EUROPEAN EVALUATION HELPDESK FOR RURAL DEVELOPMENT

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WORKING DOCUMENT

UPDATED FICHES FOR

ANSWERING COMMON EVALUATION QUESTIONS 11 – 14 FOR RDPS 2014-2020

WORKING PACKAGE 2

THEMATIC WORKING GROUP NO 8

'EX POST EVALUATION OF RDPS 2014-2020: LEARNING FROM PRACTICE'

OCTOBER 2020

Disclaimer: *This document has been prepared by evaluation experts based on good practice available from the current programming period. The document has been consulted with a Sounding Board including Member States' representatives in September 2020 and has been reviewed in line with the comments received. This document is non-binding and only intended to facilitate the work of evaluators and managing authorities in the context of preparing for the ex post evaluation of the RDPs 2014-2020.*

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The Evaluation Helpdesk is responsible for the evaluation function within the European Network for Rural Development (ENRD) by providing guidance on the evaluation of RDPs and policies falling under the remit and guidance of DG AGRI's Unit C.4 'Monitoring and Evaluation' of the European Commission (EC). In order to improve the evaluation of EU rural development policy the Evaluation Helpdesk supports all evaluation stakeholders, in particular DG AGRI, national authorities, RDP managing authorities and evaluators, through the development and dissemination of appropriate methodologies and tools; the collection and exchange of good practices; capacity building, and communicating with network members on evaluation related topics.

Additional information about the activities of European Evaluation Helpdesk for Rural Development is available on the Internet through the Europa server (http://enrd.ec.europa.eu).

CONTENT

INTRODUCTION

This Working Document is one of the outputs of the Working Package 2 **'Assessment of RDP effects on ensuring the sustainable management of natural resources, and climate action'** which analyses the emerging evaluation issues related to the calculation and reporting of the **Complementary Result Indicators (CRI) 13, 14, 15, 18 and 19** and aims to facilitate the exchange and learning from current practices of the assessment of the environmental complementary result indicators in order to improve the quality of evaluations when preparing for the **ex post evaluation of RDPs 2014-2020**.

This document includes **the updated version of the fiches for answering Common Evaluation Questions 11 to 14 for RDPs 2014 - 2020**. This document has been prepared by evaluation experts taking into account various information sources including:

- Annual Implementation Reports submitted in 2019;
- Synthesis of the Evaluation Components of the Enhanced AIRs 2019;
- Yearly Capacity Building Events in the Member States;
- Working Document 'Evaluation-related Queries';
- Technical support documents (e.g. guidelines, indicator fiches).

To improve **reporting on complementary result indicators in the ex post evaluation**, the fiches for answering CEQs 11 to 14 for RDPs 2014-2020 (Annex 11 to the Guidelines. Assessment of RDP results: How to prepare for reporting on evaluation in 2017.) have been updated by:

- clarifying and updating data sources,
- clarifying methodology to calculate gross and net values of the complementary result indicators,
- adding information where useful,
- proposing recommendations how to use indicators in the situation of lack of data,
- adding examples and further information sources.

The drafting of this document has been carried out in the context of the Evaluation Helpdesk's Thematic Working Group on the **'Ex post evaluation of RDPs 2014-2020: Learning from practice'**.

1 FOCUS AREA 5A, EVALUATION QUESTION 11

1.1 Common evaluation question

To what extent have RDP interventions contributed to increasing efficiency in water use by agriculture?

1.2 List of measures contributing to the FA 5A

Primarily programmed measures/sub-measures (proposed by EC)[1]:

- Measures and sub-measures of Art.[2] 15 Advisory services, farm management and farm relief services
- Measures and sub-measures of Art. 14 Knowledge transfer and information actions
- Measures and sub-measures of Art. 17, Investment in physical assets
- Measures and sub-measures of Art. 35 Co-operation
- Measures and sub-measures of Art. 28 Agri-environment-climate

Examples of measures/sub-measures programmed under other FAs but potentially **showing secondary contributions** to this FA:

- All above measures if programmed under another FA other than FA 5A and contributing to increasing efficiency in water use by agriculture
- Measures and sub-measures of Art. 19 Farm and business development
- Measures and sub-measures of Art. 18 Restoring agricultural production potential damaged by natural disasters and introduction of appropriate prevention
- Measures and sub-measures of Art. 21 Investment in forest area development and improvement of viability of forests (sub-measures 8.1 and 8.2)
- Measures and sub-measures of Art. 27, Setting up producer groups and organisations in agriculture and forestry sectors
- Measures and sub-measures of Art. 30, Natura 2000 and Water Framework Directive ('WFD') payments
- Measures and sub-measures of Art.34 Forest-environment and climate services and forest conservation
- Measures and sub-measures of Art. 35 of Regulation (EU) no 1303/2013, Support for Leader local development

1.3 Consistency check between CEQ, judgement criteria and indicators

1.3.1 Judgement criteria

Judgement criteria (JC) proposed by the WD Common Evaluation Questions for Rural Development Programmes 2014- 2020**:**

- Efficiency in water use by agriculture has increased, due to the RDP

Note: stakeholders in Member States might add/change judgement criteria in line with the intervention logic of the FA (selection and combination of measures)

1.3.2 Indicators

The following *common indicators should* be used to answer the CEQ:

Common result indicator:

- R12/T14 - % of irrigated land switching to more efficient irrigation system

[1] WP: Guidelines for strategic programming for the period 2014-2020, European Commission, 04/03/2014, published on ECAS/circabc

[2] All articles mentioned in this section of each fiche for answering CEQ 1 – 18 are of Regulation (EU) No 1305/2013 and in the Part 5 of the Annex I of the Regulation (EU) No 808/2014, unless it is stated otherwise in the text directly

- R13 - Increase in efficiency of water use in agriculture in RDP supported projects (complementary result indicator)

The following other *common indicators might* be used to answer the CEQ:

Common output and results indicators[3] (Data collected via the operations database):

- O5 Total area (ha),
- O6 Physical area supported (ha)
- R8 % of agricultural land under management contracts to improve water management
- R9 % of forestry land under management contracts to improve water management

Common results indicators of possible secondary contributions (Data collected via the operations database):

- R10 % of Agricultural land under management contracts to improve soil management and/or prevent soil erosion
- R11 % of forestry land under management contracts to improve soil management and/or prevent soil erosion

Common context and impact indicators (Data need and data sources are described in the Working document: Proposed list of common context indicators):

- CCI 20 Irrigated land
- CCI 39 Water abstraction in agriculture (also impact indicator 10)
- CCI 40 Water quality (also impact indicator 11),
- CCI 41 Soil organic matter in arable land (also impact indicator 12),
- CCI 42 Soil erosion by water (also impact indicator 13)

Additional indicators and information

If the common indicator is not sufficient to answer the evaluation question, or if the quality and validity of the answer can be improved, additional **quantitative indicators** are suggested:

- Percentage of area under RDP-supported operations practising residue management (e.g. mulching);
- Percentage of area under RDP-supported operations practising conservation tillage;
- Percentage of area under RDP-supported operations practising specific soil carbon-building measures.

If the RDP supports water efficiency and water savings projects, which do not target primarily irrigation but address other agricultural activities, an additional indicator can be used to reflect the results in water efficiency. This additional indicator must be distinctively different from R13 in order to avoid double counting. Water efficiency is defined as the ratio of the water volume in m^3 divided by the standard output generated by the activity in €. The numerator should include the water volume directed to livestock or other non-crop producing activities. The denominator should include the standard output generated by these other non-crop activities (i.e. livestock, on-farm food processing, tourism, and other non-crop producing activities).

The evaluator should judge if the above common indicators are enough to answer the evaluation question. If they are not, the evaluator should gather additional quantitative and/or qualitative information (e.g. through additional indicators). This information may refer, for example, to the use of Resource Conservation Technologies (RCTs). RCTs aim to cut off evaporation (zero or minimum tillage, mulching, cover crops, stubble maintenance, crop diversification and rotation, use of short duration crop cultivars, etc.) or to cut off drainage losses (soil water monitoring, irrigation scheduling, levelling, etc.). Actions under FA 4B and FA 4C support many of these RCTs. Soil carbon-building practices enhance

[3] WD: Data item list for Pillar II operation database and WD RD programming and target setting

organic matter, which support the soil to retain moisture, reduce surface runoff and increases water infiltration into soil. Therefore, soil carbon-building practices directly affect the water retention capacity of soils and their need for irrigation.

The evaluator can take into account cross-compliance measures as well, for example, the standards established from the Good Agricultural and Environmental Conditions (GAEC) of land and especially those related to water (GAEC 1 and GAEC 2) and soil and carbon stock (GAECs 4, 5 and 6). Evaluators may review the checklists for cross-compliance controls established by the Member State to take into account those effects that are not caused by the RDP's activities. Checklists show the requirements by farmers under GAECs and Statutory Management Requirement (SMRs).

River Basin Management Plans (RBMPs) under the Water Framework Directive (WFD) are a prerequisite for investments to irrigation (Article 46 of Regulation (EU) 1305/2013). Under Article 46 for investments to improve an existing irrigation system, the application must establish that the investment will result in a minimum of 5% to 25% water savings for water bodies of 'good' quantitative status. However, Member States are free to set the percentage required. RBMPs also contain an 'Implementation of Programmes and Measures (PoMs)' with which RDP supported actions should comply.

Note: More additional indicators can be developed also when judgement criteria are added to specify the evaluation question in MS.

Qualitative indicators and information

Further on the evaluator can collect additional **qualitative information**, e.g. perception of beneficiaries on how efficiency in water use by agriculture has increased as a result of the RDP support. The evaluator can also explore the effects of training and cooperation activities. Information may refer to the 'Number of training actions that contribute to the more efficient use of water in the agricultural sector' in the case of training actions and to the 'Number of projects supported under cooperation activities related to improving water management' in the case of the cooperation measures. The evaluator can further explore if there is a demand for training activities and address its financing.

1.4 Data needs and data sources

1.4.1 Common indicators

R12/T14 - % of irrigated land switching to more efficient irrigation system

Data needed	Data source
Beneficiaries: • Number of hectares switching to more efficient irrigation systems through the RDP Measures 4 and 10 • Total irrigated land in the base year and for each year of intervention for the RDP area	*Beneficiaries:* • Application forms (before the project starts) • Payment requests (after the project ends) • Monitoring tables *Total irrigated land:* • Eurostat variable aei_ef_ir from FSS at the regional level • National/regional statistical authorities handling FSS or nation/region-specific agricultural surveys

R13 - Increase in efficiency of water use in agriculture in RDP supported projects

Definitions:

Increase in efficiency of water use in agriculture (for irrigation) in RDP supported projects.

Water efficiency = $\frac{\text{Volume of irrigation water}}{\text{Standard unit of crop output}}$, per year.

Change in water efficiency = water efficiency in irrigation before the implementation of projects (m^3/€, per year) – water efficiency after the completion of the projects (m^3/€, per year).

A positive change shows an increase in the efficiency of water use in irrigation due to the projects' implementation.

The following table provides an overview of data requirements and data sources for the calculation of gross and net values of the complementary result indicator. Netting out of this indicator is not mandatory, but it is considered a good practice.

Data needed	Data source

Beneficiaries and non-beneficiaries:
• Identification and basic farm characteristics to be used mainly for matching beneficiaries to non-beneficiaries:
  ○ physical and economic size,
  ○ type of farm,
  ○ physical and climatic characteristics (average altitude, average rainfall, a broad category of soil types, distance to water resources surface and groundwater)
• Irrigation characteristics:
  ○ Type of irrigation (gravity, flooding, low pressure, high pressure, etc.)
  ○ Volume used by irrigation method
• Total volume of water consumed or irrigation before and after the implementation in m^3:
  ○ Volume from irrigation networks
  ○ Volume from general water supply networks
  ○ Volume from farm-owned surface and groundwater sources
• Information on Standard Output of crops before and after the implementation:
  ○ Areas per crop (ha), irrigated and non-irrigated
• Technical information of the supported project or of non-supported projects undertaken by non-beneficiaries and especially if:
  ○ Implementation was accompanied by installation of metering device
	Projects implemented on the farm
	Beneficiaries:
	Application forms (before the project starts)
	Payment requests (after the project ends)
	Monitoring tables (with water savings/efficiency component)
	
	Beneficiaries and non-beneficiaries:
	A field survey can take into account the following information:
	• The Farm Structure Survey (FSS) for information on areas per crop and number of livestock and total irrigated area
	• The FADN for information on areas, quantities, value and percentage of irrigated area per crop and number of livestock (Table I) of the farm return
	• Other national/regional surveys maintained for similar or other reasons
	
	Other external information sources to complement the survey:
	• Average rainfall from the meteorological service
	• Longitude and latitude of the farm's main location
	• A soil map with broadly defined soil categories
	• Hydrological maps - spatial distribution of water table depth
	
	Water volume (before and after):
	• Water metering devices or water supply records from irrigation water supply agencies
	• In the case of farm owned sources, an irrigation calculator can estimate the irrigation water needs for each one of the crops irrigated on the farm and for different irrigation technologies
	• Many public extension services and research stations provide average water requirements (and irrigation schedules) under various irrigation technologies (technology coefficients) for most crops of their region or country
	
	FADN Standard Output – Crop output per farm (before and after):
	Formula:
	http://ec.europa.eu/agriculture/rica/annex003_en.cfm#ii
	Database:
	http://ec.europa.eu/agriculture/rica/database/database_en.cfm

○ Irrigated area increased	Eurostat - Standard output coefficients per MS and region. The SO 2013 is calculated using the average of 2011, 2012, 2013, 2014 and 2015 prices. http://ec.europa.eu/eurostat/web/agriculture/so-coefficients Standard outputs (overall economic size of farm) per MS and region and per year: http://ec.europa.eu/agriculture/rica/database/report_en.cfm?dwh=SO Other relevant national and regional statistics

CCI 39 - Water abstraction in agriculture

The 2018 update can be found at:

https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/cap-indicators-doc-c39_2018_en.pdf

I.10 – Water abstraction in agriculture

Guidelines to estimate I.10 are available in the 'Guidelines. Assessing RDP achievements and impacts in 2019'[4] (See Chapter 2.6 in Part II (page 56) and Chapter 4.4 in Part IV (page 42)).

