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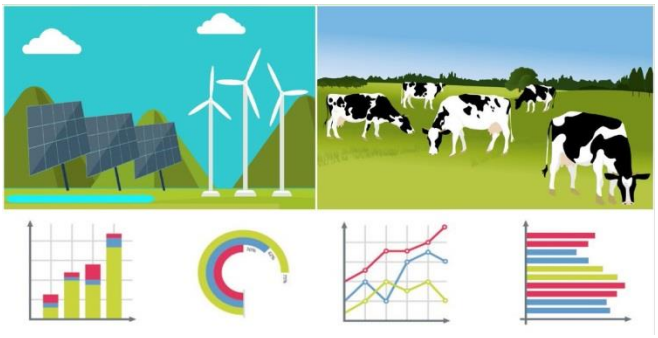
# Precision Energy Management for Dairy Farming systems



Key external stakeholders:
Dairy processors, dairy farmers, equipment manufacturers, Irish Cattle Breeding Federation (ICBF), Bord Bia, DAFM, consultancy agencies, Sustainable Energy Authority of Ireland (SEAI)

Practical implications for stakeholders:

- Quantified the energy intensity of milk production on Irish farms using farm specific data
- Developed optimisation methodologies and algorithms for dairy farm infrastructure
- Developed a dairy energy decision support tool which can be used to obtain farm specific recommendations relating to energy use, technology investments, $CO_2$ mitigation and renewable energy consumption

## Main results:

- A comprehensive statistical analysis of a dataset comprising electricity and water consumption data from 58 Irish dairy farms throughout Jan 2014 – May 2016 was carried out. On average, for the study population, 39.84 Watt hours per litre of milk (Wh $Lm^{-1}$) and 7.42 litres of water per litre of milk (Lw $Lm^{-1}$) was consumed.
- A multi-objective optimisation method was developed and implemented to optimise dairy farm technology, management practices and electricity tariffs.
- A dairy energy decision support tool was developed which can be used to obtain farm specific recommendations relating to energy use, technology investments, $CO_2$ mitigation and renewable energy consumption. It can also be used to support government bodies in forming new policy relating to provision of grant aid for energy efficient and renewable energy technologies. The tool is available at: http://messo.cit.ie/dairy

## Opportunity / Benefit:

Milk production proved to be a common driver of electricity consumption on Irish dairy farms explaining 41% of the on-farm variability in consumption. Hence, it is of critical importance to initiate environmental mitigation strategies to reduce the energy intensity of Irish dairy production. This project found that solar photovoltaic systems could be very suitable for deployment on Irish dairy farms. It was found that widespread implementation of micro-generation sized solar photovoltaic systems using module efficiencies of 19.6% could offset 41 kilotonnes of $CO_2$ nationally per annum. This illustrates the importance of this technology in achieving our national emissions targets.

## Collaborating Institutions:

Cork Institute of Technology, Bord Bia, Wageningen University, Sustainable Energy Authority of Ireland

**Teagasc project team:**
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## 1. Project background:

Increased dairy herd sizes and milk production levels in Ireland as well as changing regulations concerning emissions, renewable penetration and energy efficiency have necessitated a means of financial decision support for farmers. Milk production is an energy intensive operation, even when produced in a grass based system, requiring a total energy input (i.e. direct plus indirect energy) of 2.5 Mega Joules per litre of liquid milk produced. Electricity in particular makes up 60% of the direct on-farm energy use, or 12% of total energy use on Irish dairy farms. Hence, forecasting electricity consumption and optimising infrastructure to minimise energy spend would have the potential to reduce overall energy use and reduce production costs. The selection of dairy farm technology as well as details of the management of the farm affects the annual farm electricity costs and therefore the return on investment (ROI) of the chosen dairy farm infrastructure. Furthermore, an approximate increase of 22% in global milk production by the year 2030 has been predicted, compared to 2018 levels. This rise in milk production may result in an increase in electricity price per litre of milk harvested. Decision support in the form of an optimisation platform is required for dairy farmers regarding investments in dairy farm technology and changes to on-farm management practices such as milking start times, as well as the electricity tariff used by the farm. Therefore this body of work focused on the creation of a comprehensive method for optimising dairy farm technology selection, management practices and electricity tariffs.

