Energy efficiency and renewable options for dairy farms

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• Milk cooling and water heating on dairy farms

• Energy efficient technologies for dairy farms
  • Milk precooling
  • Variable speed drives (VSDs) for milking machines

• Optimal dairy farm infrastructure

• Renewable energy options for dairy farms
  • Solar panels
  • Heat recovery systems

• Overall objective of research

• Summary
Energy audits

- General farm data were collected using a once off survey
- Electricity consumption was recorded using a wireless monitoring system
Electricity costs

- Average electricity costs = 0.51 c/L (range 0.23 – 0.76 c/L)
Energy model

Model Inputs
Milk yield, Cow numbers, Farm infrastructure, Farm management practices, Electricity tariff structure.

Model Outputs
Monthly and total kWh consumption, component running costs.

Consumption:
- Milk Cooling Consumption
- Water Heating Consumption
- Milking Machine Consumption
- Lighting Consumption
- Water Pump Consumption
- Wash Pump Consumption
- Winter Housing Consumption
Key electricity consumers

- Milk cooling
- Water heating
- Vacuum pumps
Milk cooling

Two possible milk cooling systems on dairy farms:

- Direct Expansion (DX)
- Ice Bank (IB)
Direct Expansion (DX)

- Direct expansion systems cool milk directly using a refrigeration system installed in the tank wall
Direct Expansion (DX)

• **Advantages:**
  - The most efficient way to cool milk in terms of kWh/litre of milk cooled
  - High COP (coefficient of performance)
  - Low capital cost

• **Disadvantages:**
  - Large compressor units (could be a problem for large farms on single-phase supply)
  - High proportion of day rate electricity used
Ice Bank (IB)

- Ice bank systems use a refrigeration system to freeze water which is then used to cool the milk.
Ice Bank (IB)

- **Advantages:**
  - Can be configured to use 100% night rate electricity resulting in low running costs
  - Smaller compressor units

- **Disadvantages:**
  - More electricity used
  - Higher capital costs
  - Lower COP
Adjusting milk cooling system

• Case of 195 cow farm, producing approx 800,000 litres per annum

• Stocked at 2.4 LU/hectare

• What happens if farm changes from Direct expansion to Ice bank cooling?
<table>
<thead>
<tr>
<th>Strategy</th>
<th>DX, No precooling</th>
<th>Mode Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Milking Time</td>
<td>07:00 h</td>
<td>Annual electricity use (kWh)</td>
</tr>
<tr>
<td>PM Milking Time</td>
<td>17:00 h</td>
<td>Electricity use per Liter (Wh/L)</td>
</tr>
<tr>
<td>Tariff</td>
<td>Day/Night</td>
<td>Annual electricity costs (€)</td>
</tr>
<tr>
<td>Cooling System</td>
<td>Direct Expansion</td>
<td>Electricity cost per Litre (C/L)</td>
</tr>
<tr>
<td>Precooling (Y/N)</td>
<td>N</td>
<td>C0₂ emissions (kg)</td>
</tr>
<tr>
<td>Water Heating System</td>
<td>Electric</td>
<td></td>
</tr>
<tr>
<td>Vacuum Pumps</td>
<td>Standard</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing load (kW) over time from 00:00 to 24:00 for each month (Jan to Dec).](graph_asset)
<table>
<thead>
<tr>
<th>Strategy</th>
<th>IB, No precooling</th>
<th>Mode Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Milking Time</td>
<td>07:00 h</td>
<td>Annual electricity use (kWh) 33,901(+4%)</td>
</tr>
<tr>
<td>PM Milking Time</td>
<td>17:00 h</td>
<td>Electricity use per Liter (Wh/L) 44</td>
</tr>
<tr>
<td>Tariff</td>
<td>Day/Night</td>
<td>Annual electricity costs (€) 3,218 (-29%)</td>
</tr>
<tr>
<td>Cooling System</td>
<td>Ice Bank</td>
<td>Electricity cost per Litre(C/L) 0.42</td>
</tr>
<tr>
<td>Precooling (Y/N)</td>
<td>N</td>
<td>C0₂ emissions (kg) 16,513</td>
</tr>
<tr>
<td>Water Heating System</td>
<td>Electric</td>
<td></td>
</tr>
<tr>
<td>Vacuum Pumps</td>
<td>Standard</td>
<td></td>
</tr>
</tbody>
</table>