1.4.2 Additional indicators

Percentage of area under RDP-supported operations practising residue management (e.g. mulching)

Data needed	Data source
Area under operations practising residue management	Operations database: Application forms (before the project starts) Payment requests (after the project ends) UAA from Eurostat or national statistics If a farm survey is planned or has been carried out for evaluating I.12 (Soil organic matter in arable land) or I.13 (Soil erosion by water) and included residue management as a measure, then the evaluator can make secondary use of the survey and its results

Percentage of area under RDP-supported operations practising conservation tillage

Data needed	Data source
Area under operations practising conservation tillage	Operations database: Application forms (before the project starts) Payment requests (after the project ends) UAA from Eurostat or national statistics If a farm survey is planned or has been carried out for evaluating I.12 (Soil organic matter in arable land) or I.13 (Soil erosion by water) and included conservation tillage as a measure, then the evaluator can make secondary use of the survey and its results

[4] European Commission – Directorate-General for Agriculture and Rural Development – Unit C.4 (2018): Guidelines. Assessing RDP achievements and impacts in 2019. Brussels.

Percentage of area under RDP-supported operations practising soil carbon-building measures

Data needed	Data source
Area under operations practising other carbon – building measures	Operations database: Application forms (before the project starts) Payment requests (after the project ends) UAA from Eurostat or national statistics If a farm survey is planned or has been carried out for evaluating I.12 (Soil organic matter in arable land) or I.13 (Soil erosion by water) and included relevant soil carbon measures, then the evaluator can make secondary use of the survey and its results

1.5 Timing of data collection

The data on beneficiaries and non-beneficiaries should address two points in time, before and at least one year after the completion of the operation. Collected data on beneficiaries can be stored during the project's application (application form), implementation and completion (payment request). Additional supplementary data on completed operations from beneficiaries or data on non-beneficiaries may be collected by evaluators during the evaluation.

1.6 Methodology to calculate complementary result indicator R13 - Increase in efficiency of water use in agriculture in RDP supported projects (gross and net value)

Projects in this focus area may be extremely diverse in terms of their size, volume of the irrigation water involved, expenditures, the type of the activity (efficiency on farm, efficiency at conveyance, water re-use and rain harvesting) technology (sprinkler, drip, subsurface) and the owner/beneficiary of the project.

When calculating the indicator, both primary and secondary contributions should be taken into consideration and estimated. The methodology proposed below can be applied separately to the projects or actions flagged as contributing to the focus area as primary and secondary contributions.

The **steps** identified below should be followed.

Step 1: Establish the samples

1a. Establish the treatment group of beneficiaries. Identify a sample of beneficiaries from the population of completed operations, which have adopted enhanced irrigation/other water saving practices on the farm with RDP support.

1b. Establish the control group of non-beneficiaries. Identify a sample to serve as a control group from the population of potential beneficiaries who have not adopted enhanced irrigation/other water saving practices *with RDP support*. These should have the same or very similar characteristics with the beneficiaries in Step 1a. The group of non-beneficiaries may consist of units which have *not* adopted any specific irrigation/other water saving practices or have adopted irrigation/other water saving practices, but without RDP support.

In both groups of farms (i.e. RDP beneficiaries and non-beneficiaries) various adopted irrigation/other water saving practices can be explicitly accounted for by inserting into the list of control variables a suitable categorical control variable (e.g. showing a farm's adoption of a specific type of irrigation/water saving practice = 0, 1, 2, 3).

Adopt smart sampling procedures: Before drawing a sample, examine carefully the population of all supported projects. Examine the projects in terms of technology or other characteristics to identify strata or homogenous subgroups of projects. The objective of stratified sampling is to improve the precision of the whole sample by reducing the sampling error. Stratified sampling always leads to smaller samples and can be less costly[5]. Results from the stratified sampling will be extrapolated to the whole population of all supported projects to estimate the irrigation water use in m^3 and the standard output in €.

Example: If farm projects can be classified as (a) projects installing drip irrigation, (b) projects installing sprinkler irrigation and (c) projects saving water by repairing canals on the farms, then these three activities can serve as subgroups on which sampling can take place.

Step 2: Implement the survey

2a. Collect the data on water consumption in m^3 and standard output in € for the beneficiaries (farms in Step 1a) before the start of the project (baseline) and one year after the operation has been completed. Data may be sourced from the operations database (application forms) especially when these include a proposed irrigation plan and payment requests.

2b. Collect the data on water consumption in m^3 and standard output in € for the non-beneficiaries (farms in Step 1b) at time periods which are similar to the before and after periods of beneficiaries in Step 2a. Alternative data sources and methods to estimate water consumption and standard output are described in Section 1.4.1. above. The survey should also record other data that will facilitate successful matching.

Note: Take care that estimates of standard output are based on coefficients for the same year for all projects and the before and after measurements. Hence when the crop standard output values are aggregated to the RDP level the only variation will come from the areas cultivated and not from the different prices used to calculate the standard output. Volumes of water use are subject to extreme variation if extreme weather conditions prevail. The survey of beneficiaries in Step 2a and non-beneficiaries in Step 2b should also record other data that will facilitate successful matching between beneficiaries and non-beneficiaries. In principle, the best approach to record water use for irrigation is to use a two or three year average in order to 'smooth' yearly variations due to weather conditions and especially rainfall. In practice, this is not always easy. For this reason, extreme weather conditions are 'harmonised', for example, when estimating irrigation needs with an irrigation calculator, by using long-term average values for rainfall and temperature.

Step 3: Estimate the gross value of the result indicator

3a. Extrapolate (upscale) the sample results of Step 2a to the population of farms which have adopted enhanced irrigation/other water saving practices with RDP support. Calculate the aggregate water volume in m^3 and the aggregate standard output in € for all projects for before (baseline) implementation and after completion.

3b. Calculate water efficiency before and after by dividing the aggregate water volume in m^3 by the aggregate standard output in € of Step 3a for the period before and after implementation. Calculate the indicator R13 as a difference (change) between efficiency before minus efficiency after.

Step 4: Estimate the net value of the result indicator

Use a matching algorithm to match beneficiaries (cases) of the survey in Step 2a with non-beneficiaries (cases) in Step 2b. It is important that matching should be performed not only on the physical and economic characteristics of the farms, but also, on rainfall, soil type, distance to water, access to public water saving operations and the year of observation after operations completion. The latter is very important to ensure that matching pairs refer to the hydrological conditions of the same year or an

[5] It is important to remember that a given strata is representative only for a specific sub-population.

'average' weather condition. For the baseline, differences in control variables characterising matching pairs should not be statistically significant. The Average Treatment Effect on Treated (ATT) will be used to estimate the net values for the supported projects.

Note: Why is netting out the estimates of R13 highly advisable?

R13 is about water use and standard output. When calculating the indicator it is advisable to use standard output coefficients from one year and apply them to the before and after estimates for beneficiaries and non-beneficiaries. As such, all farms in all years face the same product prices. This is not true for the volume of irrigation water, which depends on uncontrolled weather conditions.

Example case: The baseline year was a very wet year and the first year after the completion of the project was a very dry year. As a result, for the same standard output, it is possible that the farm used more water after the completion of the project, because it had to overcome very dry conditions. Thus, the apparent situation is that the farm's water efficiency deteriorated instead of being improved (i.e. the *gross* RDP's effect is negative). However, in comparison to a twin farm which was not supported by the RDP to perform any water efficiency activity the supported farm's water efficiency may show an improvement (i.e. the RDPs *net* effect will be positive). Even if the non-beneficiary had carried some other water saving investment, the difference with the beneficiary would be small, but likely not negative. In any case, the evaluator should try to always estimate the net effect.

Primary contributions

If the number of projects and the evaluation resources allow, evaluators can survey all projects with primary contributions to the focus area to determine and calculate the needed information. Otherwise, evaluators will survey a sample of completed projects. The sample's estimates will be extrapolated to the population of projects flagged as having a primary contribution.

Secondary contributions

It is advisable to calculate secondary contributions separately. The secondary gross and net contributions are calculated based on the methodology described above with those beneficiaries which are implementing operations via different focus areas (e.g. 2A, 4B and 4C) yet contributing to FA 5A. This also includes those operations implemented via CLLD strategies, which show secondary contributions to the water use efficiency in agriculture. If the number of projects and the evaluation resources allow, evaluators can survey all projects flagged as having secondary contributions to the focus area to determine and calculate the needed information. Otherwise, evaluators will survey a sample of completed operations flagged as having secondary contribution to the focus area. The sample's estimates will be extrapolated to the population of projects flagged as having a secondary contribution. If the number of projects having a secondary contribution is too small to justify a separate survey, the evaluator can survey both projects with primary and secondary contributions together. In this case, the evaluator can insert a control dummy variable (0-1) to indicate primary or secondary contribution and still derive separate estimates for primary and secondary contributions.

Qualitative assessment

The **qualitative assessment** is done via surveys, interviews and focus groups, which can serve to contextualise the water use and its efficiency. Indicative themes may include:

- identifying and describing all the factors that contribute to the loss of irrigation water in agriculture during 'conveyance' and 'on farm' consumption (storage, transportation, climate, soil type, topography, hydrology, type of irrigation technology, etc.).

- screening and describing unanticipated negative effects in the selected cases.[6]
- considering the water use at multiple scales from field, farm to drainage basin/catchment. Thus, there is a need to look at the impacts on the whole water system.

  Example of wider system effects: drip irrigation can impact the groundwater recharge (reducing it) and thereby impact downstream users. Better capture of water by the crop will reduce stream flow and increase the pollution load, so a more comprehensive scanning of the catchment for adverse effects should be undertaken where irrigated areas are expanded or irrigation technologies are changed.
- examining the factors constraining the adoption of irrigation water efficient technologies spanning from institutional and cultural to physical and organisational.
- identifying the potential role of soft factors such as improvement in irrigation scheduling, constraint irrigation, meteorological early warnings, familiarity with established technologies (e.g. smartphones, tensiometers) or emerging technologies (e.g. artificial intelligence, robotics).
- identifying the role of agronomic factors and cultivation techniques which utilise rain water (e.g. shorter period and early cultivars) cut off surface runoff (e.g. levelling by terraces) reduce evaporation or even switch to less water demanding cultivations, but with a standard output that increases the value of crop per drop.

1.7 Principal challenges

- Evaluators should be consistent in their choice of method and of data sources. For example, if evaluators choose to evaluate irrigation consumption with the aid of an irrigation calculator, they should use the same method for all farmers, beneficiaries, or non-beneficiaries. If evaluators estimate standard output by applying FADN standard output coefficients, then the same coefficients should be applied for the estimation of gross output 'before' and 'after'.
- Water use efficiency can be considered at multiple scales from field, to farm to drainage basin/catchment. All are legitimate concerns and scale of evaluation should be contingent on the scale of the RDP-supported scheme. Arguably there is a need to look at the whole water system and related data linked to the water use on the farm. However, the level of efficiency that can potentially be attained is not simply the amount of water used compared to the amount of water applied (Fairweather et al.). In the assessment of indicators and setting up the control groups, it is important to take into account all the factors that contribute to the loss of water on the farm (climate, soil type, hydrology, type of irrigation and topography, used technology). There might be some difficulties in data availability, since many factors are mostly unpredictable and heterogeneous and therefore complicate the measurement of the system.
- As an example of wider system effects, drip irrigation can impact on groundwater recharge as explained above.
- Eurostat reports that there is likely to be significant illegal and unmonitored use of water in some parts of Europe.
- It is very important to note that at the field, saving water via providing more efficient irrigation is not the only technique increasing efficiency in water use. Several other techniques are also important in increasing efficiency of water use in agriculture. For instance:
  - Residue management (e.g. mulching) leaving plant residue on the soil surface improve the ability of the soil to hold moisture – and reduces water run-off from the field – as well as surface evaporation.
  - Conservation tillage – same effect as above.
  - Soil-carbon building practices (e.g. regular application of livestock manure, growth of perennial legumes) increases soil carbon and water holding capacity. Some of these are part of agri-environment schemes. Employing alternative sources of water for irrigation, such as rainwater harvesting and utilising treated (low salinity) wastewater.

[6] See Ward and Pulido-Velazque, 2008 at: https://www.pnas.org/content/pnas/105/47/18215.full.pdf

1.8 How to use the indicator in the situation of a lack of data

The evaluator may come across situations or cases where they are faced by serious or even extreme data constraints. In this section we list the most common cases and try to provide guidance on how to deal with each of them.

Small number of projects

The indicator measures the result of the RDP on water efficiency. Thus, a small number of projects implies that the recorded number of observations will be small, but still measurable. The calculation of the indicator's gross value does not depend on the number of supported projects. The evaluator adds up the few cases and calculates the indicator's result. The small number of supported projects (e.g. less than twenty (20), may create a problem of statistical significance when the indicator's net value is estimated). Netting out involves the comparison between matched pairs of beneficiaries and non-beneficiaries. As a rule of thumb and depending on the number of control variables, the evaluator should not carry out such a comparison (or any statistical comparison) with less than 20 supported projects (cases). One remedy may be to try and increase the number of projects by pooling together projects flagged as having primary and secondary contributions. If the overall number of projects (primary and secondary contributions) is still very small then the evaluator can calculate only the indicator's gross effects. In any statistical estimation, which involves a point estimate, such as the Average Treatment Effect on the Treated (ATT), the evaluator should also provide the confidence interval of the estimation. A larger sample will tend to produce a better estimate (lower confidence interval) of the population parameter when all other factors are equal. For example, an ATT estimated on 15 matched pairs will, in general, have wider confidence intervals than the same estimation carried out on 50 matched pairs.

Information gaps in the operations database

Information gaps refer to the situation in which the two crucial pieces of information (i.e. irrigation water volumes and standard output before and after the project's implementation are missing from the application). In this case, the evaluator should base sampling procedures on proxies of farm size. Such proxies may be the size of the cultivated area, the size of the cultivations that are usually irrigated, the size of the project in terms of expenditures, the technology used, etc. This is important because information gaps can be filled (imputed) only for the projects in the sample and not for all supported projects.

