# Energy Impact Matrix: using Italian FADN to estimate energy costs impact at farm level

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## ABSTRACT

Agriculture accountsbetween 2 and 3 percentof national energy consumption even if direct and indirect energy usesconstitutean important part of farmer's costs. Furthermore, the considerable increase of energy prices in the past years, affected significantly farmers, generating disturbing effects on production costs.

This paper present a novel approach to estimate energy impact on operating costs at farm level.To point out the impact of global energy costs of Italian farms, "Energy Impact Matrices" (EIMs) were defined through an analysis of national Farm Accountancy Data Network (FADN), collecting data concerning the costs of direct (electricity, fuel, gas) and indirect (seeds and plants, fertilizers,pesticides and herbicides,) energy uses for each Type of Farming (TF) and Economic Size Class (ESC) of farms.

The EIMs obtained, show the differences for each intersection TF/ESC referred to the percentage weight of energy expenditures on operating costs of farms, highlighting those cases with values above national average.

The results of the analysis are useful to identify specific agricultural sectors where adopt measures at regulatory level - addressing public funding and investments - as well as at private level, promoting actions forreducing energy coststhrough management approaches such as energy audits.

**Keywords:** Farm Accountancy Data Network,energy costs,energy impact,energy audit.

# 1. Introduction

The Italian national Authority for electricity gas and water services (AEEGSI) highlighted,in its 2015annual report,a total agricultural consumptions of 2,69%, the 0,47% from electricity, the 0,12% from gas, the 2,09% from oil and the0,01% from renewable sources.Although it can be considered a small percentage of national consumptions, for farmers it represents a topic issue, as direct and indirect energy uses, have an high incidence on total farm inputs.

Furthermore, in the stream of consumption of 500-2.000 MWh/Year (most representative in Italy) prices are over EU average for 20% (except, taxes and charges) and of 26% considering the gross price (AEEGSI, 2015).

Energy consumption in agriculture can be direct – as with gasoline, diesel, petroleum, natural gas, electricity - or indirect as with fertilizers (Sands R. et al. 2011). The impact of costs related,on farms activity, depends strictly from type of farming and economic size.

In the past years Italian agriculture has been affected by an increasing of production costs, that, in 2011, reached about 5%, with peaks of 19% for feed and agricultural fuels.

Coldiretti, one of the most representative Italian farmers organization, estimated 200 million euros of additional costs for the whole agricultural sector.

This high level of costs concernedespecially energy intensive activities such as livestock companies, those ones needing energy to heatgreenhouses (such as flowers, vegetables and mushrooms) and for drying forages for animals, in addition to all those with energy demanding processes with high level of mechanization.

Such increasing of energy price was due by a combination of external dynamics, mainly the constant growth of oil prices from 2009 to 2012 and the charges in energy bills due to incentives for renewable energy production,near to 10 billion euros in 2012.Those factors entailed energy price variability, hampered farmers to make reliable predictions on their own energy costs andgenerated unexpected additional expenditures,whose incidence can vary between different type and size of farms and between farm to farm belonging to the same category.

For this reasons,energy efficiency-basedmanagement approaches can led to farm's competitiveness, considering also that, with the future climate change and population growth,pathway for improving energy efficiency and reducing environmental footprint need to be identified (Khan et al., 2009).

This paper analysesthe impact of energy costs of Italian farms, using "Energy Impact Matrices" built through an analysis of national FADN. The FADN methodology - often used to estimate sustainability indicators at farm level like "Sustainability Farm Index" (SuFI) (Longhitano et al. 2012) or energy use and energy use efficiency of specific set of specialized dairy farms (Meul et al. 2007) - classifies farms in Type of Farming and Economic Size Class.

By referring to the concept that we can't manage what we don't know, this kind of analysis is an useful tool to identify specific targets in the agricultural sector to use energy efficiency as driver for farm's performance improvements, both under economic and environmental perspective(Fabiani, 2014).

In addition, this kind of assessment can provide the building blocks for a national energy efficiency plan, where, one of the focus is better approach to energy management farms. Similar approaches have already been undertaken by some European countries (i.e. see the

*Plan de Performance Energetique- PPE*, in France. http://agriculture.gouv.fr/ministere/le-plan-de-performance-energetique-2009-2013-des-exploitations-agricoles).