### Load (kW) vs Time

- **Jan**
- **Feb**
- **Mar**
- **Apr**
- **May**
- **Jun**
- **Jul**
- **Aug**
- **Sep**
- **Oct**
- **Nov**
- **Dec**
Water heating

- Electrical water heating is most common
- Recommended to use night rate electricity with timers
- 0:00 – 09:00 summer time, 23:00 – 08:00 winter time

<table>
<thead>
<tr>
<th>Price per 100 litres of hot water (80°C)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Day Rate Electricity</td>
<td>€1.66</td>
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<tr>
<td>Night Rate Electricity</td>
<td>€0.89</td>
</tr>
<tr>
<td>Gas Fired System</td>
<td>€0.66</td>
</tr>
<tr>
<td>Oil Fired System</td>
<td>€0.62</td>
</tr>
</tbody>
</table>
Energy efficient technologies

- Two common energy efficient technologies to consider:
  - Milk precooling
  - Variable speed drives (VSDs) for milking machine vacuum pumps
• Energy efficient technology 1: Milk precooling
Energy efficient technology 1: Milk precooling

- Milk is cooled before entering DX/IB using water pumped through a plate heat exchanger
- Goal of precooling is to cool milk to within 5 degrees Celsius of incoming water temperature
- This goal rarely achieved in practice
- Variable speed milk pump and correct sizing of plate cooler important
- Water:Milk flow ratio crucial
Effect of precooling

- Aim for water:milk ratio of 2:1
- Can reduce milk cooling energy use by 50%
- Installing plate heat exchanger for pre-cooling will save >€1,000 on a 100 cow dairy farm
Effect of precooling

2:1 - Recommended water/milk ratio
Installation of precooling system

- Case of 195 cow farm, producing approx. 800,000 litres per annum
- Stocked at 2.4 LU/hectare
- What happens if farm installs precooling?
<table>
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<tr>
<th>Strategy</th>
<th>DX, No precooling</th>
<th>Mode Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Milking Time</td>
<td>07:00 h</td>
<td>Annual electricity use (kWh)</td>
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<td></td>
<td></td>
<td>32,670</td>
</tr>
<tr>
<td>PM Milking Time</td>
<td>17:00 h</td>
<td>Electricity use per Liter (Wh/L)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Tariff</td>
<td>Day/Night</td>
<td>Annual electricity costs (€)</td>
</tr>
<tr>
<td></td>
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<td>4,571</td>
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<tr>
<td>Cooling System</td>
<td>Direct Expansion</td>
<td>Electricity cost per Litre (C/L)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.59</td>
</tr>
<tr>
<td>Precooling (Y/N)</td>
<td>N</td>
<td>C0₂ emissions (kg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17,315</td>
</tr>
<tr>
<td>Water Heating System</td>
<td>Electric</td>
<td></td>
</tr>
<tr>
<td>Vacuum Pumps</td>
<td>Standard</td>
<td></td>
</tr>
</tbody>
</table>

### Load Graph

- **Axes:**
  - Y-axis: Load (kW)
  - X-axis: Time (00:00 to 24:00)

- **Months:**
  - Jan
  - Feb
  - Mar
  - Apr
  - May
  - Jun
  - Jul
  - Aug
  - Sep
  - Oct
  - Nov
  - Dec
<table>
<thead>
<tr>
<th>Strategy</th>
<th>DX, with precooling</th>
<th>Mode Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Milking Time</td>
<td>07:00 h</td>
<td>Annual electricity use (kWh) 23,660 (-28%)</td>
</tr>
<tr>
<td>PM Milking Time</td>
<td>17:00 h</td>
<td>Electricity use per Liter (Wh/L) 31</td>
</tr>
<tr>
<td>Tariff</td>
<td>Day/Night</td>
<td>Annual electricity costs (€) 2,857 (-37%)</td>
</tr>
<tr>
<td>Cooling System</td>
<td>Direct Expansion</td>
<td>Electricity cost per Litre(C/L) 0.37</td>
</tr>
<tr>
<td>Precooling (Y/N)</td>
<td>Y</td>
<td>C0₂ emissions (kg) 12,540</td>
</tr>
<tr>
<td>Water Heating System</td>
<td>Electric</td>
<td></td>
</tr>
<tr>
<td>Vacuum Pumps</td>
<td>Standard</td>
<td></td>
</tr>
</tbody>
</table>