Filling information gaps on irrigation water

If the application has all the information on the irrigation investment plan on the beneficiary, but the water savings have not been estimated, the evaluator can estimate the water savings using one of the three indicative approaches as follows:

- If the farm has installed an irrigation metering device the evaluator can ask for the consumption at the baseline year and the consumption one year after the project was completed. The existence of a metering device allows the evaluator to estimate water consumption as a two- or three-year average for the before and after consumptions depending on data availability.
- If the farm has not installed an irrigation metering device or if the farm uses, in addition to the irrigation water supplied by the network, farm owned surface or groundwater resources, then the evaluator can use an irrigation calculator (e.g. AquaCrop). The irrigation calculator takes account of the cultivations and the change in irrigation technology. The evaluator can calculate the consumption of irrigation water before and after the implementation of the project separately. This method assumes that farmers are rational and thus adopt optimal irrigation schedules. As such, the evaluator can equalise irrigation water consumption to irrigation water needs calculated by the irrigation calculator.
- If an irrigation calculator is not available, then the evaluator can use average regional values of irrigation water needs per cultivation, adapted to the irrigation technology. In all water constrained countries and regions, extension and research services provide farmers with 'typical' irrigation schedules and associated irrigation water use volumes for attaining optimal yields under different

irrigation technologies (irrigation technology coefficients). The evaluator can use these 'average' values to obtain irrigation water use for all of the farm's crops for both before and after the project's implementation.

- The evaluator should be consistent in whatever method applied to calculate missing irrigation water information. Do not mix up the methods used. If there are no irrigation water metering devices, then information should be filled either with an irrigation water calculator for all farms or by using those average irrigation water requirements recommended by extension services for all farms. If some farms have metering devices, calculate the discrepancy between metered consumption and consumption calculated by an irrigation calculator. If the discrepancy is small and justifiable use the calculator for all farms in your sample.

Filling information gaps on standard output

If the application has all the information on the irrigation investment plan, but standard crop output estimates are missing, the evaluator can estimate standard output using standard output coefficients.

Attention: Evaluators should be aware that, when using standard output coefficients, they assume that crop yields remained the same after the completion of the project and all efficiency gains result from water savings. In other words, evaluators should adopt an input oriented perspective in which they assume that farmers are maximising their profits by minimising their inputs for a desired level of output.

Differences in standard output can emerge if farmers re-allocate the size of cultivations before and after implementation by expanding (or contracting) the size of cultivated areas before and after implementation or by doing both. Therefore, in order to estimate the missing standard crop output of a farm, the evaluator should have access to the areas per crop for the whole farm before and after the project's implementation and to the FADN standard output coefficients for the RDP's territory (regional or national). If this information is also missing and evaluator can fill these data gaps though three sources:

- **The IACS/LPIS:** This contains all the plots of a farm and contains the cultivations per year for which the farmer is liable for a Single Farm Payment or similar payment schemes. The IACS may not contain information on the cultivations of plots that are not subject to payments. This can be filled by regional cadastrals if they exist. Nevertheless, the bias introduced by this possible deficiency is not considerable.
- **The FADN:** If the farmer is part of the FADN sample they may provide consent to use the FADN farm returns for the baseline year and a year after the project's completion. Table I of the farm return details all cultivated areas per crop. It also records quantity produced, value of production and the percentage of the crop's area that was irrigated. This information can be used for various triangulation exercises.
- **The FSS:** If the farmer is part of the FSS sample for at least the year before or the year after the project was completed, they may provide consent to use the FSS questionnaire for whichever year the farmer was included in the survey. The evaluator can use this questionnaire to recreate the conditions of the missing year (i.e. to record only the changes). The FSS questionnaire records all cultivated areas per crop. Usually, the FSS records the aggregate amount of irrigated areas not broken down by cultivation.

Filling information gaps on the 'before' situation

Sometimes the 'before' situation of a project is decided to be filled during evaluation (i.e. after some years have passed). This creates a problem because information is timewise 'distant' and farmers are not able to remember or recall it. The evaluator can assist the farmer by providing information from sources that keep the 'history' of the farm such as irrigation water supplying agencies or cooperatives, the IACS/LPIS, the FADN returns, and others. The farm also maintains 'historical' data in the sense of electricity bills associated with water irrigation pumps, cross-compliance forms or data kept on farm for cross-compliance inspections, etc. The farm's advisor also may be able to fill in some of these past gaps.

Lack of data for the creation of control groups

Control groups are established during evaluation and are not part of the operations database. As such, by default, the information before is missing. For this reason, it is advisable to source information from a database that has records of the farm 'before' and 'after'. FADN may serve this purpose. In general, FADN, does not provide the quantity of water, but the cost for water. Code 5040 of Table H, records the water cost of connection to the mains and consumption of water for all farm purposes including irrigation. The costs of using farm-owned water equipment are entered through the appropriate codes including depreciation of machinery and equipment, current upkeep of machinery and equipment, motor fuels, electricity, etc. Therefore, the cost of water recorded by FADN is useful as a guide to derive quantities only in the case of farmers connected to an irrigation network (mains). Which may mean that water cost recorded by FADN may be misleading. Irrigation water consumption should be estimated based on cultivations included in Table I of the FADN return and with an irrigation water calculator or using average suggested irrigation water quantities by extension services. The evaluator should be consistent and whatever method is used to calculate missing irrigation water information of the control group should also be used for the beneficiaries (treatment group). Do not mix up the methods used. The farm's standard output also can be calculated with the alternative approaches presented above. If the evaluator does not have access to FADN data, then the control group may be created by FSS questionnaires or other surveys maintained by the Member State or regional authorities. These surveys (FADN, FSS, other surveys) can serve the purpose of netting out the complementary indicator even if they are anonymised and the farmer cannot be contacted. With all these surveys (FADN, FSS, other panel surveys) attrition will always be a problem and will introduce a form of bias.

1.9 Examples

Bio-intelligence Services (2012). Water saving potential in agriculture in Europe: findings from the existing studies and application to case studies. Final report DG ENV. In collaboration with Cranfield University and Risk and Policy Analysts. Available at:

http://ec.europa.eu/environment/water/quantity/pdf/BIO_Water%20savings%20in%20agiculture_Final%20report.pdf

Anon (2016) Example Irrigated Farm Water Use Efficiency Assessment (IFWUEA)

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/598420/example-ifwuea-round-7.pdf (Example of detailed analysis of water use efficiency at farm scale based on Australian (New South Wales) study).

Sub-surface drip irrigation, for instance: http://www.agriculture-xprt.com/applications/irrigation-solutions-for-citrics-crops-1126

Advantages of the Watering Community, for instance at: http://www.agriculture-xprt.com/applications/water-filtration-solutions-for-irrigation-sector-1121

1.10 Further information

Evaluations and projects

CMEF evaluations, external studies, EU-EIP:

- Impact of the CAP on water (November 2019): https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cmef/sustainability/impact-cap-water_en
- Evaluation study of the payment for agricultural practices beneficial for the climate and the environment (November 2017): https://op.europa.eu/en/publication-detail/-/publication/598b81ff-dfbc-11e7-9749-01aa75ed71a1

- The EIP Water & agriculture: adaptive strategies at farm level has dedicated sections and minipapers on “Tools for improving Irrigation scheduling”, “Soil management for improved water availability” and “Diversification, Improved Varieties”: https://ec.europa.eu/eip/agriculture/en/focus-groups/water-agriculture-adaptive-strategies-farm-level

Indicative Horizon 2020 and FP7 related projects:

- DIANA https://diana-h2020.eu/en/
- HYDROUSA https://www.hydrousa.org/
- APOLLO http://apollo-h2020.eu/project/
- FATIMA http://fatima-h2020.eu/
- SUFISA https://www.sufisa.eu/
- WATERBEE DA (WaterBee Smart Irrigation Systems Demonstration Action) https://cordis.europa.eu/project/id/283638/reporting
- SIRIUS http://sirius-gmes.es/objectives/
- FLINT https://www.flint-fp7.eu/
- OpiRIS https://cordis.europa.eu/project/id/613717

Other projects and studies

Anon (2016) Example Irrigated Farm Water Use Efficiency Assessment (IFWUEA) http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/598420/example-ifwuea-round-7.pdf

BIO Intelligence Service, Cranfield University and Risk and policy Analysts (2012) Water saving potential in agriculture in Europe: findings from the existing studies and application to case studies. http://ec.europa.eu/environment/water/quantity/pdf/BIO_Water%20savings%20in%20agiculture_Final%20report.pdf

Burt, C. M., Clemmens, A. J., Strelkoff, T. S., Solomon, K. H., Bliesner, R. D., Hardy, L. A., Howell, T. A. and Eisenhauer, D. E. (1997) Irrigation performance measures: efficiency and uniformity. *Journal of Irrigation and Drainage Engineering*, 123:423-442 available at http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1015&context=bae_fac

Fairweather, H., Austin, N. and Hope. M., (undated) Water use Efficiency An information package Water Insights 5. Avalable at:

http://www.insidecotton.com/xmlui/bitstream/handle/1/2108/pr030566.pdf?sequence=3&isAllowed=y

Giordano, M., Turral, H., Scheierling, S., Tréguer, D. and McCornick, P. (2017). Beyond “More Crop per Drop”: Evolving Thinking on Agricultural Water Productivity. International Water Management Institute (IWMI), Report 169. Available at:

http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub169/rr169.pdf

Scheierling, S., Treguer, D., Booker, J. and Decker, E. (2014). How to Assess Agricultural Water Productivity?. World Bank Group, Policy Research Working Paper 6982. Available at: http://documents1.worldbank.org/curated/en/757951468146378459/pdf/WPS6982.pdf

Scheierling, S. and Treguer, D. (2018). Beyond Crop per Drop: Assessing Agricultural Water Productivity and Efficiency in a Maturing Water Economy. World Bank Group, International Development in Focus. Available at:

https://openknowledge.worldbank.org/bitstream/handle/10986/29922/9781464812989.pdf?sequence=2&isAllowed=y

1.11 Answer to CEQ

The answer is provided following a critical analysis and discussion based on the calculated indicator values, on the collected qualitative information or on the qualitative assessment.

Conclusions	Recommendations
Main conclusions are stated here for the FA based on the evaluation findings.	Main recommendations linked to the conclusions are stated here for the FA.

2 FOCUS AREA 5B, EVALUATION QUESTION 12

2.1 Common evaluation question

To what extent have RDP interventions contributed to increasing efficiency in energy use in agriculture and food processing?

2.2 List of measures contributing to the FA 5B

Primarily programmed measures/sub-measures (proposed by EC):

- Measures and sub-measures of Art. 15 Advisory services, farm management and farm relief services
- Measures and sub-measures of Art. 14 Knowledge transfer and information actions
- Measures and sub-measures of Art. 17, Investment in physical assets
- Measures and sub-measures of Art. 35 Co-operation
- Measures and sub-measures of Art. 20 Basic services and village renewal in rural areas

Examples of measures/sub-measures programmed under other FAs but potentially **showing secondary contributions** to this FA:

- All the above measures if programmed under another FA other than FA 5B and contributing to increasing efficiency in energy use by agriculture
- Measures and sub-measures of Art. 19, Farm and business development
- Measures and sub-measures of Art. 27, Setting up producer groups and organisations in agriculture and forestry sectors
- Measures and sub-measures of Art. 35 of Regulation (EU) No 1303/2013, Support for Leader local development

2.3 Consistency check between CEQ, judgement criteria and indicators

2.3.1 Judgement criteria

Judgement criteria (JC) proposed by the Working Document: Common Evaluation Questions for Rural Development Programmes 2014- 2020**:**

- Efficiency of energy use in agriculture and food processing has increased due to RDP

Note: Member States might add/change judgement criteria in line with the intervention logic of the FA (selection and combination of measures)

2.3.2 Indicators

The following *common indicators should* be used to answer the CEQ:

Common result indicators:

- T15 - Total investment for energy efficiency
- R14 - Increase in efficiency of energy use in agriculture and food-processing in RDP supported projects (complementary result indicator)

The following other *common indicators might* be used to answer the CEQ:

Common output indicators[7] (data collected via the operations database):

- O2 Total investment € (public + private)

Common context indicator (data need and data sources are described in the Working document: Proposed list of common context indicators):

[7] WD: Data item list for Pillar II operation database and WD RD programming and target setting

- CCI 44 Energy use in agriculture, forestry and food industry

Additional indicators

If the common indicator is not enough to answer the common evaluation question or if stakeholders in MS have added additional judgement criteria, then additional indicators, consistent with the proposed additional judgement criteria, can be applied.

Qualitative indicators and information

Additional qualitative information may also be collected in the assessment of whether efficiency in energy use in agriculture and food processing has increased, for example:

- The perception of beneficiaries on how efficiency of energy use in agriculture and food processing has increased as a result of the RDP support
- The types of actions that have proved effective in improving energy efficiency
- Identify the role and action of other national projects in energy savings/efficiency operating in rural areas
- Explore the effects of training and cooperation activities on energy efficiency

2.4 Data needs and data sources

2.4.1 Common indicators

T15 - Total investment for energy efficiency

Data needed	Data source
Beneficiaries: Total amount of investments in energy saving and efficiency supported under the RDP	*Beneficiaries* Application forms (prior the project starts) Payment requests (after project completions)

R14 - Increase in efficiency of energy use in agriculture and food-processing in RDP supported projects

Definitions:

Increase in efficiency of energy use in agriculture and food processing in RDP supported projects.

Efficiency = Amount of energy used in one year ÷ Output in one year.

Amount of energy = the sum of all energy forms consumed in one year.

Output for farms = the standard crop and livestock output according to FADN terminology.

Output for enterprises in the food sector = Gross output = Sales + Changes in Inventories.

The change in efficiency is the difference between the efficiency in the baseline (before the project) and after the completion of the programme.

Change in efficiency = Efficiency before – Efficiency after

A positive change shows an increase in the efficiency of energy use in agriculture and food processing due to the projects' implementation.

The following table provides an overview of data requirements and data sources for the calculation of gross and net values of the complementary result indicator. Netting out of this indicator is not mandatory, but it is considered as good practice.