## 2. Materials and methods

### 2.1 Farm Accountancy Data Network

The Farm Accountancy Data Networkwas launched in 1965 and established by the Council Regulation number 79/65/EEC.It is an yearly survey carried out by the Member States of the European Union and represents an important tool for the evaluation farms' income and the assessment of the Common Agricultural Policy (CAP) impacts. The FADN is a unique source of microeconomic data harmonized at European level, i.e. the bookkeeping principles are the same in all countries, as well as established by Council Regulation 79/65 (the legal basis for the organization of the network).

The scope of the FADN survey covers only farms whose size exceeds a minimum threshold[1] so as to represent the largest possible proportion of agricultural output, agricultural area and farm labour, only for market orientated farms. For Italy the threshold that farms must meet to join the FADN sample was set equal to 4000 euro ofStandard Output – SO[2].

The services responsible for the operation of the FADN, collect every year accountancy data from a sample of farms in the European Union. Farms are selected to take part in the survey on the basis of sampling plans established at nationallevel in the Union. The methodology applied aims to provide representative data along three dimensions: regional, economic size and type of farming.

The main purpose of the survey is to gather accountancy data for the determination of incomes and business analysis at farm level. The information collected concerns approximately 1000 variables and is transmitted by Liaison Agencies to the EU. The FADN database, widely recognized as an efficient tool to estimate environmental performance and footprints (Westbury, 2011 and Dalgaard, 2006),contains, among other, data on energy costs related to direct uses (divided inelectricity, fuel, gas) and to indirect consumptions (seeds and plants, fertilizers, pesticides and herbicides) for each Type of Farming and Economic Size Class.

Data collected at farm level are aggregated in a set of standard groupings and, for each accounting year, the standard results are computed at the level of the European Union and for each Member State.

In this work FADN data were aggregated as follow (Table 1):

- Types of Farming (TF), 8 classes:a farm is classified as specialist if the Standard Output (SO) of one of the farms productive activities (or more than one if the activities are related) represents over two thirds of the total SO of the farm, otherwise it's classified as Mixed.

[1]Thresholds of economic size establishing the minimum size of agricultural holdings included into FADN field of observation differs between Member States.

[2]The Standard Output (SO)is the average monetary value of the agricultural output at farm-gate price of each agricultural product (crop or livestock) in a given Region. The SO is calculated by Member States per hectare or per head of livestock, by using basic data for a reference period of 5 successive years; for example, SO 2007 covers the calendar years 2005 to 2009. The SO coefficients are calculated for more than 90 separate crop and livestock items. This large number of items not only reflects the diversity of agriculture within the European Union, but also indicates the level of detail that is required to ensure that the results of the FADN and of other surveys are comprehensive and reliable. (FADN website).

- Economic Size Classes (ESC), 8 classes:the economic size of an agricultural holding is measured as the total SO of the holding expressed in euro[3].

**Table 1**:*Types of farming (TF) left, and Economic Size Classes (ESC- €) right*

| Classes | Type of Farming |
|---|---|
| 1 | Fieldcrops |
| 2 | Horticulture |
| 3 | Wine |
| 4 | Other permanent crops |
| 5 | Milk |
| 6 | Other grazing livestock |
| 7 | Granivores |
| 8 | Mixed |

| Economic Size Class | Description |
|---|---|
| I | < 4.000 euro |
| II | from 4.000 to 8.000 euro |
| III | from 8.000 to 25.000 euro |
| IV | from 25.000 to 50.000 euro |
| V | from 50.000 to 100.000 euro |
| VI | from 100.000 to 500.000 euro |
| VII | from 500.000 to1.000.000 euro |
| VIII | > 1.000.000 euro |

## 2.2 Methodology of analysis and Energy Impact Matrix (EIM)

The analysis of this work is based on theFADN2013 database, the last update available. For eachtype of farming and economic size class,“Direct energy”, “Indirect energy” and “Globalenergy”(direct + indirect) costswere considered andcorrelated with the farm economic index“Operating costs”.Operating costs represent those costs linked to the agricultural activity of the holder and covers the categories “Off farms consumption factor” (seeds, plants, fertilizers, pesticides and herbicides, water, electricity, fuel, feed and forage), “Other costs”(such as commercialization and transformation expenditures, overheads and land related costs), and “Third party services” (rental expenses, health costs, insurance, etc.).

The first part of the analysis allowed us to define the national average value of direct, indirect andglobal energy costs and their impact (%) on operating costs for each intersection of TF and ESC. The followingTable 2presents an example for ESC I.