Payback of 3 years
Energy efficient technology 2: Variable speed drives (VSDs) for milking machine vacuum pumps
Energy efficient technology 2: VSDs for vacuum pumps

- Stable vacuum needed for milking cows
- Conventional milking machine - constant speed vacuum pump
- Actual amount of vacuum needed varies
Energy efficient technology 2: VSDs for vacuum pumps

- Variable speed drive adjusts pumping speed based on system vacuum requirement
- Example: 16 unit plant, recommended pump capacity is 2160 l/min, whereas average capacity required for milking is 560 l/min
- 65% savings using variable speed drives (VSD) in this case
- Cost of VSD = €3,000
- Payback period on VSD = Approximately 10 years
Investigation of optimal farm infrastructure

- Highest farm profitability (under normal circumstances)
  - Direct expansion milk cooling
  - Precooling with a water:milk ratio of 2:1
  - Electrical water heating using night rate electricity
  - Standard vacuum pumps

- Highest farm profitability where pre-cooling is not possible (i.e. water shortage) or where electricity supply is limiting
  - Ice bank milk cooling
  - Electrical water heating using night rate electricity
  - Standard vacuum pumps
Renewable options

• Two renewable technologies to consider:
  • Solar panels
  • Heat recovery systems
Method used for analysis of renewable systems

- Two models used to simulate the effect of two different renewable technologies:
  - Solar panels
  - Heat recovery systems
- Models were combined with Energy model (MECD) to calculate annual dairy farm savings and investment potential for each renewable option
Farm considered for analysis of renewable systems

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cows</td>
<td>195</td>
</tr>
<tr>
<td>Number of milking units</td>
<td>24</td>
</tr>
<tr>
<td>Number of milkings per day</td>
<td>2</td>
</tr>
<tr>
<td>Annual milk yield (litres)</td>
<td>800,000</td>
</tr>
<tr>
<td>Hot wash frequency</td>
<td>Once per day</td>
</tr>
</tbody>
</table>
• Renewable option 1: Solar panels
Renewable option 1: Solar panels

• Solar panels collect sunlight which heats a fluid in the panels

• This fluid is passed through a coil in the hot water cylinder, transferring heat to the water

• Solar panel model built using data collected at Teagasc Moorepark

• 10 square meter system used for simulations

• Initial capital cost = €7,500
Solar panels - Results

• Under the conditions examined:
  
  • Annual savings = €300
  
  • Cooling system (DX/IB/precooling) irrelevant as solar panels only affect water heating
  
  • What is the maximum you should pay when purchasing solar panels in order to get payback on your investment?

  €1,100
• Renewable option 2: Heat recovery systems
Renewable option 2: Heat recovery systems

- Heat extracted from milk during cooling is recycled to preheat water for sanitation

- Heat recovery system model built using data collected at Teagasc Moorepark

- Initial capital cost = €3,000 (post 40% grant)
Heat recovery systems - Results

- Under the conditions examined, annual savings are as follows:

<table>
<thead>
<tr>
<th>Cooling method</th>
<th>DX</th>
<th>IB</th>
</tr>
</thead>
<tbody>
<tr>
<td>No precooling</td>
<td>€223</td>
<td>€196</td>
</tr>
<tr>
<td>With precooling</td>
<td>€200</td>
<td>€190</td>
</tr>
</tbody>
</table>
Heat recovery systems - Results

• When using precooling:
  • What is the maximum you should pay when purchasing a heat recovery system in order to get payback on your investment?
    €1,900

• When using no precooling:
  • What is the maximum you should pay when purchasing a heat recovery system in order to get payback on your investment?
    €2,900
Overall objective of research

- Develop decision support tool to help farmers choose between technologies and options including:
  - Energy efficiency technologies
  - Renewable systems
  - Farm management practices

- Include other renewable systems for analysis such as solar photovoltaics (PV) and wind turbines
Summary

• There is a large variation in energy costs on Irish dairy farms

• Farm energy costs should be calculated before installing new equipment

• By introducing both precooling of milk and variable speed drives on milking machine vacuum pumps, overall farm energy consumption can be reduced by up to 40%

• For a large farm, investment in a solar panel system should not be considered unless initial capital cost is €1,100 or less

• For a large farm, investment in a heat recovery system should not be considered unless initial capital cost is €1,900 or less when using precooling, and €2,900 or less when using no precooling
Thank you