Data needed	Data source

Beneficiaries and non-beneficiaries:
• Energy consumed before and after the implementation of the project in Tonnes of Oil Equivalent (T.O.E) per year:
  ○ Energy from the grid
  ○ Energy from farm or enterprise – off-grid
○ Information on standard output for farms or gross output for enterprises in the food sector before and after the implementation
○ Technical information on the supported project:
  ○ Main activity (e.g. insulation, replacing or upgrading of old machinery, change of energy source, energy management)
  ○ Energy audit exists
○ Identification and basic farm and enterprise characteristics to be used mainly for matching beneficiaries to non-beneficiaries:
  ○ physical and economic size,
  ○ type of farm, type of food enterprise
  ○ physical and climatic characteristics (average temperature)
	Beneficiaries:
	• Application forms (prior to the project starts)
	• Payment requests (after project completions)
	• Energy audit (especially for processing industries)
	
	Beneficiaries and non-beneficiaries:
	A field survey can take account of data existing in:
	• The Farm Structure Survey (FSS) for information on areas per crop and number of livestock to derive the farm's standard output before and after the project's implementation
	• The FADN for information on areas per crop and number of livestock per type to derive the farm's standard output before and after project implementation (Table I) of the farm return
	• Financial statement or databases of enterprises' accounting statements to derive the gross output before and after the project's implementation
	• Other national/regional surveys or accounting/financial databases maintained for similar or other reasons
	
	Energy consumption before and after:
	• Energy bills for electricity and other fuels
	• The FADN farm return and especially Table H records costs for heating fuels, electricity and motor fuels as overhead costs. These costs may be converted to energy if prices correspond to energy output
	• Cost of energy from accounting statements (if recorded)
	
	FADN - Total output per farm:
	Formula:
	http://ec.europa.eu/agriculture/rica/annex003_en.cfm#ii
	Database:
	http://ec.europa.eu/agriculture/rica/database/database_en.cfm
	
	Eurostat – standard outputs:
	Standard outputs per MS and region and year – average 2010:
	http://ec.europa.eu/eurostat/web/agriculture/so-coefficients
	Total standard outputs (overall economic size of farm) per MS and region and per year:
	http://ec.europa.eu/agriculture/rica/database/report_en.cfm?dwh=SO
	Other relevant national and regional statistics

2.4.2 Additional indicators

The evaluator should judge if the common indicators are enough to answer the evaluation question. If they are not, the evaluator should gather additional quantitative or qualitative information (e.g. through additional indicators). Additional indicators may target the number of farmers who received trainings or advice on issues concerning energy efficiency or energy conservation. Also, farmers and other entities who participated in innovative energy efficiency projects or combined energy efficiency with other interventions (e.g. the production of renewable energy or improvement of irrigation water efficiency).

2.5 Timing of data collection

The data on beneficiaries and non-beneficiaries should address two points in time, one before the project's implementation to establish the situation 'before' (capacity created) and a second at one year after the completion of the project to establish the situation 'after' (energy generated). Collected data on beneficiaries should be stored during the project's application (application form), implementation and completion (payment request). Supplementary data on completed projects from beneficiaries or data on non-beneficiaries may be collected by evaluators during the evaluation.

2.6 Methodology to calculate complementary result indicator R14 - Increase in efficiency of energy use in agriculture and food-processing in RDP supported projects (gross and net value)

Projects in this focus area may be heterogeneous and diverse as concerns their size in terms of energy savings, the type of the activity (energy upgrading of buildings, energy upgrading of machinery, the substitution of energy resources, etc.) and other characteristics specific to the farm of the food sector in which the farm or enterprise operates.

When calculating the indicator, both primary and secondary contributions should be taken into consideration and estimated. The methodology proposed below can be applied separately to the projects or actions flagged as contributing to the focus area as primary and secondary contributions.

Total energy use before and after project implementation will concern all sources of energy consumption for a farm or a food-processing enterprise. Examples include electricity used in cooling systems for dairy farms, fuel in machinery and tractors, electricity use in food processing enterprises. The consumption from the different sources are converted to Tonnes of Oil Equivalent (T.O.E) and are added up to calculate the total energy use for a supported farm or enterprise. An energy audit estimates energy consumption before and after the implementation of the intervention and calculates expected energy savings. It is advisable that farm or food processing projects are accompanied by an energy audit like the ones required in the framework of energy efficiency obligation schemes and should be a prerequisite for any farm or food processing industry (or potentially Leader–funded entity) applying for this measure. As such, information on energy before and after and energy savings should be accessible to the evaluator. Coefficients for the conversion of energy consumption and savings from various energy units to T.O.E are available by the International Energy Agency unit converter at:

https://www.iea.org/reports/unit-converter-and-glossary

Standard unit of outputs (Eurostat) are used as a denominator in the calculation of the indicator. For food manufacturing businesses the gross output is the closest proxy to the farm standard output.

The following **steps** should then be used in the calculation of the indicator:

Step 1: Establish the samples

1a. Establish the treatment group of beneficiaries. Identify sampling procedures and a sample of farms and food processing enterprises from the population of completed operations which have implemented energy savings projects with RDP support, while adopting smart sampling procedures.

1b. Establish the control group of non-beneficiaries (through smart sampling procedure). Identify a sample of farms and food processing enterprises to serve as a control group from the population of farms and food processing enterprises which have not received RDP support. These farms and food processing enterprises should have the same or very similar characteristics as those included in the treatment group of Step 1a.

Smart sampling procedures

Before drawing a sample of supported projects, the evaluator should examine carefully the population of all supported projects. Examine the projects in terms of technology or other characteristics to identify strata or homogenous groups of projects. Stratified sampling results always to smaller samples and is less costly. In both groups of farms (i.e. RDP beneficiaries and non-beneficiaries) various energy saving practices can be explicitly accounted for by inserting into the list of control variables a suitable categorical control variable (e.g. showing a farm's or food-processing enterprise's adoption of specific type of energy saving practice = 0, 1, 2, 3).

Step 2: Implement the survey

2a. Collect the data on energy consumption in T.O.E and standard output in millions € for the beneficiaries (farms and food processing enterprises in Step 1a) before the implementation of the project (baseline) and at least one year after the operation has been completed. Data may be sourced from the application forms mainly when these include an energy audit or a technical/business plan. The survey should also record other data that will facilitate successful matching.

2b. Collect the data on energy consumption in T.O.E and standard output in millions € for the non-beneficiaries (farms and food processing enterprises in Step 1b) at time periods which are similar to the before and after periods of beneficiaries in Step 2a. The survey should also record other data that will facilitate successful matching.

Note: Pay attention that estimates of standard output are based on coefficients for the same year for all projects and for the before and after measurements. Hence when the standard output values of farms are aggregated to the RDP level the only variation will come from the areas cultivated or the number of livestock and not from the different prices used to calculate the standard output. Gross output for enterprises is less volatile. Energy consumption is subject to considerable variation if extreme weather conditions prevail.

Step 3: Estimate the gross value of the result indicator

3a. Extrapolate (upscale) the sample results of Step 2a to the population of farms and food processing enterprises which have adopted energy efficiency with RDP support. Calculate the aggregate energy consumption in T.O.E and the aggregate standard and gross output in millions € for all projects for before (baseline) and after (at least 1 year after operation is completed) the implementation of projects.

3b. Calculate energy efficiency before and after by dividing the aggregate energy consumption in T.O.E and the aggregate standard output in millions € of Step 3a for the period before and after implementation. Calculate the indicator R14 as a difference (change) between efficiency before minus efficiency after.

Step 4: Estimate the net value of the result indicator

Use a matching algorithm to match beneficiary farms and food processing enterprises (cases) of survey in Step 2a with non-beneficiary farms and food processing enterprises (cases) in Step 2b. It is important that matching should be performed not only on the physical and economic characteristics of the farms and enterprises, but also, on average yearly temperature and other characteristics that may affect energy consumption. Matching should also take into consideration of the year of observation after the project's completion. Estimation of the Average Treatment Effect on the Treated will be used to estimate the net values of supported projects. Follow Step 3 to calculate the net value of the indicator. Extrapolate the net results of the farms and food processing enterprises' sample in Step 2a, calculate aggregate energy consumption and aggregate standard and gross output (Step 3a) and then calculate the indicator (Step 3b).

Note: Netting out R14 may be very challenging not only because of the heterogeneity in supported projects but also because a mix of farms and food processing enterprises are supported. The evaluator may find it difficult to establish a counterfactual for such a wide range of activities. However, due to the long-term operations of energy savings programmes in many Member States, there may be already evaluations netting out operations in many enterprises in the food manufacturing sector. These evaluation results may be used for netting out the results of the enterprises supported by the RDP for energy efficiency projects.

Primary contributions

If the number of projects and the evaluation resources allow, evaluators can survey all projects having primary contributions to the focus area to determine and calculate the needed information. Otherwise, evaluators will survey a sample of completed projects. The sample's estimates will be extrapolated to the population of projects flagged as having a primary contribution.

Secondary contributions

It is advisable to calculate secondary contributions separately. The secondary gross and net contributions are calculated based on the methodology described above with those beneficiaries which are implementing operations via different focus areas (e.g. 2A, 6A, 6B) yet contributing to FA 5B. If the number of projects and the evaluation resources allow, evaluators can survey all projects flagged as secondary contributions to the focus area to determine and calculate the needed information. Otherwise, evaluators will survey a sample of completed operations flagged as having secondary contribution to the focus area. The sample's estimates will be extrapolated to the population of projects flagged as having a secondary contribution. If the number of projects having a secondary contribution is very small to justify a separate survey, the evaluator can pool together projects with primary and secondary contribution. In this case, the evaluator can insert a control dummy variable (0-1) to indicate primary or secondary contributions and still derive separate estimates for primary and secondary contributions.

Qualitative assessment

The qualitative assessment is done via surveys, interviews and focus groups, which can serve to contextualise the energy use and its efficiency. Indicative themes may include:

- Identifying and describing all the factors that contribute to energy savings.
- Examining the factors constraining adoption of energy efficient technologies spanning from institutional, cultural to physical and organisational.
- Identifying the potential role of soft factors and of behavioural changes. Consider that many RDPs have employed training and advisory programmes for the FA 5B.

2.7 Principal challenges

- The definition of energy efficiency used by the indicator may be confusing for evaluators familiar with the energy efficiency Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. In the Directive, 'energy efficiency' means the ratio of output of performance, service, goods or energy, to input of energy (i.e. the reverse of indicator R14).
- The indicator requires a measure of the farm's or enterprise's output in the denominator. Output is defined in terms of standard output for farm enterprises. This can be calculated from FADN national/regional coefficients if area by type of cultivation and number of livestock by type is

available. The corresponding measure for enterprises in the food sector is gross output. Gross output is defined as sales + changes in inventories and is the closest measure to standard output.

  - **Attention:** Sales exclude product taxes and include product subsidies. Changes in inventories refer to the difference between ending inventory and beginning inventory. This measure is more difficult to calculate. Very small enterprises in many Member States are not subject of publicly announced financial statements. Therefore, there may not be an objective source for estimating gross output. This may be a challenge when the counterfactual is established, and the indicator is netted out.

- Price volatility of agricultural and food products may distort the indicator's estimates. For farm products, price volatility can be smoothed by using standard output coefficients of the same year for the before and after periods. For enterprises in the food sector linked to different products, it is proposed to use as the standard output the gross output of all commodities (food processing enterprises).
- Increase in energy efficiency may be related to energy savings. In other words, less energy is used in the production. These energy savings may be thought of as energy not produced by fossil fuels. Therefore, the evaluator may, optionally, convert net energy savings to GHG emission reductions. Emissions factors for the conversion of energy savings to GHG emission savings from Annex 1 'Default Emission Factors' of 'The Covenant of Mayors for Climate and Energy Reporting Guidelines'. at:

  https://www.covenantofmayors.eu/IMG/pdf/Reporting_Guidelines_Final_EN.pdf

2.8 How to use the indicator in the situation of lack of data

The evaluator may come across situations or cases where they are faced by serious or even extreme data constraints. In this section we list the most common cases and try to provide guidance on how to deal with each of them.

Small number of projects

The indicator measures the results of the RDP on energy efficiency. Therefore, a small number of projects implies that the results will be small, but still measurable. Nevertheless, even with a small sample the indicator's gross value can still be calculated. The evaluator should add up the few cases in the operations database and calculate the indicator's results.

Information gaps in the operations database

Information gaps refer to the situation in which the two crucial pieces of information (i.e. energy consumption and standard or gross outputs before and after the project's implementation) cannot be retrieved or are missing from the project's application file. If the evaluator decides to carry out the indicator's estimation on a sample of supported projects and then extrapolate the findings to the population of supported projects, information gaps create two problems. First, information on energy consumption and standard output, which is crucial for sampling the projects, is missing. Second, information which is crucial for estimating the indicator's gross value is missing and the indicator cannot be calculated. For the first issue, the evaluator should base sampling procedures on proxies of size and energy consumption. Such proxies may be the size of the cultivated area for a farm, or the number of employees for an enterprise, the size of the project in terms of expenditures, the technology used, etc. This is important because data gaps can be filled only for the projects in the sample and not for all supported projects.

Filling information gaps on energy consumption or standard output

If the application has all the information on the energy investment plan, but energy savings or standard output have not been included, the evaluator can estimate them from an alternative source described in Section 2.4.1.

Filling information gaps for the 'before' situation

Sometimes the 'before' situation of a project is filled during the evaluation (i.e. after some years have passed). This creates a problem because information is collected after the fact. Farmers or firm managers may not be able to remember or recall it. The evaluator can assist the farmer by providing information from sources that keep the 'history' of the farm, such as, energy bills, the IACS, the FADN returns, and others. The farm also maintains 'historical' data of electricity bills associated with water irrigation pumps, expenditures for fuel or data kept on farm for cross-compliance inspections. For enterprises it is more difficult to locate 'historical' data unless the enterprise keeps a record of energy bills or maintains published financial statements.

Lack of data for the creation of control groups

Control groups are established during the evaluation and are not part of the operations database. As such, by default, the information before is missing. For this reason, it is advisable to source information from a database that has records of the farm at the baseline and during the RDP's operation period. FADN may serve this mission and offer data on cultivated areas for estimating the farm's standard output and cost of energy for estimating energy needs by converting costs to quantities. For enterprises, 're-creating' the past and finding past energy data or gross output may be more challenging.

