farm details configurations

The current farm configuration and optimum farm configuration details are displayed here. The following farm details are displayed: morning milking time, evening milking time, water heating system, water heating system start time, solar PV system size, energy required (kWh/cow), energy offset by solar PV (%) (i.e. the percentage of total electricity use being met by solar PV), and solar PV energy used on-farm (%) (i.e. the percentage of generated PV energy consumed on-farm and not exported to electrical grid).

Environmental

Figure 10f. CO_2 emissions

See page 9 for explanation.

Figure 10g. Energy use

The energy use bar chart demonstrates the impact the solar PV system, and changes to milking times and water heating system and start time (if any) has on the annual energy use of the farm. The *before* bar illustrates the farm's energy use prior to any changes being carried out, while the *after* bar illustrates the farm's energy use after changes have been implemented.

Figure 10h. CO_2 saved

See page 9 for explanation

Figure 10i. kWh for water heating provided by kerosene/gas

This displays the kWh equivalent of energy provided by kerosene or gas for water heating purposes.

2.3 Dairy energy statistics

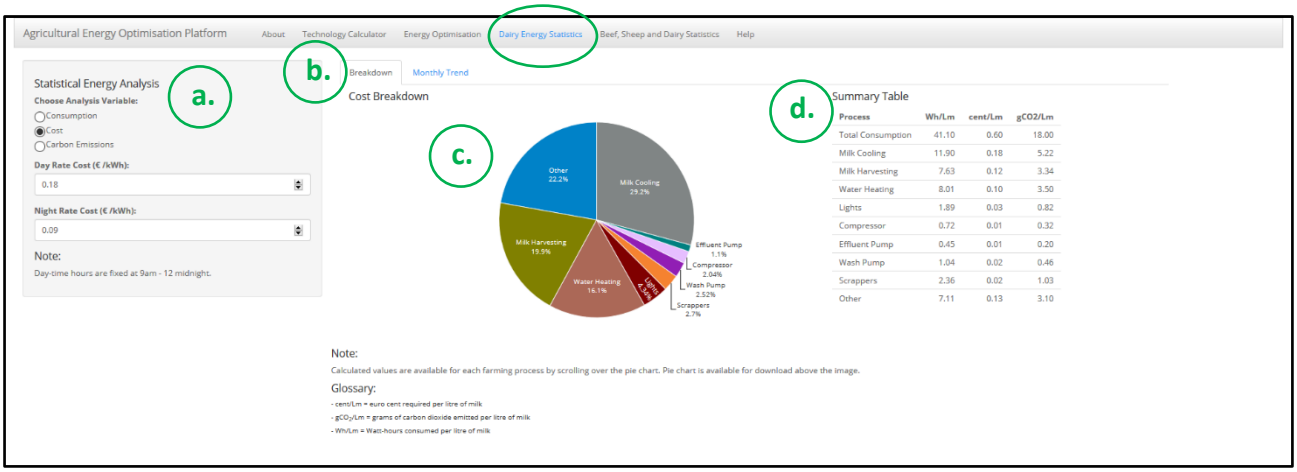

Figure 11 Dairy energy statistics page, breakdown tab

Figure 11a. Choose analysis variable

Here, user's can choose which analysis variable is to be broken down and assessed. Users can choose between electricity consumption, electricity cost, and CO_2 emissions. If electricity cost is selected, day and night electricity rates (€/kWh) may be adjusted accordingly (as in Figure 11). Similarly, if carbon emissions is selected, carbon intensity (gCO_2/kWh) may be adjusted.

Figure 11b. Select between *breakdown* and *monthly trend*

Here, user's can choose how the data is presented by selecting either the *breakdown* (as in Figure 11) or *monthly trend tab* (as in Figure 12). The *breakdown* tab presents a graphical (pie chart) breakdown of the selected analysis variable and a numerical breakdown of mean annual energy consumption, cost and carbon efficiencies (per litre of milk produced) according to each energy consuming process on a dairy farm.

Figure 11c. Breakdown

Here, a pie chart displaying a breakdown of either energy consumption, cost or CO_2 emissions according to each energy consumption process on a dairy farm is presented. Consumption, cost or CO_2 emissions are broken down according to the share due to milk cooling, milk harvesting, water heating, lighting, compressors, effluent pumping, wash pumping, scrappers and other miscellaneous usage throughout the farm. Note: calculated values are available for each farming process by scrolling over the pie chart. The pie chart can be downloaded by hovering the cursor over the chart, and clicking the camera symbol.

