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Investment appraisal of technology innovations on dairy farm electricity consumption

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ABSTRACT

The aim of this study was to conduct an investment appraisal for milk-cooling, water-heating, and milk-harvesting technologies on a range of farm sizes in 2 different electricity-pricing environments. This was achieved by using a model for electricity consumption on dairy farms. The model simulated the effect of 6 technology investment scenarios on the electricity consumption and electricity costs of the 3 largest electricity-consuming systems within the dairy farm (i.e., milk-cooling, water-heating, and milking machine systems). The technology investment scenarios were direct expansion milk-cooling, ice bank milk-cooling, milk precooling, solar water-heating, and variable speed drive vacuum pump-milking systems. A dairy farm profitability calculator was combined with the electricity consumption model to assess the effect of each investment scenario on the total discounted net income over a 10-yr period subsequent to the investment taking place. Included in the calculation were the initial investments, which were depreciated to zero over the 10-yr period. The return on additional investment for 5 investment scenarios compared with a base scenario was computed as the investment appraisal metric. The results of this study showed that the highest return on investment figures were realized by using a direct expansion milk-cooling system with precooling of milk to 15°C with water before milk entry to the storage tank, heating water with an electrical water-heating system, and using standard vacuum pump control on the milking system. Return on investment figures did not exceed the suggested hurdle rate of 10% for any of the ice bank scenarios, making the ice bank system reliant on a grant aid framework to reduce the initial capital investment and improve the return on investment. The solar water-heating and variable speed drive vacuum pump scenarios failed to produce positive return on investment figures on any of the 3 farm sizes considered on either the day and night tariff or the flat tariff, even when the technology costs were reduced by 40% in a sensitivity analysis of technology costs.
Key words: dairy technology, electricity, milk production, profitability

INTRODUCTION

Global energy prices increased steadily over the last 5 yr, resulting in increases in electricity costs on European farms of over 30% from 2007 to 2013 (Eurostat, 2013). Electricity consumption represents 60% of direct energy use, or 0.31 MJ/L of milk produced on Irish dairy farms (Upton et al., 2013). The quantity of electricity consumed per liter of milk produced on dairy farms may increase in the coming years if farmers respond to government policies in countries such as Ireland, where increases in milk output are actively encouraged as a result of the abolition of European Union milk quotas in 2015 (DAFM, 2010). Increased milk production is generally associated with investments in labor-saving technology to manage larger dairy herds, along with more industrial milk harvesting and cooling equipment, which might increase electricity consumption per liter of milk (Upton et al., 2015). The major electricity-consuming systems on Irish dairy farms were identified in previous studies as milk-cooling (31% of total), water-heating (23% of total), and milking systems (20% of total), with the remaining 26% of total electricity consumption made up of lighting, water pumping, and wintering facility electricity consumption (Upton et al., 2013). To make informed decisions, farmers need insight into the electricity consumption, electricity costs, and associated investment costs of potential technology investment strategies.

The aim of the current study, therefore, was to provide a scientific-based investment appraisal for the best combination of milk-cooling, water-heating, and milk-harvesting technologies tested in this analysis on a

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range of farm sizes in 2 different electricity pricing environments. This objective was achieved by using a model for electricity consumption on dairy farms (Upton et al., 2014) to analyze the effect of various technologies on the electricity consumption and costs on the 3 largest electricity-consuming systems within the dairy farm (i.e., milk-cooling, water-heating, and milking machine systems). These outputs were used as inputs to a farm profitability calculator using annual farm-related costs from the Teagasc Eprofit Monitor for 2011. The Eprofit monitor is a financial benchmarking tool supplied by Teagasc (Moorepark, Co. Cork, Ireland). The combined models were used to compute the return on additional investment (**ROI**) and the discounted annual net income for 5 investment scenarios compared with a base level of investment over a 10-yr period.

MATERIALS AND METHODS

Outline of the Model for Electricity Consumption on Dairy Farms

A model developed by Upton et al. (2014) was used to simulate the annual electricity consumption and associated costs of 6 technology investment scenarios on 3 representative farms in Ireland. The model for electricity consumption on dairy farms is a mechanistic mathematical representation of the electricity consumption that simulates farm equipment under the following headings: milk-cooling system, water-heating system, milking machine system, lighting systems, water pump systems, and the winter housing facilities. The main inputs to the model are milk production, cow numbers, and details relating to the milk-cooling system, milking machine system, water-heating system, lighting systems, water pump systems, and the winter housing facilities, as well as details relating to the management of the farm (e.g., season of calving, frequency of milking, and milking start time; milking end time is computed by the model). The energy consumption of each of the 7 dairy farm systems described was computed using the model for electricity consumption on dairy farms in a 12 × 24 matrix structure that simulated a representative day for each month of the year (12 mo × 24 h). Both of the electricity tariffs were compiled in an identical 12 × 24 matrix. Dairy farm electricity costs were then calculated by multiplying the energy consumption matrix by the tariff matrix. For this analysis, a technology permutation algorithm was developed and applied to the model for electricity consumption on dairy farms, which allowed for autonomous cycling through technologies and tariffs. The outputs from the model for electricity consumption on dairy farms were annual electricity consumption (kWh) and associated costs for each of the 6 technology investment scenarios studied under 2 electricity pricing structures [flat tariff and day and night (**DN**) tariff]. The farms morning milking start time was set to 0700 h and the evening milking start time was set to 1700 h.

Model Inputs

The electricity consumption and related costs of a small farm with 45 milking cows, a medium farm with 88 milking cows, and a large farm with 195 milking cows was simulated using the model for electricity consumption on dairy farms. Background data from an on-farm energy study of these farms presented by Upton et al. (2013) was used to populate the model for electricity consumption with data pertaining to the infrastructural configuration on each of these 3 farms. The farms were spring-calving herds operating grass-based milk production systems with low supplementary feed input (mean of 540 kg of concentrate/cow), similar to most Irish dairy farms. Milk sales were 255,278 L for the small farm, 499,898 L for the medium farm, and 774,089 L for the large farm. Further data related to the scale and production levels of the farms are presented in Table 1. The farm sizes used in our analysis are based on the farm sizes used to validate the model (Upton et al., 2014).

Scenario Description

A range of technologies were commercially available to reduce the electricity consumption of these systems. In the current analysis, it was assumed that there was a requirement for investment in a milk-cooling system, milking system vacuum pumps, and a water-heating system. The scenarios analyzed were as follows.

Base. The base scenario included investment in a direct expansion milk-cooling system, standard milking system vacuum pumps (i.e., without variable speed drive; **VSD**), and an electrical water-heating system. All other options were compared with this base scenario. Direct expansion refers to a system where the evaporator plates are incorporated in the lower portion of the storage tank that is in direct contact with the milk. Liquid refrigerant expands inside the evaporator taking heat out of the milk.

Direct Expansion Cooling System with Precooling of Milk. The direct expansion cooling system with precooling of milk (**DXPHE**) scenario included investment in a direct expansion milk-cooling system with a water-cooled plate heat exchanger precooling system that cooled milk to 15°C before entry to the milk storage tank; the milking system remained standard and water heating remained electric. The precooler had