2.9 Examples

TEGASC (2016). Energy data for Glasshouse nurseries. Available at:

https://www.teagasc.ie/media/website/publications/2016/15.-Energy-data-for-Glasshouse-nurseries.pdf

Finland's National Energy Efficiency Action Plan NEEAP-4 (2017 revision). This is an example of how national plans include and target agriculture, set expected targets and mobilise resources and instruments. The Finish National Plan is available at:

https://ec.europa.eu/energy/sites/ener/files/documents/fi_neeap_2017_en.pdf

2.10 Further information

EU Energy efficiency databases

MURE (Mesures d'Utilisation Rationnelle de l'Energie) a database on energy efficiency policies and measures that have been carried out in the Member States of the European Union. Available at:

https://www.measures.odyssee-mure.eu/

ODYSSEE is a database managed by Enerdata, that contains detailed energy efficiency and CO2-indicators with data on energy consumption, their drivers (activity indicators) and their related CO2-emissions. Available at:

https://www.indicators.odyssee-mure.eu/

Evaluations and studies

The State and Local Energy Efficiency Action Network. 2012. Energy Efficiency Program Impact Evaluation Guide. Evaluation, Measurement, and Verification Working Group. Available at:

https://www.energy.gov/sites/prod/files/2013/11/f5/emv_ee_program_impact_guide.pdf

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2.11 Answer to CEQ

The answer is provided following a critical analysis and discussion based on the calculated indicator values, on the collected qualitative information or on the qualitative assessment.

Conclusions	Recommendations
Main conclusions are stated here for the FA based on the evaluation findings.	Main recommendations linked to the conclusions are stated here for the FA.

3 FOCUS AREA 5C, EVALUATION QUESTION 13

3.1 Common evaluation question

To what extent have RDP interventions contributed to the supply and use of renewable sources of energy, of by-products, wastes, residues and other non-food raw material for purposes of the bio-economy?

3.2 List of measures contributing to the FA 5C

Primarily programmed measures/sub-measures (proposed by EC)[8]:

- Measures and sub-measures of Art.[9] 15 Advisory services, farm management and farm relief services
- Measures and sub-measures of Art. 14 Knowledge transfer and information actions
- Measures and sub-measures of Art. 17 Investment in physical assets
- Measures and sub-measures of Art. 35 Co-operation
- Measures and sub-measures of Art. 20 Basic services and village renewal in rural areas
- Measures and sub-measures of Art. 19 Farm and business development
- Measures and sub-measures of Art. 26 Investments in forestry technologies and in processing, mobilising and marketing of forestry products
- Measures and sub-measures of Art. 21 investments in forest area development and improvement of the viability of forests

Examples of measures/sub-measures programmed under the other FAs but potentially **showing secondary contributions** to this FA:

- All above measures if programmed under another FA other than FA 5C and contributing to the supply and use of renewable sources of energy, of by-products, wastes, residues and other non-food raw material for purposes of the bio-economy
- Measures and sub-measures of Art. 27 Setting up producer groups and organisations in agriculture and forestry sectors
- Measures and sub-measures of Art. 35 of Regulation (EU) No 1303/2013, Support for Leader local development

3.3 Consistency check between CEQ, judgement criteria and indicators

3.3.1 Judgement criteria

Judgement criteria (JC) proposed by the Working Document: Common Evaluation Questions for Rural Development Programmes 2014- 2020**:**

- The supply of renewable energy has increased, due to RDP.
- The use of renewable energy has increased

Note: Stakeholders in Member States might add/change judgement criteria in line with the intervention logic of the FA (selection and combination of measures).

3.3.2 Indicators

The following *common indicators should* be preliminary used to answer the CEQ:

Common result indicators:

- T16 - Total investment in renewable energy production

[8] WP: Guidelines for strategic programming for the period 2014-2020, European Commission, 04/03/2014, published on ECAS/circabc

[9] All articles mentioned in this section of each fiche for answering CEQ 1 – 18 are of Regulation (EU) No 1305/2013, unless it is stated otherwise in the text directly

- R15 - Renewable energy produced from supported projects (complementary result indicator)

The following other *common indicators might* be used to answer the CEQ:

Common output indicators[10](data collected via the operations database):

- O2 - Total investments € (public and private)

Common context indicators (data need and data sources are described in the Working document: Proposed list of common context indicators):

- CCI 43 Production of renewable energy from agriculture and forestry
- CCI 44 Energy use in agriculture, forestry and food industry

Additional indicators and information

If the common indicator is not sufficient to answer the evaluation question, or if the quality and validity of the answer can be improved, or If the Member State has added an additional judgement criteria then additional indicators can be applied for:

- The production of by-products from agriculture and forestry (e.g. volume of products and forest area by species in which wood is extracted for biomass production).
- The production and potential utilisation of wastes.
- The use of residues from agriculture and forestry (e.g. number of pellet or solid biofuel factories supported).
- The use of other non-food raw material for the purpose of the bio-economy.

Qualitative indicators and information

Qualitative information may also be used with the following (indicative) themes:

- Perception of beneficiaries on how the supply and use of renewable energy has been increased due to the RDP's support.
- Description of actions to increase the production and supply of renewable energies (e.g. biomass based through cultivating annual and perennial crops, such as, grasses and coppice trees, forest biomass based, biogas) and involvement of stakeholders.
- The types of actions that have proved effective in improving the adoption of renewable energy.
- Identification of the reasons for the low uptake of renewable energy production, if this is the case.
- Identification of the role and actions of other national projects promoting renewable energy and operating in rural areas.
- Identification of the potential use of agricultural and forestry products, by-products and wastes for producing bio-fuels, biomass and biogas.

3.4 Data needs and data sources

3.4.1 Common indicators

T16 - Total investment in renewable energy production

Data needed	Data source
Beneficiaries	*Beneficiaries* • Application forms (before the project starts)

[10] WD: Data item list for Pillar II operation database and WD RD programming and target setting

• Total investment in renewable energy production under Measures 4, 6.2, 6.4, 7.2 and 8.6 • Total investment in renewable energy production in agriculture and forestry • The technology used for the production of renewable energy	• Payment requests (after project completions) Other sources: • National and regional statistics • Renewable energy supply by type of energy from national energy regulatory authorities • Eurostat – energy statistics http://ec.europa.eu/eurostat/web/energy/data/database

R15 - Renewable energy produced from supported projects

Definitions:

Capacity created and energy generated in RDP supported renewable energy projects expressed in Tonnes of Oil Equivalent (T.O.E).

Capacity is the maximum output of energy that a generator has the ability to create. This is usually measured in Megawatts (MW) or Gigawatts (GW).

For the purposes of this indicator capacity is defined as the maximum output of energy that a generator can produce under ideal conditions in an operating hour. This is measured in energy units, usually in terms of Megawatt hour (MWh) Kilowatt hour (KWh) (e.g. smaller generators) or Tonnes of Oil Equivalent (T.O.E).

However, energy generators do not operate all the time or do not operate at maximum output. Energy generated is the amount of energy actually produced over a year by a specific generator.

The evaluator must be aware of the difference between the concepts of energy capacity and energy generated. The capacity is the ability of a generator to produce energy under ideal conditions. However, the total amount of energy that will be produced in a year depends on the conditions and on the operating hours of the generator.

For example, a project that supported a photovoltaic installation with 10 KW of power has the capacity of producing 10 KWh (0.00086 T.O.E) of energy in an hour under ideal conditions. This installation in Estonia can generate 9,000 KWh (0.773861 T.O.E) because ideal conditions are met for an equivalent of 900 hours per year. In Greece, the same installation can generate 14,000 KWh (1.203783 T.O.E) because ideal conditions are met for an equivalent of 1,400 hours per year. In another example, the RDP supports the installation of a pellet burner which has an equivalent electrical power of 20 KW and thus a capacity of 20 KWh (0.00172 T.O.E) (i.e. it can generate an energy of 20KWh if it operates for an hour). The electrical energy that will be generated by this burner in a year depends on the hours of operation. If this burner operates for 1000 hours in a year because it is installed in a mountainous northern area, it will generate 20,000 KWh (1.719690 T.O.E). If it operates for only 500 hours in a year because it is installed in a more temperate southern environment it will generate 10,000 KWh (0.859845 T.O.E). The above examples use the conversion rate of 1 KWh to 0.000086 T.O.E.

The following table provides an overview of the data requirements and data sources for the calculation of gross and net values of the complementary result indicator. Netting out of this indicator is not mandatory, but it is considered a good practice.

Data needed	Data source
Beneficiaries and non-beneficiaries: • Installed renewable energy capacity • Actual renewable energy production • Size and type of project (renewable energy technology)	*Beneficiaries* • Application forms for installed capacity by certified installer or seller (before the project starts) • Payment requests (after project completions)

	Beneficiaries and non-beneficiaries *For installed capacity* • Capacity certified by the installer (certification of installation) • Capacity certified by the seller (certification of operations manual) *For actual energy generation* • Energy sales to the grid for a year (for electricity generating devices such as photo voltaic or wind turbines) • Devices metering hours of operation • Quantity of fuel for thermal energy generation (e.g. pellet for biomass heating equipment) to be converted to hours of operation and actual energy generation • Other technology specific factors which relate operation with actual energy generated (e.g. a coefficient converting various capacities of photovoltaic technologies to yearly energy generation depending on climatic conditions) • Research or extension services coefficients that relate the time of operation of a renewable energy generating device with the climatic zone or other objective conditions (e.g. operation of a biogas generator depending on the size of the livestock) Other sources: • National/regional statistics • Renewable energy supply by type of energy from national energy regulating authorities • Research and extension "suggested" coefficients of use • Eurostat – energy statistics http://ec.europa.eu/eurostat/web/energy/data/database • Surveys/focus groups

3.4.2 Additional indicators

The evaluator should judge if the common indicators are sufficient to answer the evaluation question. If they are not, the evaluator should gather additional quantitative or qualitative information (e.g. through additional indicators). For example, the evaluator may combine T16 (Total investment in renewable energy production) and R15 (Renewable energy capacity created and energy generated) to produce an indicator of the value of investment per unit of installed capacity and of renewable energy generated in T.O.E by type of renewable energy generated.

3.5 Timing of data collection

The data on beneficiaries and non-beneficiaries should address two points in time to establish installed renewable energy capacity and renewable energy generation. One point before the implementation of the project and one point at least one year after the completion of the project. Collected data on beneficiaries for renewable energy capacity should be stored during the project's application (application form) implementation and completion (payment request). Additional data on completed projects (e.g. actual energy generated in a year for beneficiaries and capacity and energy generated for non-beneficiaries may be collected by evaluators during the evaluation).

3.6 Methodology to calculate complementary result indicator R15 - Renewable energy produced from supported projects (gross and net values)

Projects in this focus area may vary with regard to their size in terms of renewable energy capacity and generation, the type of renewable energy generated (wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases), beneficiary characteristics (e.g. a farm, firm or household) and other characteristics specific to the purpose of generating renewable energy (to use it on farm, to use it in the household, etc.).

When calculating the indicator, both primary and secondary contributions should be taken into consideration and estimated. The methodology proposed below can be applied separately to the projects or actions flagged as contributing to the focus area as primary and secondary contributions.

Total renewable energy capacity and generation after project implementation will arise from all sources of renewable energy generation for a farm, firm or household. Examples include photovoltaic systems for heating glasshouses, renewable biogas energy for cooling and heating systems on dairy farms, biofuel burners for heating buildings. The capacity and generated energy from the different sources are converted to T.O.E and added up to calculate the total renewable energy capacity and actual energy generation for a supported farm, firm or household. Coefficients for the conversion of renewable energy capacity and generation from various energy units to T.O.E are available by the International Energy Agency unit converter at: https://www.iea.org/reports/unit-converter-and-glossary

The following **steps** should then be used in the calculation of the indicator:

Step 1: Establish the samples

1a. Establish the Treatment Group of beneficiaries. Identify a sample of supported projects from the population of completed operations which have implemented renewable energy capacity/generation projects with RDP support.

1b. Establish the Control Group of non-beneficiaries. Identify a sample of farms, firms or households to serve as a control group from the population of farms, firms or households, which have not received RDP support. These farms, firms or households should have the same or very similar characteristics with the corresponding farms, firms and households in Step 1a.

Adopt smart sampling procedures: Before drawing a sample of supported projects, the evaluator should examine carefully the population of supported projects. Examine the projects in terms of technology or other characteristics to identify strata or homogenous groups of projects. For example, energy generation in households may be a homogenous group of projects. Stratified sampling always results in smaller samples and is usually less costly. In both groups of farms and firms (i.e. RDP beneficiaries and control group) renewable energy generation projects can be explicitly accounted for by inserting into the list of control variables a suitable categorical control variable (e.g. showing a farm's adoption of specific type of renewable energy generation = 0, 1, 2, 3).

Step 2: Implement the survey

2a. Collect the data on renewable energy generated in T.O.E for the beneficiaries. Data on installed capacity should be collected from the application, based on a certification issued by a certified installer or seller.

2b. Collect the data on installed capacity and on renewable energy generated in T.O.E if the control farms, firms or households have implemented renewable energy generation actions. Otherwise, their renewable energy capacity and energy generation is zero. The survey should also record other data that will facilitate successful matching.

Step 3: Estimate the gross value of the result indicator

Extrapolate (upscale) the sample results of Step 2a to the population of supported projects which have adopted renewable energy generation investments with RDP support. Calculate the aggregate energy capacity for all projects supported by the RDP and aggregate energy generation per year for all projects in T.O.E. These two estimates serve as the data for R15.

Step 4: Estimate the net value of the result indicator

Use a matching algorithm to match beneficiary farms, firms and households (cases) of the survey in Step 2a with corresponding non-beneficiaries in Step 2b. Estimation of the Average Treatment Effect on the Treated will be used to estimate the net values of supported projects. Follow Step 3 to calculate the net value of the indicator. In other words, extrapolate the net results of the beneficiaries' sample to the population of beneficiaries, calculate aggregate renewable energy capacity and generation and then calculate the indicator (Step 3).

Note: Netting out R15 may be very challenging because of the heterogeneity in supported projects. The evaluator may find it difficult to establish a counterfactual for such a wide range of activities. However, due to the long-term operations of renewable energy generation programmes in many Member States, there may already be evaluations netting out operations in many economic sectors and households. These evaluation results may be used for netting out the results of farms, firms or households supported by the RDP for renewable energy generation projects.

Primary contributions

If the number of projects and the evaluation resources allow, evaluators can survey all projects flagged as having primary contributions to the focus area to determine and calculate the needed information. Otherwise, evaluators will survey a sample of completed projects. The sample's estimates will be extrapolated to the population of projects flagged as having a primary contribution.