Figure 11d. Summary table

Here, energy consumption, cost and CO_2 emissions data used to create the pie charts are also displayed in a easy to interpret data table. Data is presented for each energy consuming process in terms of the energy consumption per litre of milk, electricity cost per litre of milk and CO_2 emissions per litre of milk (gCO_2/litre).

Figure 12 Dairy energy statistics page, monthly trend tab

Figure 12e. Monthly trend

Here, the *monthly trend* tab presents a graphical (stacked bar chart) breakdown of monthly energy consumption, cost or carbon emission (depending which analysis variable is selected) according to each energy consuming process on a dairy farm. This bar chart can be downloaded by hovering the cursor over the chart and clicking the camera symbol.

Figure 12f. Select criteria

Here, monthly energy consumption, cost or carbon emissions may be displayed relative to either herd size (number of cows) or milk production.

Figure 12g. Legend

Here, users can identify which colour on the monthly trend bar chart is associated with which energy consuming process by utilising the legend to the right of the chart. Users can also remove/add certain processes from the bar chart by clicking their identified on the legend (see Section 3.2).

2.4 Beef, sheep and dairy statistics

Figure 13 Beef, sheep and dairy statistics page, historical trend

Figure 13a. Choose analysis variable

Here, user's can choose which analysis variable is to be displayed. Users can choose between electricity consumption (kWh), electricity cost (€) or carbon emissions (CO_2). Energy consumption, cost or carbon emissions may be displayed relative to either herd size (number of cows), land use (ha) or overall consumption, cost or emissions.

Figure 13b. Select between *historical trend* and *statistics*

Here, user's can choose how the data is presented by selecting either the *historical trend* (as in Figure 13) or *statistics tab* (as in Figure 14).

Figure 13c. Historical trend

The *historical trend* tab presents a graphical (bar chart) representation of either average electricity consumption, electricity cost, or carbon emissions relative to either herd size, land use or overall consumption, cost or emissions across Irish beef, sheep and dairy farms between 2014 and 2017. This bar chart can be downloaded by hovering the cursor over the chart, and clicking the camera symbol (see Section 3.1).

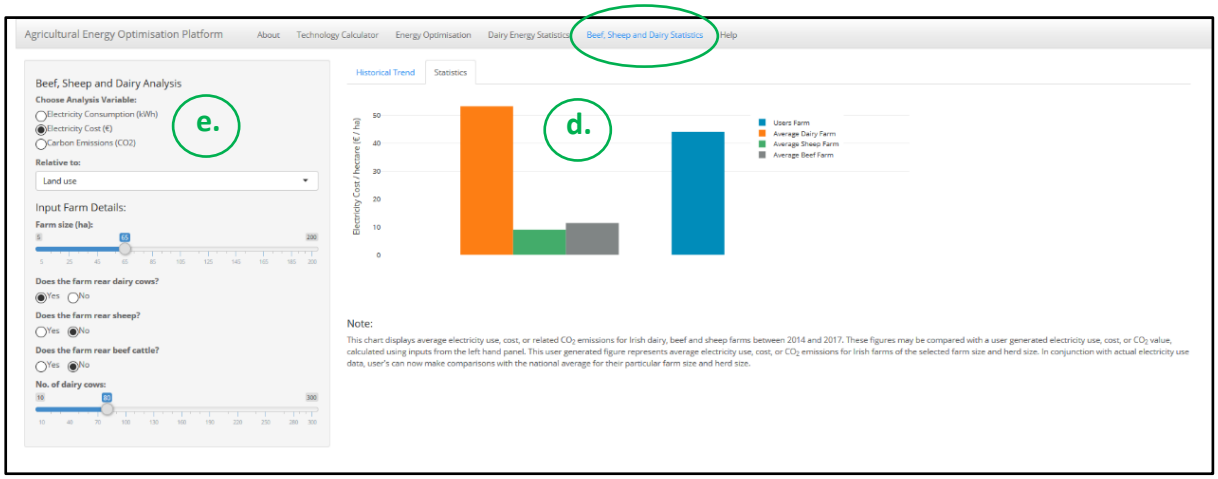

Figure 14 Beef, sheep and dairy statistics page, statistics

Figure 14d. Statistics graph

The statistics tab presents a graphical (bar chart) representation of either average (average of four years between 2014 and 2017) electricity consumption, electricity cost, or carbon emissions relative to either herd size, land use or overall values across Irish beef, sheep and dairy farms. Concurrently, an estimated electricity consumption, electricity cost, or carbon

emissions figure of the user's farm is presented, using farm size and herd size data inputted in the *input farm details* section (Figure 14e).