**Table 2**: *Example ofDirect, Indirect and Global energy costs and impact of ESC class I.*

| Type of Farming (TF) | EconomicSizeClass (ESC) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | I | | | | | | | |
| | Farms | A-Operating Costs | B-Direct Energy | Impact % (B/A) | C - Indirecte nergy | Impact % (C/A) | Global Energy (D=B+C) | Impact % (D/A) |
| **Field Crops** | 12 | 2.506,00 | 754,72 | 30% | 657,42 | 26% | 1.412,14 | 56% |
| **Horticulture** | 0 | - | - | NA | - | NA | - | NA |
| **PermanentCrops** | 4 | 1.462,25 | 568,26 | 39% | 503,75 | **34%** | 1.072,01 | **73%** |
| **Grazing livestock** | 4 | 1.711,25 | 717,68 | **42%** | 82,50 | 5% | 800,18 | 47% |
| **Granivore** | 0 | - | - | NA | - | NA | - | NA |
| **Mixed Cropping** | 2 | 3.156,50 | 1.890,75 | **60%** | 330,50 | 10% | 2.221,25 | **70%** |
| **Mixed Livestock** | 0 | - | - | NA | - | NA | - | NA |
| **Mixed Crops-Livestock** | 0 | - | - | NA | - | NA | - | NA |
| ***Italy*** | ***22*** | ***2.230,86*** | ***817,36*** | ***37%*** | ***495,23*** | ***22%*** | ***1.312,59*** | ***59%*** |

In the definition of the EIMs only values consistently higher then national average were considered using the statistical criteria of "Average Coefficient of Variation" to highlightthose intersection TF/ESC with an high incidence (red values). The Coefficient of Variation (CV) represents a standardized measure of dispersion of a probability distribution. It is often expressed as a percentage and defined as the ratio of a group of data's standard deviation σ to its mean μ:

$$CV = \frac{\sigma}{\mu} \text{ with } \mu \neq 0$$

The CV shows the extent of variability in relation to the average of the population. When its value is high, it means that the data has high variability and less stability, when is low, it means the data has less variability and high stability.In this work CV was calculated as the average of the coefficients of variation of each group identified for TF and ESC.All percentage value obtainedapplying CV criteria, representing high incidence for those specific intersection TF/ESC, generated the three Energy impact matricesfor costs related to direct, indirect and global energy use on operating costs.

## 3. Results

The analysis performed implies some important assessments: energy costs seems to affect Italian farms in relation to specific farm economic dimension and for giventype of farming.Considering direct energy impact matrix (Table 3), field cropsis the most affected class, presenting values above national average, especially in the last 3 economic size classes (VI, VII, and VIII). Considering also the agricultural surfaceavailable for those classes, it is probably due to the high use of tractor and field machinery, with high fuels consumption. The economic size classes where an high weight of direct energy costs is most widespread is the second class (SO form 4.000 to 8.000 Euro), characterized byhorticulture, permanent crops, grazing livestock, mixed cropping and mixed crop-livestock. A consistent impact of direct energy use costs appears also for the VIII economic size class, particularly for horticulture and mixed-livestock. Also this evidence seems to be correlated with the farms size as,for instance,large size greenhouses for horticulture require high electricity and gas consumption for cooling, as well as large surfaces for mixed-livestock farms have great direct energy consumption, mainly electricity for irrigation of forage crops often associated with livestock,milking and stable activities.

**Table 3**: *DirectEnergy Impact Matrix*

| | EconomicSize Class (ESC) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Type of Farming (TF)** | I | **II** | III | IV | V | VI | VII | VIII |
| **Field crops** | | | | | | **23%** | **20%** | **21%** |
| Horticulture | | **25%** | | | | | | 17% |
| Permanentcrops | | **26%** | | | | | | |
| Grazing livestock | 42% | **30%** | | | | | | |
| Granivore | | | | | | | | |
| Mixed cropping | 60% | **23%** | | | | | | |
| Mixed livestock | | | 31% | | | | | 16% |
| Mixed crops-Livestock | | **29%** | | | | | 19% | |
| ***Italy*** | ***37%*** | ***19%*** | ***27%*** | ***24%*** | ***22%*** | ***18%*** | ***14%*** | ***10%*** |

Concerning indirect energy consumptionscosts (Table 4), a strong correlation between farm size and operating costs is clear.Five TF classes out of eight(field crops, horticulture, permanent crops, mixed cropping and mixed crop-livestock) present a percentage impact even four time above the national average in the VIII ESC. Horticulture is clearly the he specific type of farming most affected by indirect energy consumptions, presenting high levels of impact for all economic size classes except the field crops.Similar results can be recordedalso for field crops, mixed cropping and the for permanent crops. The fact that such kind of farms are significantly affected by indirect energy costs probably depends on the huge quantity on chemical inputs needed, especiallyfor big farm sizes.