Secondary contributions

It is advisable to calculate secondary contributions separately. The secondary gross and net contributions are calculated based on the methodology described above with those beneficiaries which are implementing operations via different focus areas (e.g. 2A, 6A, 6B) yet contributing to FA 5C. This also includes those operations implemented via CLLD strategies, which show secondary contributions to renewable energy generation. If the number of projects and the evaluation resources allow, evaluators can survey all projects flagged as having secondary contributions to the focus area to determine and calculate the needed information. Otherwise, evaluators will survey a sample of completed operations flagged as having secondary contributions to the focus area. The sample's estimates will be extrapolated to the population of projects flagged as having secondary contributions. If the number of projects having secondary contributions are very small and do not justify a separate survey, the evaluator can pool together projects with primary and secondary contributions. In this case, the evaluator can insert a control dummy variable (0-1) to indicate primary or secondary contributions and still derive separate estimates for primary and secondary contributions.

Qualitative assessment

The qualitative assessment is done via surveys, interviews and focus groups, which can serve to contextualise renewable energy generation. Indicative themes may include:

- Identifying and describing all the factors that contribute to renewable energy generation.
- Identifying drivers for the production and utilisation of by-products, residues and wastes from agriculture and forestry and the use of non-food materials for the purpose of the bioeconomy.

- Examining the factors constraining adoption of renewable energy generation spanning from institutional and cultural to physical and organisational.
- Identifying the potential role of soft factors and of behavioural changes. Taking into account that many RDPs have employed trainings and advisory programmes for the FA 5C.

3.7 Principal challenges

- It is important that the evaluator is clear with regard to the concepts of 'renewable energy production' and 'renewable fuels'. For example, the production of biomass or of 'biofuels' is not 'energy production'. It is the production of a commodity. Energy is produced when biomass is burned. This requires the purchase and installation of a burner and of the system that heats and distributes heated water to, for example, the glasshouse. Of course, production of biomass supports answering the CEQ as it is promoting the bioeconomy and circular economy, but it does not count towards the calculation of this indicator.
- Most values for installed capacity are provided in KW and for electrical energy generated in KWh. The evaluator should consider energy capacity as the ability of the generator to produce energy if it operates for an hour. Capacity, for the purposes of this indicator is measured in energy units. Energy generated also is measured in energy units. Therefore, both energy capacity and energy generated can be converted to T.O.E, which is also an energy unit.
- Some projects may support thermal energy generators, such as, biomass and biogas generators. If the installed capacity and energy generated are provided as thermal energy, these should be converted to electrical energy before considered for the calculation of the indicator.
- In many Member States a range of programmes support the generation of renewables, which are also adopted by farms or farm and rural households. Such programmes should be ignored in this calculation of renewable energy production from RDP-supported projects. However, they may impact the RDP supported schemes and this should be noted by the evaluator.
- National programmes for the installation of renewable energy production may be long-standing. Such programmes may have already searched for the percentage of firms, farms or households that have adopted renewable production at a national or regional level. Such estimates may be taken into account when the evaluator draws the sample of non-beneficiaries to be used for netting out the indicator's value.
- Issues related to the drivers to adopt and install renewable energy production on farm may be raised by evaluators in addressing the common evaluation question. Such drivers directly affect the uptake of the scheme, its installed capacity and energy generation. For example, the provision of subsidised electricity to farms may be a significant barrier for the adoption of on farm renewable energy production. The cost of renewable energy production from certain activities may be high for small farms. For example, the production of biogas from livestock waste may be economically feasible for herd sizes above 200 milking cows. However, in regions dominated by small livestock farms this may require common actions among farms or synergies between producers of different wastes (e.g. municipal and agricultural). See a feasibility calculator for small scale biogas farms: http://www.bioenergyfarm.eu/tool/
- Increase in renewable energy generation may be thought of as energy not produced by fossil fuels. Therefore, the evaluator may, optionally, convert generated energy savings to GHG emission reductions. Emissions factors for the conversion of energy savings to GHG emission savings can be found in Annex 1 'Default Emission Factors' of 'The Covenant of Mayors for Climate and Energy Reporting Guidelines' at:

  https://www.covenantofmayors.eu/IMG/pdf/Reporting_Guidelines_Final_EN.pdf

3.8 How to use the indicator in the situation of lack of data

The evaluator may come across situations or cases where they are faced by serious or even extreme data constraints. In this section we list the most common cases and try to provide guidance on how to deal with each of them.

Small number of projects

The indicator measures the results of the RDP on renewable energy installation capacity and energy generation. Therefore, a small number of projects implies that the result will be small, but still measurable. The RDP may support very few renewable energy projects, but the ones it does could be quite large in scale. Nevertheless, even with a small sample the indicator's gross value can still be calculated. The evaluator should add up the few cases in the operations database and calculate the indicator's value on installed capacity. The results of the survey will assist the evaluator to calculate the value of the energy generated.

Information gaps in the operations database

Information gaps refer to the situation in which the two crucial pieces of information (i.e. installed capacity and energy generated are missing from the application). Filling information gaps on installed capacity is rather easy as this requires only the certified capacity from the installer or the seller. If the application has the information on energy capacity, but information on energy generation is not included, the evaluator can estimate it from alternative sources described in Section 3.4.1.

Lack of data for the creation of control groups

Sometimes control groups are difficult to establish because of the projects' variety and heterogeneity. Prior knowledge of the rates of adoption of renewable energy production among different beneficiaries (farms, firms, households) from national or regional renewable energy production surveys may be very useful. The evaluator may use these proportions to employ a targeted sampling of non-beneficiaries who have installed or not renewable energy production. This makes sampling a lot easier and less costly.

3.9 Examples

The EIP on 'Enhancing production and use of renewable energy on the farm' has many mini papers including examples on:

- advising and equipping farmers,
- biofuels in a short circular farm economy,
- business models and financial alternatives for on farm renewable energy projects,
- electromobility on farms,
- solar and wind combined with energy storage,
- flexible symbiosis for energy, food, feed and other biobased products,
- forests management biomass side streams,
- societal aspects of renewable energy on farm.

Further information on renewables can be found on the EIP website:

https://ec.europa.eu/eip/agriculture/en/focus-groups/enhancing-production-and-use-renewable-energy-farm

The EU's implementation plan for BioEnergy Farm project aimed at increasing the use and production of bioenergy and biofuels by farmers. The project's results and numerous examples are available at:

https://ec.europa.eu/energy/intelligent/projects/en/projects/bioenergy-farm

3.10 Further information

CMEF and other evaluation studies

- Impacts of renewable energy on European farmers available at:

  https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cmef/sustainability/impacts-renewable-energy-european-farmers_en

- European Parliament. 2016. Renewable energy in EU agriculture. European Parliamentary Research Service. Authors: Francesco Tropea with Pieter Devuyst, M available at:

  https://www.europarl.europa.eu/RegData/etudes/ATAG/2016/593546/EPRS_ATA(2016)593546_EN.pdf

EU Programmes (indicative list)

- AgroRES – Interreg Europe: Investing in Renewable Energies for Agriculture

  https://www.interregeurope.eu/AgroRES/

- BIOSURF: The BIOSURF project strives to increase the production and use of biomethane

  http://www.biosurf.eu/en_GB/

- BIOGAS3 - promotes the sustainable production of renewable energy from the biogas obtained of agricultural residues and food and beverage industry waste (agro-food waste) in small-scale concepts for energy self-sufficiency. http://www.biogas3.eu/eng/index.html

- Grass to Green Gas - The GR3 project aims to promote the use of grass and other herbaceous residues from landscape management as a resource for biogas in Belgium, Italy, Germany, Denmark and Portugal. http://www.izes.de/en/projekte/gr3-grass-green-gas

- FORBIO - A project that develops a methodology to assess the sustainable bioenergy production potential on available “underutilized lands” in Europe (contaminated, abandoned, marginal, fallow land etc.) at local, site-specific level. https://forbio-project.eu/

- GRASS2GRIT – LIFE Project.

  https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=6743&docType=pdf

- Bioenergy4Business - The H2020 project Bioenergy4Business (B4B) aims at supporting and promoting the (partial) substitution of fossil fuels (such as coal, oil, gas) used for heating with available bioenergy sources (such as by-products of the wood-based industry, forest biomass, pellets, straw and other agricultural biomass products).

  https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/bioenergy-market-uptake/bioenergy4business

Other publications and resources:

Held J., Mathiasson,A. and Nylander, A.,(2008) Biogas from manure and waste products - Swedish case studies

Van Foreest, F. (2012) Perspectives for Biogas in Europe, Oxford Institute for Energy Studies NG 70. Available at: https://www.oxfordenergy.org/wpcms/wp-content/uploads/2012/12/NG-70.pdf

USDA web page on energy at: https://www.nal.usda.gov/afsic/energy-1

Yuliana de Jesus Acosta-Silva and others. 2019. Applications of solar and wind renewable energy in agriculture: A review. Science Progress, Volume: 102 issue: 2, page(s): 127-140. Available at:

https://journals.sagepub.com/doi/full/10.1177/0036850419832696

Online unit converter: https://www.unitjuggler.com/convert-energy-from-kWh-to-toe.html

3.11 Answer to CEQ

The answer is provided following a critical analysis and discussion based on the calculated indicator values, the collected qualitative information or the qualitative assessment.

Conclusions	Recommendations
Main conclusions are stated here for the FA based on the evaluation findings.	Main recommendations linked to the conclusions are stated here for the FA.

4 FOCUS AREA 5D, EVALUATION QUESTION 14

4.1 Common evaluation question

To what extent have RDP interventions contributed to reducing GHG and ammonia emissions from agriculture?

4.2 List of measures contributing to the FA 5D

Primarily programmed measures/sub-m**easures** (proposed by EC)[11]:

- Measures and sub-measures of Art.[12] 15 Advisory services, farm management and farm relief services
- Measures and sub-measures of Art. 14 Knowledge transfer and information actions
- Measures and sub-measures of Art. 17 Investment in physical assets
- Measures and sub-measures of Art. 35 Co-operation
- Measures and sub-measures of Art. 28 Agri-environment-climate
- Measures and sub-measures of Art. 29 Organic farming

Examples of measures/sub-measures programmed under other FAs but potentially **showing secondary contributions** to this FA:

- All above measures if programmed under other FAs than FA 5C and contributing to the supply and use of renewable sources of energy, of by-products, wastes, residues and other non-food raw material for purposes of the bio-economy
- Measures and sub-measures of Art. 21 Investments in forest area development and improvement of the viability of forests (sub-measures 8.1, 8.5)
- Measures and sub-measures of Art. 30 Natura 2000 and water framework directive
- Measures and sub-measures of Art. 33 Animal welfare
- Measures and sub-measures of Art. 35 of Regulation (EU) No 1303/2013, Support for Leader local development

4.3 Consistency check between CEQ, judgement criteria and indicators

4.3.1 Judgement criteria

Judgement criteria (JC) proposed by the Working Document: Common Evaluation Questions for Rural Development Programmes 2014- 2020**:**

- GHG and ammonia emissions from agriculture have been reduced, due to RDP.

Note: Stakeholders in Member States might add/change judgement criteria in line with the intervention logic of the FA (selection and combination of measures).

4.3.2 Indicators

The following *common indicators should* be preliminary used to answer the CEQ:

Common result indicators

- R16/T17 - % of LU concerned by investments in livestock management in view of reducing GHG and/or ammonia emissions
- R17/T18 - % of agricultural land under management contracts targeting reduction of GHG and/or ammonia emissions

[11] WP: Guidelines for strategic programming for the period 2014-2020, European Commission, 04/03/2014, published on ECAS/circabc

[12] All articles mentioned in this section of each fiche for answering CEQ 1 – 18 are of Regulation (EU) No 1305/2013, unless it is stated otherwise in the text directly

- R18 - Reduced emissions of methane and nitrous oxide (complementary result indicator)
- R19 - Reduced ammonia emissions (complementary result indicator)

The following other *common indicators might* be used to answer the CEQ:

Common output indicators[13] *(*data collected via the operations database):

- O5 Total area (ha)
- O6 Physical area supported (ha)
- O8 Number of Livestock units (concerned by investment in livestock management in view of reducing GHG and ammonia emissions)

Common context indicators (data need and data sources are described in the Working document: Proposed list of common context indicators):

- CCI 18 Agriculture area
- CCI 21 Livestock units
- CCI 45 GHG emissions from agriculture

Qualitative indicators and information

If needed, qualitative information can be collected on the following:

- Typology of methods/approaches followed by farmers in order to reduce GHG and ammonia emissions. These may include the more efficient application of fertilisers, manure and sludge, better manure management at storage and transportation, compliance with the livestock capacity limits on grasslands, the management of crop residues, etc.
- Perception of beneficiaries on how RDP interventions have contributed to reduce GHG and ammonia emissions from agriculture and how synergies with soil protection are developed.
- Factors preventing or slowing down the adoption of GHG emissions practices (institutional, organisational, farm and farmer specific).

4.4 Data needs and data sources

4.4.1 Common indicators

R16/T17 - % of LU concerned by investments in livestock management in view of reducing GHG and/or ammonia emissions

Data needed	Data source
Beneficiaries • Livestock units concerned by investments in livestock management in view to reduce GHG and/or ammonia emissions as supported by RDP • Total number of livestock units	*Beneficiaries* • Application forms (before the project starts) • Payment requests (after project completions) • The above may contain basic activity data (livestock numbers by type and number of livestock concerned by investment) Eurostat - Farm Structure Survey http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics Total number of LU:

[13] WD: Data item list for Pillar II operation database and WD RD programming and target setting

	• Eurostat - Annual animal populations data at the national level for Bovine, Pig, Sheep, Goats, Poultry, Equidae • FSS for regional LU number at NUTS 2 level • National and regional statistics for the total LU number

R17/T18 - % of agricultural land under management contracts targeting reduction of GHG and/or ammonia emissions

Data needed	Data source
Beneficiaries • Agriculture land under management contracts targeting reduction of GHG and/or ammonia emissions • Total agriculture area – UAA (arable land, permanent grassland and meadows, permanent crops and respective carbon capture capacity)	*Beneficiaries* • Application forms (before the project starts) • Payment requests (after project completions) • The above may contain basic activity data (area of cultivations by type of crop and by type of management activity) Total agricultural area: • Share of main land types in utilised agricultural area • FSS for regional LU number at NUTS 2 level • National and regional statistics for total UAA

R18 - Reduced emissions of methane and nitrous oxide

Definition:

Reduced emissions of methane and nitrous oxide from agriculture in RDP supported projects measured in Tonnes of CO2 equivalent per year.