Figure 14e. Input farm details

The user's farm electricity consumption, electricity cost, or carbon emissions are estimated using an empirical model requiring data related to farm size (hectares), number of dairy cows, number of sheep, and number of beef cattle.

3 Frequently Asked Questions

3.1 How do I download charts as images?

Step 1. Hover cursor over required chart

Step 2. Click on camera symbol to download chart and .png file (see Figure 15)

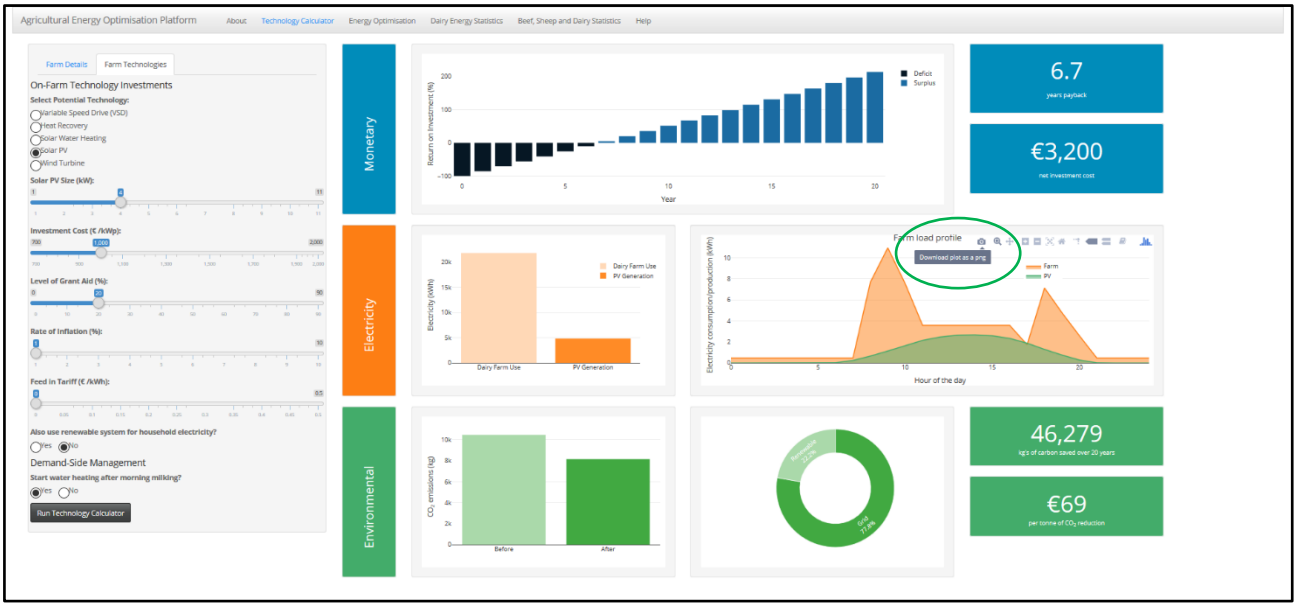

Figure 15 Downloading chart and .png file

Step 3. Save file, and click OK (see Figure 16).