## 2. Questions addressed by the project:

• This project answers industry and farmer questions around quantifying the effect of farm infrastructure design, specification and management on the financial and environmental performance of Irish dairy farms
• Furthermore, it addressed the requirements of stakeholders to develop a farm optimisation tool that can be used by advisors, manufacturers and farmers to make decisions around optimal equipment specifications and management of dairy farm infrastructure

## 3. The experimental studies:

Electricity consumption data for 58 commercial dairy arms, primarily based in the Munster region were recorded to span the period between 1st Jan 2014 – 31st May 2016. Total electricity consumption was explored to define usage figures per Lm, percentage of electricity consumed during day time hours (08:00 h – 23:00 h) and electricity costs per Lm for milk cooling, milk harvesting, water heating, usage for air compressor, lighting, wash down and effluent water pumping and miscellaneous usage (calculated through balance equations). Following this analysis, an optimisation method was developed to maximise ROI on dairy farms, by comparing relevant optimisation algorithms. This method obtained the optimal farm technology, management and electricity tariff combination for ROI maximisation. In addition to this, scalable models of heat recovery, solar thermal and solar photovoltaic systems were developed and validated. Once these models were developed, and economic and renewable multi-objective optimisation of dairy farm technology and management practices was carried out to maximise farm net profit and maximise farm renewable contribution based on a trade-off parameter. These data and models were used in the development of the on-line dairy energy decision support tool which operates on a web based platform, and encompasses a user interface that supplies information to a mechanistic model for dairy farm energy consumption.

- **Main results:**
- A dairy farm energy load forecasting tool has been developed and integrated with a model to calculate dynamic energy costs and $CO_2$ consumptions per litre of milk produced
- A multi-objective parameter optimisation model has been developed which will be used to model optimal dairy farm infrastructure
- Energy profiles of automatic milking farms have been documented
- A comprehensive statistical analysis of a dataset comprising of electricity and water consumption data from 58 Irish dairy farms has been carried out
- A decision support tool for dairy farm energy use has been developed which can be used by advisors and farmers to help make prudent decisions to maximise profitability in the area of dairy farm infrastructure

## 4. Opportunity/Benefit:

This project delivered a useable suite of models and decision support options for farmers, advisors and policy makers which demonstrated that the optimal combination of technologies, management practices and



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electricity tariffs could increase farm profitability while improving the environmental impact of producing milk. This is significant in the current climate where environmental emissions from intensive agriculture are a leading national source of GHG emissions. Furthermore, strict energy efficiency and renewable generation targets are in place up to 2030 which will not be achieved through a business as usual approach. This project demonstrated that implementation of micro-generation sized solar photovoltaic systems could offset 41 kilotonnes of $CO_2$ nationally per annum. This illustrates the importance of putting the correct supports in place to incentivise farmers to utilise these types of technologies on a mass scale to ensure we meet our national targets and obligations.

## 5. Dissemination:

### Main publications:

Breen, M., Upton, J., & Murphy, M. D. (2019). Development of a discrete infrastructure optimization model for economic assessment on dairy farms (DIOMOND). Computers and Electronics in Agriculture, 156, 508–522.
Breen, M., Murphy, M. D., & Upton, J. (2019). Development of a dairy multi-objective optimization (DAIRYMOO) method for economic and environmental optimization of dairy farms. Applied Energy, 242, 1697–1711.
Shine, P., T. Scully, J. Upton, L. Shalloo, and M. D. Murphy. 2017. Electricity & direct water consumption on Irish pasture based dairy farms: A statistical analysis. Applied Energy 2018;210:529-537; doi 10.1016/j.apenergy.2017.07.029

### International conferences

Results were presented at numerous conferences such as the Agricultural and Biological System Engineering (ASABE) in 2016, 2017 and 2018. International Manufacturing conference in Belfast, Northern Ireland 2017 and the European Precision Livestock Farming Conference 2019

### National conferences and seminars

Presented at national dairy conference and at the national manufacturing conference throughout the duration of the project as well as presenting to Dairy business degree students that undertake their undergraduate programmes at Teagasc Moorepark. Results of the project were presented at the Energy in Agriculture Conference throughout the project.

### Open days:

Presented at Moorepark, Grange and Gurteen open days, as well as at a number of open days that were held on individual farms throughout the country.

### Industry consultation

Different industry groups were collaborators on this project and therefore got first-hand knowledge of the projects findings. For other national industry groups there were many other meetings at different points throughout the project.

### Farmer discussion groups

Results were presented and discussed at several farmer discussion groups and seminars. There were also intensive sessions completed with the farmers involved in the overall study on a number of occasions throughout the project to provide feedback on an on-going basis.

## 6. Compiled by: Dr. John Upton



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