Methane and nitrous oxide are emitted in operations described by Tables 3A, 3B, 3C, 3D, 3E, 3F and 3J of the Common Report Format Tables of the National Inventory Report of each Member State.

The following table provides an overview of data requirements and data sources for the calculation of gross and net values of the complementary result indicator. Netting out of this indicator is not mandatory, but it is considered a good practice.

Data needed	Data source
Beneficiaries and non-beneficiaries: Activity data (indicative): • Livestock per type • Slurry and farmyard manure storage practices • Livestock diets • Excretion of C and N by livestock • Use of nitrogenous fertilisers and organic manure • Management of crop residues Management practices: • Manure management • Manure application on soils • Management of residues • Tillage • Other management practices Implied emission values/coefficients:	*Beneficiaries* • Application forms (before the project starts) • Payment requests (after project completions) • The above may contain basic activity data (area of cultivations by type of crop and by type of management activity, livestock number by type and description of management practices and obligations to be followed by beneficiaries from their participation to the programme) *Beneficiaries and non-beneficiaries* Survey of beneficiaries and non-beneficiaries to collect activity data and management practices: • FADN and the FSS may be a good base for building a survey as they both contain the area of cultivation by crop and livestock number by type. However, they do not record livestock and manure management practices and land and soil management data which should be acquired through the survey • Eurostat's analysis of methodologies for calculating GHG emissions on IPCC's guidelines may be useful to those planning the survey

• For enteric fermentation by type of livestock • For manure management by type of livestock • Indirect and direct nitrous oxide emissions for manure management • Area of rice cultivation by type of irrigation/watering practice • Inorganic and organic N fertilizers applied • Liming, urea and other carbon-containing fertilizers • Animal manure and sewage sludge applied to soils • Other organic fertilisers applied to soils • Urine and dung deposited by grazing animals • Crop residues management • Prescribed burning of forestland and grassland • Emission factors for field burning of residues by type of cultivation Other data to support matching: • Farm size and type • Location by temperate zone • Physical characteristics of the farm • Other characteristics, if available (days animals are outside, milk production per head, etc.)	(http://ec.europa.eu/eurostat/documents/3888793/5850629/KS-RA-11-024-EN.PDF) The evaluator may decide to use a GHG emissions calculator that follows IPCC guidelines and records both methane and nitrous oxide and work directly with activity data Implied emissions sources: • National methodologies for the estimation of the emissions in the different IPCC chapters (e.g. Tier 1 or 2, or various national average assumed values and adaptation to the methodology) is detailed in the National Inventory Report (NIR) and the latest Common Reporting Format (CRF) tables at: https://unfccc.int/ghg-inventories-annex-i-parties/2020 Implied emission coefficients for GHG emissions related to specific management practices, production technologies are not included in the NIR but can be searched at the IPCC's Emission Factor DataBase (EFDB) at: https://www.ipcc-nggip.iges.or.jp/EFDB/main.php • The evaluator can source information for implied emission coefficients of innovative activities not included in the NIR or the EFDB from relevant research projects and the academic literature. GHG emissions databases: • European Environment Agency (EEA) National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism at: https://unfccc.int/ghg-inventories-annex-i-parties/2020 or at https://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-16 or • UNCC - Greenhouse Gas Inventory Data - Detailed data by Party https://di.unfccc.int/detailed_data_by_party Methodology for reporting at: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Agriculture, Forestry and Other Land Use https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html

R19 - Reduced ammonia emissions

Definition:

Reduced emissions of ammonia from agriculture in RDP supported projects.

Ammonia, according to the National Emission Ceiling Directive (NECD) and the National emission inventories is emitted from the agricultural activities of Sector K AgriLivestock (NFR Code 3B) and Sector L_AgriOther (NFR Code 3D).

The following table provides an overview of data requirements and data sources for the calculation of gross and net values of the complementary result indicator. Netting out of this indicator is not mandatory, but it is considered a good practice.

Data needed	Data source
Beneficiaries and non-beneficiaries: Activity data (indicative): • Livestock per type	*Beneficiaries* • Application forms (before the project starts) • Payment requests (after project completions)

• Slurry and farmyard manure storage practices • Livestock diets • Excretion of C and N by livestock • Use of nitrogenous fertilisers and organic manure • Use of pesticides • Management of crop residues • On farm stored production • Off-farm storage, handling and transport of bulk agricultural products Management practices: • Manure management • Manure application on soils • Management of residues • Tillage • Other management practices • Storage of farm inputs and products Implied emission values/coefficients: • For enteric fermentation by type of livestock • For manure management by type of livestock • Indirect and direct nitrous oxide emissions for manure management • Area of rice cultivation by type of irrigation/watering practice • Inorganic and organic N fertilisers applied • Liming, urea and other carbon-containing fertilizers • Animal manure and sewage sludge applied to soils • Other organic fertilizers applied to soils • Urine and dung deposited by grazing animals • Crop residues management • Emission factors for field burning of residues by type of cultivation Other data to support matching: • Farm size and type • Location by temperate zone • Physical characteristics of the farm Other characteristics, if available (days animals are outside, milk production per head, etc.)	• The above may contain basic activity data (area of cultivations by type of crop and by type of management activity, livestock number by type and description of management practices and obligations to be followed by beneficiaries from their participation to the programme) *Beneficiaries and non-beneficiaries:* Survey of beneficiaries and non-beneficiaries to collect activity data and management practices: • FADN and the FSS may be a good base for building the survey as they both contain area of cultivation by crop, livestock number by type, but they do not record livestock and manure management practices, land and soil management data as well as data related to the on farm storage of inputs and products, which should be acquired through the survey • Eurostat's analysis of methodologies for calculating GHG and ammonia emissions on IPCC's guidelines may be useful to those planning the survey (http://ec.europa.eu/eurostat/documents/3888793/5850629/KS-RA-11-024-EN.PDF) Implied emissions sources: • National methodology for the estimation of ammonia emissions in sectors K and L is detailed in the Informative Inventory Report (IIR) and the latest Nomenclature for Reporting (NFR) Tables of each MS under the National Emission Ceilings (NEC) Directive emission inventory data • The evaluator can source information for implied emission coefficients of innovative activities not included in the IIR from the Member State's reporter, research projects and the academic literature. Ammonia emissions databases: • European Environment Agency (EEA) National Emission Ceilings (NEC) Directive emission inventory data https://www.eea.europa.eu/data-and-maps/data/national-emission-ceilings-nec-directive-inventory-17 or • Convention on Long Range Transboundary Air Pollution Ammonia emissions: officially reported emissions data https://www.ceip.at/webdab-emission-database/reported-emissiondata • Convention on Long Range Transboundary Air Pollution Ammonia emissions: Emissions as used in the European Monitoring and Evaluation Programme (EMEP) models (gridded data) https://www.ceip.at/webdab-emission-database/emissions-as-used-in-emep-models • Convention on Long Range Transboundary Air Pollution Ammonia emissions: Reported activity data to the EMEP programme via the UNECE Secretariat https://www.ceip.at/webdab-emission-database/officially-reported-activity-data Methodology for reporting: • Standard emission factors are obtained from guidance sources such as the EMEP/EEA Air Pollutant Emission Inventory Guidebook specifically for agriculture at EEA's website: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/4-agriculture

	• National methodology for the estimation of emission for each one of the NECD sectors is detailed in the National "Informative Inventory Report" as above.

I.07 – Emissions from agriculture

Guidelines to estimate I.07 available in 'Guidelines. Assessing RDP achievements and impacts in 2019'[14] (See Chapter 2.3 in Part II (page 42) and Chapter 4.2 in Part IV (page 19)).

4.4.2 Additional indicators

The evaluator should judge if the common indicators are sufficient to answer the evaluation question. If it is not, the evaluator should gather additional quantitative or qualitative information, e.g. through additional indicators.

4.5 Timing of data collection

The data on beneficiaries and non-beneficiaries should address two points in time, before and after the completion of the activity. Collected data on beneficiaries should be stored during the project's application (application form), implementation and completion (payment request). Additional data on completed projects from beneficiaries and data on non-beneficiaries may be collected by evaluators during the evaluation.

4.6 Methodology to calculate gross and net complementary result indicators R18 and R19 - Reduced emissions of methane and nitrous oxide (R18) and ammonia (R19)

Projects in this focus area may vary in size, type of activity (livestock and manure management, reduction of fertilisers and soil conservation management, etc.) and other characteristics specific to the farm.

When calculating the indicator, both primary and secondary contributions should be taken into consideration and estimated. The methodology proposed below can be applied separately to the projects or actions flagged as contributing to the focus area as primary and secondary contributions.

Total GHG and ammonia emissions before and after project implementation will arise from all sources of IPCC Tables for GHG and NECD sectors for ammonia for a farm. Examples include the change in manure management storage and application, reductions in N fertilizer applied to soils, management of crop residues. GHGs for methane and nitrous oxide are converted to tones of CO2 equivalent. Ammonia reduction is recorded in tones.

In IPPC terminology (National Inventory Reports and associated Tables), methane is emitted from the following activities:

- Enteric fermentation (Table 3A)
- Manure management (Table 3B)
- Rice cultivation (Table 3C)
- Field burning of agricultural residues (Table 3F)
- Other activities (Table 3J)

[14] European Commission – Directorate-General for Agriculture and Rural Development – Unit C.4 (2018): Guidelines. Assessing RDP achievements and impacts in 2019. Brussels.

Nitrous oxide is emitted from:

- Manure management (Table 3B)
- Agricultural soils (Table 3D)
- Field burning of agricultural residues (Table 3F)
- Other activities (Table 3J)

According to the terminology in the National Emission Ceiling Directive (NECD) and the National emission inventories Ammonia is emitted from the following agricultural activities:

- Sector K AgriLivestock (NFR Code 3B) that cover manure managements separately for Dairy cattle, Non-dairy cattle, Sheep, Swine, Buffalo, Goats, Horses, Mules and asses, Laying hens, Broilers, Turkeys, Other poultry, Other animals).
- Sector L_AgriOther (NFR Code 3D) that covers Inorganic N-fertilizers (includes also urea application), Animal manure applied to soils, sewage sludge applied to soils, other organic fertilisers applied to soils including compost, urine and dung deposited by grazing animals, crop residues applied to soils, indirect emissions from managed soils, farm-level agricultural operations including storage, handling and transport of agricultural products, off-farm storage, handling and transport of bulk agricultural products, cultivated crops, use of pesticides, field burning of agricultural residues, other agriculture or agriculture related sources specified in the national Informative Inventory Report (IIR).

The following **steps** should then be used in the calculation of the indicator:

Step 1: Establish the samples

1a. Establish the treatment group of beneficiaries. Identify a sampling procedure (e.g. smart sampling procedure) and a sample of farms from the population of completed operations which have implemented GHG emissions and ammonia reductions with RDP support.

1b. Establish the control group of non-beneficiaries. Identify a sample of farms (e.g. via smart sampling procedure) to serve as a control group from the population of farms which have not implemented GHG and ammonia reductions projects with RDP support. These farms should have the same or very similar characteristics with the farms and firms in Step 1a.

Smart sampling procedures: Before drawing a sample of supported projects, the evaluator should examine carefully the population of all supported projects. Examine the projects in terms of technology or other characteristics to identify strata or homogenous groups of projects. For example, manure management may be a homogenous group of projects. Stratified sampling always results in smaller samples and is therefore less costly. In both groups of farms (i.e. RDP beneficiaries and non-beneficiaries) GHG and ammonia emissions reduction projects can be explicitly accounted for by inserting into the list of control variables a suitable categorical control variable (e.g. showing a farm's adoption of specific type of GHG and ammonia emission reduction = 0, 1, 2, 3).

Step 2: Implement the survey

2a. Collect the activity data and convert them to ammonia emissions before the start of the project (baseline) and at least one year after the operation has been completed. Data may be sourced from application forms especially when these include a technical/business plan. The survey should also record other data that will facilitate successful matching.

2b. Collect the activity data and convert them to GHG and ammonia emissions for the non-beneficiaries (farms in Step 1b) for both the before implementation of the operations and at a second point in time that is the same as for farms in Step 2a. The survey should also record other data that will facilitate successful matching.

Note: The evaluator must use NIR or IIR implied coefficients or an IPCC GHG calculator for all farms beneficiaries and non-beneficiaries alike. The survey of supported farms in Step 2a (beneficiaries) and of non-supported farms (non-beneficiaries) in Step 2b should also record other data that will facilitate successful matching between beneficiaries and non-beneficiaries.

Step 3: Estimate the gross value of the result indicators

3a. Extrapolate (upscale) the sample results of Step 2a to the population of farms which have adopted GHG and ammonia reduction measures with RDP support. Calculate the aggregate GHG and ammonia emissions for all projects and for before (baseline) and after (at least 1 year after operation is completed) the implementation of projects.

3b. Calculate aggregate GHG and ammonia emissions before and after by adding the extrapolated results of Step 3a above. Calculate the indicators R18 and R19 as a difference (change) between emissions before minus emissions after.

Step 4: Estimate the net value of the result indicators

Use a matching algorithm to match beneficiary farms of the survey in Step 2a with non-beneficiary farms of the survey in Step 2b. Matching should also take into account the year of observation after the project's completion. Estimation of the Average Treatment Effect on the Treated will be used to estimate the net values of supported projects. Follow Step 3 to calculate the net value of the indicator. In other words, calculate aggregate net emissions of GHG and ammonia before and after (Step 3a) and then calculate the indicators (Step 3b).

Note: Netting out R18 and R19 may be challenging not only because of the heterogeneity in supported projects, but also, because data are required for two points in time (i.e. before and after project implementation). The evaluator may find it difficult to establish a counterfactual with farm managers able to record data for the before. This is why the use of FADN and/or FSS returns are highly advisable as a base for collecting activity data and the use of a survey to collect additional management data of farm practices, which, for farmers, is easier to remember.