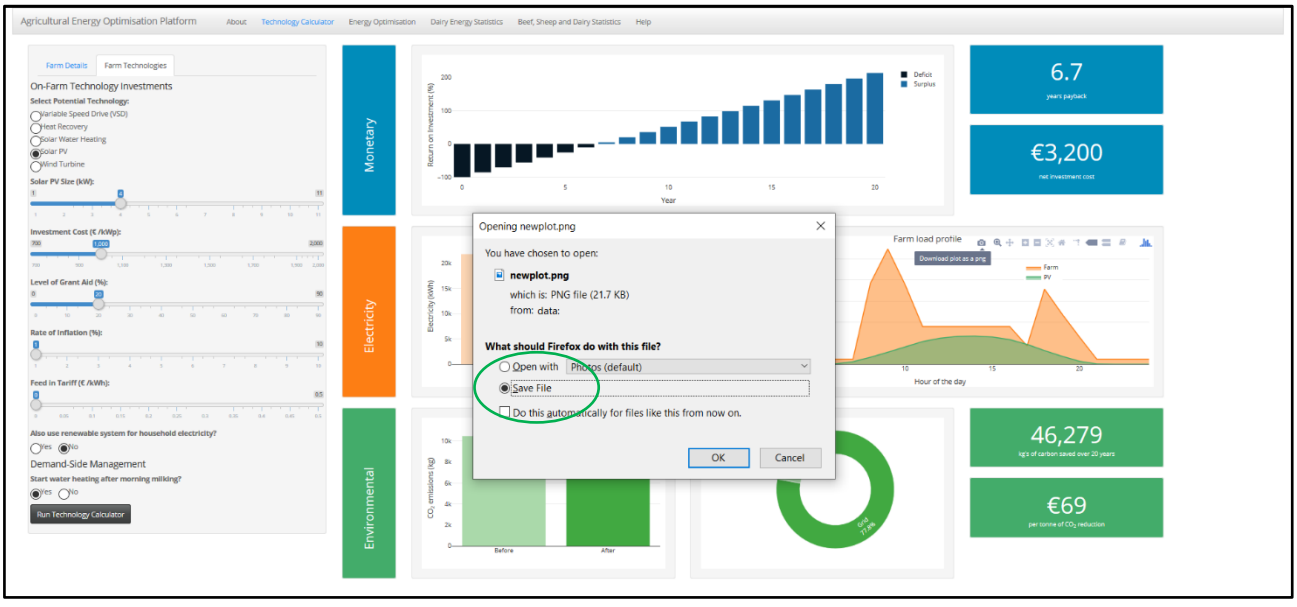

Figure 16 Download and save chart and .png image

3.2 How can I isolate single variables in a chart?

The following example shows you how to isolate single items on a chart by selecting or deselecting items on a chart legend. The following example uses the monthly sub-metered energy consumption chart as an example. However this procedure may be used on **any** chart.

Step 1. Deselect all dairy energy processes (e.g. scrappers, wash pump, etc..) with the cursor that you do not wish to appear in the related chart.

For example, Figure 17 shows the monthly electricity consumption per dairy cow of water heating, milk harvesting and milk cooling, whereby the other dairy energy processes have been deselected in the legend and thus appear in a faint grey colour.

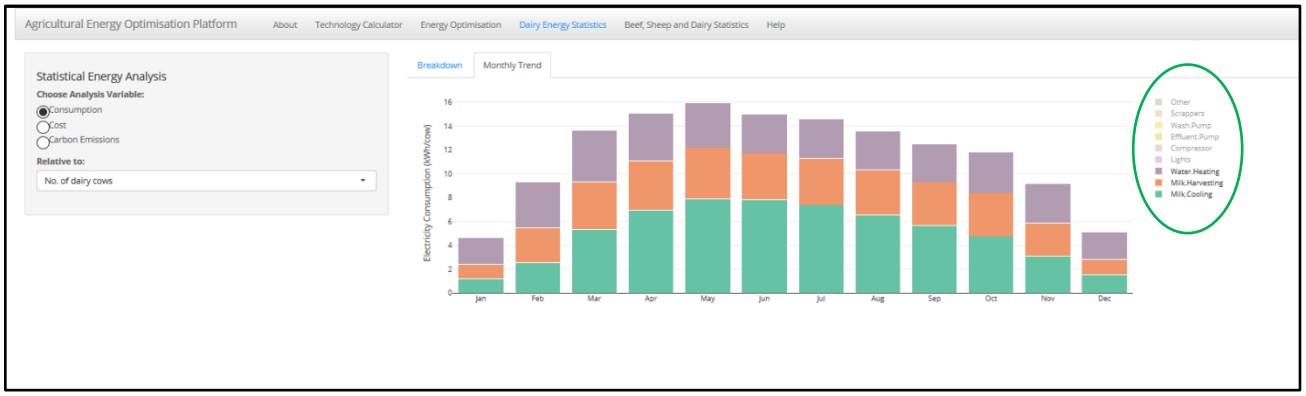

Figure 17 Showing the deselection of dairy energy processes except for water heating, milk harvesting and milk cooling.

3.3 How can I identify the actual values within a chart?

Step 1. Hover cursor over section of the chart you wish to know the numerical value. The numerical value should appear automatically.

For example, in Figure 18, the cursor was hovered over the green section (milk cooling) of month June, whereby the average cost equalled €1.19/cow.

