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Assessing the impact of changes in the electricity price structure on dairy farm energy costs

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HIGHLIGHTS

- Choosing electricity tariffs with a low off-peak rate results in financial savings.
- Cost saving potential within an electricity tariff is the greatest on large farms.
- Earlier AM milking with later PM milking helps reduce electricity consumption.

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ABSTRACT

This study aims to provide information on the changes in electricity consumption and costs on dairy farms, through the simulation of various electricity tariffs that may exist in the future and how these tariffs interact with changes in farm management (i.e. shifting the milking operation to an earlier or later time of the day). A previously developed model capable of simulating electricity consumption and costs on dairy farms (MECD) was used to simulate five different electricity tariffs (Flat, Day&Night, Time of Use Tariff 1 (TOU1), TOU2 and Real Time Pricing (RTP)) on three representative Irish dairy farms: a small farm (SF), a medium farm (MF) and a large farm (LF). The Flat tariff consisted of one electricity price for all time periods, the Day&Night tariff consisted of two electricity prices, a high rate from 09:00 to 00:00 h and a low rate thereafter. The TOU tariff structure was similar to that of the Day&Night tariff except that a peak price band was introduced between 17:00 and 19:00 h. The RTP tariff varied dynamically according to the electricity demand on the national grid. The model used in these simulations was a mechanistic mathematical representation of the electricity consumption that simulated 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 effect of milking start time was simulated to determine the effect on electricity consumption and costs at farm level. The earliest AM milking start time and the latest PM milking start time resulted in the lowest energy consumption. The difference between the lowest and highest electricity consumption within a farm was 7% for SF, 5% for MF and 5% for LF. This difference was accounted for by the variation in the milk cooling system coefficient of performance. The greatest scope to reduce total annual electricity costs by adjusting milking start times was on TOU2 (39%, 34% and 33% of total annual electricity costs on the SF, MF and LF) and the least scope for reductions using this method was on the Flat tariff (7%, 5% and 7% of total annual electricity costs). The potential for reduction of annual electricity consumption and related costs per litre of milk produced by adjusting milking times was higher for the LF than the SF or MF across all electricity tariffs. It is anticipated that these results and the use of the MECD will help support the decision-making process at farm level around increasing energy efficiency and electricity cost forecasts in future electricity pricing tariff structures.

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1. Introduction

A number of external factors are currently acting on dairy farming businesses that may increase the electricity costs associated with milk harvesting and storage, thereby affecting overall farm profitability and, therefore, economic viability. First, the electricity price for European farmers increased by 32% in the last 5 years [1], due to increases in global energy prices. Second, government policies in countries such as Ireland encourage increases in milk output after the abolition of European Union (EU) milk quotas in 2015 [2]. Increased milk production may lead to increases in electricity costs per litre of milk harvested, because increased mechanisation and more industrial milk harvesting equipment is required to manage larger dairy herds. And third, European wide directives encourage the use of smart metering as a means of driving demand side energy efficiency, which might increase dairy farm electricity costs if not anticipated by the farmer. All of these components will combine to create an unprecedented level of uncertainty around electricity costs on dairy farms.

The European Energy Services Directive 2006/32/EC was enacted to drive improvements in energy efficiency through the implementation of improved metering of electricity coupled with incentivised demand side management (DSM) of electricity for the consumer [3]. By the end of 2009, the Energy Services Directive was transposed into Irish law. Also in 2009 the Irish Government adopted the National Energy Efficiency Action Plan 2009–2020 (NEEAP) in order to help achieve Ireland's energy efficiency targets. One of the principal measures contained within this action plan was the encouragement of more energy efficient behaviour by electricity consumers through the introduction of smart meters [4]. Compared with traditional electricity pricing systems, dynamic pricing systems may entail more uncertainty for end-users with respect to the frequency and timing of high peak prices [5], however exposing electricity users to hourly real time prices is known as the most efficient tool that can urge consumers to consume more wisely and efficiently [6].