Primary contributions

If the number of supported projects and the evaluation resources allow for it, evaluators can survey all projects (a census) flagged as primary contributors to the focus area to determine and calculate the needed information on GHG and ammonia emissions. Otherwise, evaluators will survey a sample of completed operations. The sample's estimates will be extrapolated to the population of RDP projects flagged as having a primary contribution to GHG emissions and ammonia reductions.

Secondary contributions

It is advisable to calculate secondary contributions separately. The secondary gross and net contributions are calculated based on the methodology described above with those beneficiaries which are implementing operations via different focus areas (e.g. 2A, 4A, 4B, 4C) yet contributing to FA 5D. This also includes those operations implemented via CLLD strategies, which show secondary contributions to the reducing ammonia emissions. If the number of projects and the evaluation resources allow, evaluators can survey all projects flagged as secondary contributions to the focus area to determine and calculate the needed information. Otherwise, evaluators will survey a sample of completed operations flagged as having secondary contributions to the focus area. The sample's estimates will be extrapolated to the population of projects flagged as having a secondary contribution. If the number of projects having a secondary contribution is very small to justify a separate survey, the evaluator can pool together projects with primary and secondary contributions. In this case, the

evaluator can insert a control dummy variable (0-1) to indicate primary or secondary contributions and still derive separate estimates for primary and secondary contributions.

Qualitative assessment

The qualitative assessment is done via surveys, interviews and focus groups, which can serve to contextualise the GHG and ammonia reductions. Indicative themes may include:

- Identifying and describing all the factors that contribute to GHG and ammonia reductions.
- Identifying the potential role of soft factors and of behavioural changes. Taking into account that many RDPs have used trainings and advisory programmes for the FA 5D.

4.7 Principal challenges

- The calculation of GHG and ammonia emissions for each farm may be challenging, cumbersome and time consuming. It is important that the evaluator establishes implied emission coefficients for all activity data following the NIR and IIR when these are provided. RDP evaluation should not contradict with national inventories. In exceptional cases and when RDPs support an innovative activity that is not included in the emissions coefficients, the evaluator proposes a coefficient based on coefficient databases, academic and research resources. Almost all GHG and ammonia reductions will result from changes in activity data and very rarely from the need to apply a new implied emission coefficient. Care should be taken for RDP projects that affect two or more activities at the same time.
    - For example, a project on manure storage may also imply a new manure application method. If manure is stored in liquid form then it may be applied by injections and vice versa, if injections are supported, manure should be stored in a specific form. This affects both Table 3B (manure management) for methane emissions and Table 3D (agricultural soils) for methane and nitrous oxide emissions. And respectively for ammonia emissions.
- Since recording GHG emissions is time consuming, it is advisable that the evaluator substitutes as much effort in collecting raw data with existing databases.
    - For example, beneficiaries and non-beneficiaries may be part of the FADN or the FSS. Both record activity data and there will only be a need to collect additional data on the management of farm practices. This will reduce the amount of work and collected data will be more detailed and reliable.
- Setting up the counterfactual may also be challenging. There are a lot of studies at the European level which evaluate the impacts of GHG emission measures based on FADN data. These studies have already accumulated a lot of experience in using data recorded in various FADN sections and to even deducing farm management practices from that data. A selection of such works is cited in Section 4.11.

4.8 How to use the indicators in the situation of a lack of data

The evaluator may come across situations or cases where they are faced by serious or even extreme data constraints. In this section we list the most common cases and try to provide guidance on how to deal with each of them.

Small number of projects

The indicator measures the result of the RDP on GHG and ammonia emissions. Therefore, a small number of projects implies that the result will be small, but still measurable. Nevertheless, even with a small sample the indicator's gross value can still be calculated. The evaluator should add up the few cases in the operations database and calculate the indicator's results. The low number of projects may be an issue when the indicators are netted out. Netting out involves the comparison between matched

pairs of beneficiaries and non-beneficiaries. As a rule of thumb, the evaluator should not carry out such a comparison (or any statistical comparison) with less than 20 matched projects (cases). One remedy may be to try and increase the number of projects by pooling together projects flagged as having primary and secondary contribution (i.e. do not use a dummy differentiating between primary and secondary contributions). If the overall number of projects (primary and secondary contribution) is still too small, then the evaluator can calculate only the indicator's gross effects.

Information gaps in the operations database

Information gaps refer to the situation in which information for the estimation of GHG and ammonia emissions are missing from the application or the plan submitted by the farmer.

Filling information gaps on GHG and ammonia emissions activity data

If the application or the environmental plan submitted by the farms (if requested) has the technical information on GHG and ammonia reductions, but actual activity data is missing (e.g. number of livestock units on which the project applies, or number of hectares) the evaluator should collect them with a survey.

Filling information gaps on the 'before' situation

Sometimes the 'before' situation of a project is filled only during the evaluation (i.e. after some years have passed). This may be especially true for the non-beneficiaries. This creates a problem because information is collected after the fact. Farmers may not be able to remember or recall it. The evaluator can assist the farmer by providing information from sources that keep the 'history' of the farm, such as, the IACS, the FADN returns. The farm also maintains 'historical' data in the sense of purchased fertiliser and pesticides kept on farm for cross-compliance inspections.

Lack of data for the creation of control groups

Sometimes control groups are established during the evaluation. As such, by default, the information before is missing. For this reason, it is advisable to source information from a database that has records of the farm at the baseline and during the RDP's operation period. FADN may serve this mission and offer activity data on livestock numbers and cultivated areas for estimating GHG and ammonia emissions.

4.9 Examples for R18

Ireland

Ireland's Rural Development Programme 2014-2020

https://www.agriculture.gov.ie/media/migration/ruralenvironment/ruraldevelopment/ruraldevelopmentprogramme2014-2020/2017EvaluationofIrelandsRDP180917.pdf

The Green Low-Carbon Agri-Environment Scheme (GLAS) was built on the success of REPS (Rural Environment Protection Scheme) and AEOS (Agri-Environment Options Scheme) which encouraged farmers to farm in a more environmentally and climate friendly manner. GLAS promotes agricultural actions which introduce or continue to apply agricultural production methods that aim to address the issues of climate change mitigation, water quality and the preservation of priority habitats and species. Nitrous oxide and methane emissions were calculated according to the methodology of the Intergovernmental Panel on Climate Change (IPCC, 2006) wherein data on livestock numbers, crop areas, and the nitrogen contents of fertiliser and manure are multiplied by agreed emission factors, using data on productivity and manure management. This approach estimated emissions associated with agricultural production activity within the farm gate. Agricultural emissions categories included methane (CH4) emissions from enteric fermentation by ruminant livestock, methane and nitrous oxide

(N2O) emissions from the production and storage of livestock manures and nitrous oxide emissions resulting from the application of manures and synthetic fertilisers to agricultural soils. All converted to Kg of CO2 equivalent.

The 2017 counterfactual analysis used the Teagasc National Farm Survey (NFS) to establish baseline data on the GLAS beneficiaries and non-beneficiaries. The National Farm Survey (NFS) is conducted by Teagasc on an annual basis and is a random, nationally representative sample, of over 1,000 farms. 359 farms within Teagasc's NFS sample were matched as GLAS farms and represent over 37,000 farms or 44% of the total population of farms within the NFS. 540 farms within Teagasc's NFS sample were matched as non-beneficiaries (non GLAS participants) farms and represent over 47,000 farms or 56% of the total population of farms within the NFS. The 2017 analysis showed that the average Greenhouse Gas Emissions (GHG) per hectare in 2015 were lower for farms participating in GLAS (average of 3.9 Kg of CO2 equivalent per ha) compared to those outside the scheme (average of 5.2 Kg of CO2 equivalent per ha).

4.10 Examples for R19

Ireland

Ireland's Rural Development Programme 2014-2020

https://enrd.ec.europa.eu/evaluation/publications/baseline-analysis-actions-under-glas-green-low-carbon-agri-environment_en and

https://enrd.ec.europa.eu/evaluation/publications/model-evaluation-glas-green-low-carbon-agri-environment-scheme-report_pl

Example advocates an integrated approach in reducing ammonia emissions from agriculture (mainly through a new integrated agri-environment scheme "GLAS", that is expected to recruit 50,000 participants). Following actions are expected to help in reducing ammonia emissions:

- A greater uptake of low emission slurry application technologies (e.g. trailing shoe);
- Improvement of fertiliser/manure efficiency, including use of new fertiliser additives/inhibitors and the increased use of clover offering possibility to significantly reduce nitrogen fertiliser usage;
- Introduction of farm nitrogen budgets to improve the efficiency of its use and reduce nitrogen losses;
- Introduction of new quantified targets, such as LU affected by ammonia reduction supports;
- Cattle spending more time grazing outdoors;
- Improved breeding/genetic improvements in livestock, feeding and other management practices;
- Knowledge Transfer Groups stimulating farmers' enrolment in the Carbon Navigator – a tool allowing farmers to understand how their farms produce greenhouse gas – and to identify mitigation capacity and set targets and a pathway to reduce emissions.

Finland

http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160629/MMM_1b_2018.pdf

Finnish measures for reducing ammonia emissions from agriculture include:

- Well-balanced use of nutrients, including specifications on manure utilisation injecting slurry into the soil;
- Investment support for covering solid manure, slurry and liquid manure storage facilities and for cooling manure channels;
- Measures in which the use of (inorganic) nitrogen is restricted or eliminated – such as organic farming;

- Investments in more effective handing, storage and application of manure, incl. building of remote storages and purchasing of manure processing systems;
- Compulsory covering of new manure storage facilities;
- Stricter requirements for large manure storage facilities;
- Stricter rules for storing manure on heaps, manure spreading periods and incorporation of manure when applied on field;
- Financing studies on improving knowledge on ammonia behaviour and reduction measures;

Survey on manure management practices revealing data on manure management life cycle (production, storage, transportation and application) resulting in setting-up database on manure management practices. Data is used to feed an ammonia emission modelling and studies on emission reduction potentials and cost effectiveness of the reduction measures applied.

4.11 Further information

CMEF External evaluation studies and EIP

Evaluation study of the impact of the CAP on climate change and greenhouse gas emissions. 2018.

https://op.europa.eu/en/publication-detail/-/publication/29eee93e-9ed0-11e9-9d01-01aa75ed71a1

Evaluation study of the payment for agricultural practices beneficial for the climate and the environment. 2017.

https://op.europa.eu/en/publication-detail/-/publication/598b81ff-dfbc-11e7-9749-01aa75ed71a1

An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA 2). 2016.

https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/economic-assessment-ghg-mitigation-policy-options-eu-agriculture-ecampa-2

An economic assessment of GHG mitigation policy options for EU agriculture. 2015.

https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/economic-assessment-ghg-mitigation-policy-options-eu-agriculture

Emissions from agriculture and their control potentials. 2012.

https://ec.europa.eu/environment/air/pdf/TSAP-AGRI-20121129_v21.pdf

Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS). 2010.

https://op.europa.eu/en/publication-detail/-/publication/38abd8e0-9fe1-4870-81da-2455f9fd75ad

Adaptation to Climate Change in the Agricultural Sector. 2007.

https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/ext-study-adapt-climate-change-full-text_2007_en.pdf

EIP-AGRI, agriculture and climate change

https://ec.europa.eu/eip/agriculture/en/news/eip-agri-agriculture-and-climate-change

EU Projects

OSCAR – Optimal Strategies for Climate change Action in Rural areas

http://sitem.herts.ac.uk/aeru/oscar/

CIRCASA - Coordination of International Research Cooperation on Soil Carbon Sequestration in Agriculture https://www.circasa-project.eu/

Nutri2Cycle - Nurturing the Circular Economy https://www.nutri2cycle.eu/

Software and GHG calculators (Indicative):

CoolFarm Tool at: https://coolfarmtool.org/

GAINS online at: https://gains.iiasa.ac.at/models/index.html

GNOC (global nitrous calculator) at: http://gnoc.jrc.ec.europa.eu/

GHG emissions case studies using FADN data

Baldoni, E., Coderoni, S. and Esposti, R. 2017. The productivity and environment nexus with farm-level data. The Case of Carbon Footprint in Lombardy FADN farms. Bio-based and Applied Economics, 6(2), pp. 119-137

Coderoni, S. and Bonati, G. 2013. Impronta Carbonica Aziende Agricole Italiane. INEA.

Coderoni, S. and Esposti, R. 2015. The evolution of agricultural GHG emissions in Italy and the role of the CAP A farm-level assessment. 29th International Conference of Agricultural Economists. Universita Degli Studi Di Milano, August 8-14.

Coderoni, S., Valli, L. and Canavari, M. 2015. Climate Change Mitigation Options in the Italian Livestock Sector. EuroChoices, 14(1), pp. 17-24.

Coderoni, S. and Esposti, R. 2018. CAP payments and agricultural GHG emissions in Italy. A farm-level assessment. Science of The Total Environment, 627, pp. 427-437.

Dabkienė, V. 2017. A Comparative Analysis of On-Farm Greenhouse Gas Emissions from Family Farms in Lithuania. Research for Rural Development, 2, pp. 225-232.

Dillon, J.E., Hennessy, T., Buckley, C., Donnellan, T., Hanrahan, K., Moran, B. and Ryan, M. 2016. Measuring progress in agricultural sustainability to support policy-making. International Journal of Agricultural Sustainability, 14(1), pp. 31 – 44.

Gooday, R. 2018. Evaluation of RDP Impacts on Emissions from Agriculture in Ireland. Presentation to the Good Practice Workshop organised by the Evaluation Helpdesk, “Approaches to assess environmental RDP impacts in 2019”, took place on 12-13 December, Bratislava, Slovakia.

Kelly, E., Latruffe, L., Desjeuxb, Y., Ryanc, M., Uthesd, S., Diazabakanab, A., Dillonc, E. and Finn, J. 2018. Sustainability indicators for improved assessment of the effects of agricultural policy across the EU: Is FADN the answer? Ecological Indicators, 89, pp. 903-991.

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4.12 Answer to CEQ

The answer is provided following a critical analysis and discussion based on the calculated indicator values, the collected qualitative information or on the qualitative assessment.

Conclusions	Recommendations
Main conclusions are stated here for the FA based on the evaluation findings.	Main recommendations linked to the conclusions are stated here for the FA.

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