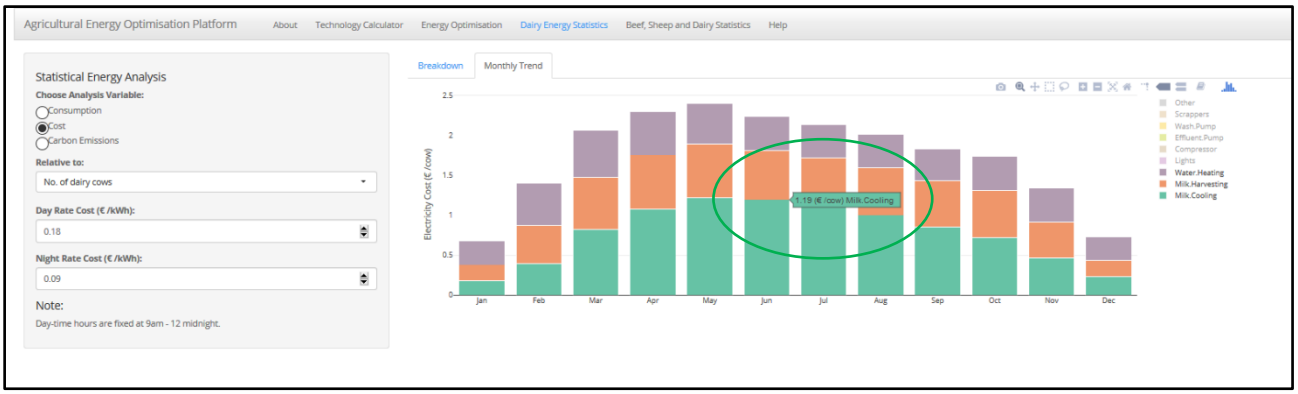

Figure 18 Showing numerical value on bar chart

3.4 How can I calculate the combined impact of farm changes on overall return on investment in solar PV?

Step 1. In the *Farm Details* tab within the *Energy Optimisation* section:

- Input farm details relevant to your farm

Step 2. In the *Other Details* tab within the *Energy Optimisation* section:

- Under the "*Select farm details that CANNOT be changed*" heading, select farm details that you do not want to assess the combined improvement. For example, if you wish to calculate the combined impact of making changes to morning and evening milking times, water heating system and water heating start time, ensure all four boxes remain unticked.
- Input details under the *Solar PV settings* heading related to grant aid availability, FIT availability, solar PV cost and inflation relevant to your situation.

Step 3. Run Optimisation

Step 4. Note optimum solar PV system size selected and calculated payback period.

Step 5. In the *Farm Details* tab within the *Technology Calculator* section:

- Input farm details relevant to your farm in the *Farm Details* tab, ensuring those details are identical to those inputted in Step 1 above.

Step 6. In the *Farm Technologies* tab within the *Technology Calculator* section:

- Under the "*Select Potential Technology*:" heading, select *solar PV*.
- Select the solar PV system size that was identified in Step 4 above.
- Input identical details related to grant aid availability, FIT availability, solar PV cost and inflation as inputted in Step 2

Step 7. Run *Technology Calculator*

Step 8. Note difference between *Technology Calculator* and *Energy Optimisation* outputs, i.e. payback period, CO_2 savings over 20 years, € cost per tonne of CO_2 reduction, etc..

4 Glossary

4.1 Milk Cooling System:

On average, an ice bank milk cooling system will consume 32% more electricity than a direct expansion system. However, ice bank bulk tanks have the ability to shift consumption to off-peak times to take advantage of cheaper rates of electricity. The effect of this load shifting capability on production costs will be impacted on whether milk is firstly pre-cooled with water.

4.2 Milk Pre-Cooling:

Pre-cooling milk with water through a plate heat exchanger saves 21% of milk cooling related electricity consumption on average. However, this figure varies according to whether a direct expansion or ice bank bulk tank is installed.

4.3 Water Heater System:

Three water heating system options may be assessed via either the *Technology Calculator* or *Energy Optimisation* tools. These include: electric, oil or gas. The selection of either will impact electricity consumption, cost and CO_2 emissions.

4.4 Electricity Tariffs:

One of two electricity tariffs may be selected for analysing the impact of energy technologies including a flat rate, a day and night rate. As default, the *Technology Calculator* uses a flat rate value of 16 cent/kWh, while the day and night rate electricity tariff uses a day rate of 18 cent/kWh and a night rate of 8 cent/kWh. Different return on investments will be calculated for different technologies based upon the electricity tariff utilised due to the electricity consumption trend of a specific dairy farm.

4.5 Technology Investments:

The *Technology Calculator* analyses the applicability of six potential technologies for specific dairy farm conditions. These technologies include: a plate cooler, variable speed drives, a heat recovery system, solar water heating, solar PV and a wind turbine. In order to simulate the potential return on investment of these renewable and energy efficient technologies, a number of specific details related to investment cost, available grant aid and the rate of inflation is required. For wind and PV systems, users may input a Feed-in tariff (FIT) to simulate potential future scenarios involving the exportation of excess electricity.