The effect of both Time of Use (TOU) and Real Time Pricing (RTP) tariffs on the residential sector [7,8,5,9–12] and the commercial building sector [13–17] has been well documented. Up until now similar analysis has not been reported in relation to the agricultural sector. Furthermore, the smart metering trial conducted in Ireland by the commission for energy regulation (CER) in 2010 to deliver the evidence for the energy efficiency potential of smart metering [18] did not include agricultural premises in the SME sector, instead it focussed on retail, service, office, entertainment and manufacturing enterprises. The trial carried out by the CER focused on various TOU tariffs, however such rates do not necessarily lead to overall conservation at the electricity grid level [19]. Another alternative is the RTP system, which can be implemented by capitalising on developments in advanced metering infrastructures [20–23].

RTP tariffs imply a dynamic electricity price based on the electricity demand on the national grid, resulting in higher electricity rates during peak periods of consumption and lower rates during off-peak periods. Peak demand is currently from 17:00 to 19:00 h [24]. If dairy farmers continue to carry out their evening milking during this peak period after the introduction of smart metering, they may be exposed to increases in electricity costs. A dynamic pricing structure, however, could also present opportunities to reduce overall electricity costs if the farmers routine could be modified to optimise energy use in off-peak periods (currently from 00:00 to 09:00 h). In the future farmers will need to develop strategies to adapt to these electricity pricing influences. However to react appropriately farmers need information about how their electricity costs will vary according to future tariff structures. The objective of this study was to provide information on the changes in dairy farm electricity costs through the simulation of various electricity tariffs that may exist in the future, which, to our knowledge, has not been reported in the literature. The impact of modifying the farms daily routine by shifting the milking operation to an earlier or later time to reduce electricity costs for each electricity tariff was investigated. It is anticipated that this analysis will help support the decision-making process at farm level around increasing energy efficiency and electricity cost forecasting in future electricity pricing tariff structures.

2. Materials and methods

2.1. Electricity consumption model

A model for electricity consumption on dairy farms (MECD), developed by Upton et al. [25], was used to apply five electricity tariffs to a number of simulated electricity consumption trends of three representative dairy farms in Ireland. The MECD was designed to simulate the electricity consumption and electricity costs on dairy farms. The MECD is a mechanistic mathematical representation of the electricity consumption that simulates 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 number and capacity of the milk cooling system, milking machine system, water heating system, lighting systems, water pump systems and the winter housing facilities as well as details of the management of the farm (e.g. season of calving, frequency of milking and milking start time). The energy consumption of each of the seven infrastructural systems described above was computed using the MECD in a 12×24 matrix structure that simulated a representative day for each month of the year (12 months $\times$ 24 h). 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.

2.2. Model inputs

The electricity consumption and related costs of a small farm (SF) with 45 milking cows, a medium farm (MF) with 88 milking cows and a large farm (LF) with 195 milking cows was simulated using the MECD. Background data from an energy study of these farms presented by Upton et al. [24] was used to populate the MECD with data pertaining to the infrastructural configuration on each of these three farms. The SF, MF and LF were spring calving herds operating grass-based milk production systems with low supplementary feed input (mean of 1.19 kg concentrate/100 kg of milk produced in 2011) similar to most Irish dairy farmers. In 2011, actual milk production was 255,278 L for SF; 499,898 L for MF and 774,089 L for LF. Further data relating to the scale and production levels of the SF, MF and LF are presented in Table 1. All farms engaged herringbone milking plants with two stalls per milking unit and were fitted with oil lubricated centrifugal vane vacuum pumps without variable speed control. Milking parlour size varied from 8 units on SF, 14 units of MF and 24 units on LF. All farms used direct expansion milk cooling systems with pre-cooling of milk via well water before entry to the bulk tank. The SF and MF used a milk pre-cooling system which chilled warm milk to 25 °C before entry to the milk cooling system, whereas the pre-cooling system on the LF was not as effective and cooled the milk to 30 °C via the same method. Standard pressurised cylinder water heating systems were used on all farms. The system effi-