**Table 4**: *IndirectEnergy Impact Matrix*

| | EconomicSize Class (ESC) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Type of Farming (TF)** | I | II | III | IV | V | VI | VII | **VIII** |
| Field crops | | | 44% | 46% | 49% | 48% | 51% | **53%** |
| **Horticulture** | | **53%** | **53%** | **48%** | **54%** | **52%** | **44%** | **48%** |
| Permanentcrops | 34% | 27% | | | | 30% | 29% | **30%** |
| Grazing livestock | | | | | | | | |
| Granivore | | | | | | | | |
| Mixed cropping | | 35% | | 39% | 43% | 51% | 63% | **45%** |
| Mixed livestock | | | | | | | | |
| Mixed crops-Livestock | | | | | | | | **27%** |
| ***Italy*** | ***22%*** | ***22%*** | ***35%*** | ***33%*** | ***31%*** | ***26%*** | ***18%*** | ***12%*** |

Table 5 presents the results for global costs; it highlights that concerning the economic size classes, the occurrence of an impact above national average, appears mostly for all economic size classes,except for the first and the third one: four times for ESC II, VI, VII and VIIIand three times for IV and V.This seems to show once again a direct correlation with farmssurface, a part from their specialization, with peak values between 70% and 80% in classes VI, VII and VIII for field crops and mixed cropping.

Horticulture and mixed cropping (seven classes on eight are over average), but also field crops (from III to VIII class) are the type of farming most affected and considerably sensible to energy.

**Table 5**: *Global energy Impact Matrix*

| | **EconomicSize Class (ESC)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Type of Farming (TF)** | I | **II** | III | IV | V | **VI** | **VII** | **VIII** |
| Field crops | | | 72% | 73% | 74% | **72%** | **71%** | **74%** |
| **Horticulture** | | **79%** | **74%** | **69%** | **74%** | **69%** | **57%** | **66%** |
| Permanentcrops | 73% | **54%** | | | | **49%** | **46%** | |
| Grazing livestock | | | | | | | | |
| Granivore | | | | | | | | |
| **Mixed cropping** | **70%** | **58%** | | **62%** | **65%** | **71%** | **80%** | **59%** |
| Mixed livestock | | | | | | | | |
| Mixed crops-Livestock | | **46%** | | | | | | **38%** |
| ***Italy*** | *59%* | *41%* | *62%* | *57%* | *53%* | *44%* | *32%* | *22%* |

## 4. Conclusions and recommendations

This kind of analysis is an useful tool to identify specific targets in the agricultural sectors most affected by energy expenses, where to obtain better operational results in terms of environmental and economic performances.

Results suggest that reducing energy costs is a crucial topic for future policy strategiesaddressed at improving energy efficiency and competiveness of farms.

Acknowledgements of regulatory framework on energy management and technical approaches in use, such as certifications systems (adoption of EMS – Energy Management System) allow us to consider energy audit as the right tools to evaluate farm's energy consumptions andincrease the level of knowledge on energy uses in agriculture.

The general audit technique, is based on the *Deming Cycle* which represent a continuous improvement methodology with four stages: plan, do, study, act (Dean and Evans, 1994)[4].

Performing an energy audit in a given structure means to do an objective analysis of energy management so it is an essential tool for achieving a reduction in energy consumptions and hence, costs.

[4]Specifically, the audit technique is referred to the traditional procedures adopted for quality and/or environmental management systems derived from ISO 19011:2003 "Guidelines for quality and/or environmental management systems auditing".

It could be useful to look at other experiences, where, in order to be properly developed and spread, energy audit has been included in a nationalenergy performance plan for agriculture, as happened in France with the *Plan de Performance Energètique*(PPE)[5].

To reach such important objectives, farmers should be fully aware of their potential and research institution and policy makers can play a central role in increase the level of public awareness.

[5]It was an holistic plan, integrated with France Rural Development Plan, made of eight axis and aimed at getting a better knowledge of energy consumption and production on French farms, spreading farm energy audits in great numbers. It also promoted research and innovation activities encouraging partnerships of public institutions with the private sector and allowed the awareness on energy efficiency as a long term issue (http://agriculture.gouv.fr/ministere/le-plan-de-performance-energetique-2009-2013-des-exploitations-agricoles).

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