The Livestock Institute (IDELE) and INRAE (UMR SAS) contributions to the CCCfarming project

- Final Report -

Project: Climate Care Cattle Farming Systems - CCCfarming

Authors: Xavier Vergé[1], Paul Robin[2] and Caroline Evrat-Georgel[1]

Affiliations: [1] Institut de l'Élevage (IDELE), France
[2] INRAE (UMR SAS)

Date: November 2023

This study was supported by:

- *"ERA-Nets SusAn-ICT-Agri-ERAGAS" project "Climate Care Cattle Farming Systems", ID: 3274.*
- *Agence Nationale de la Recherche (ANR): Projet n° ANR-19-SUGA-0004-05*

Table of Content

Figures

Table

Introduction

The main objective of the Climate Care Cattle Farming Systems (CCCFarming) was to develop cattle farming systems having as low greenhouse gases (GHG) and ammonia (NH_3) emissions as possible but with no detrimental consequences on social and production aspects.
To do so several actions have been carried out under the six work packages (WP) presented in the Figure 1. The Livestock Insitute (Institut de l'Elevage – IDELE) has been involved in the 1, 2, 3 and 5 work packages and was leading the task WP1.5 « Perform farm emission measurements ».

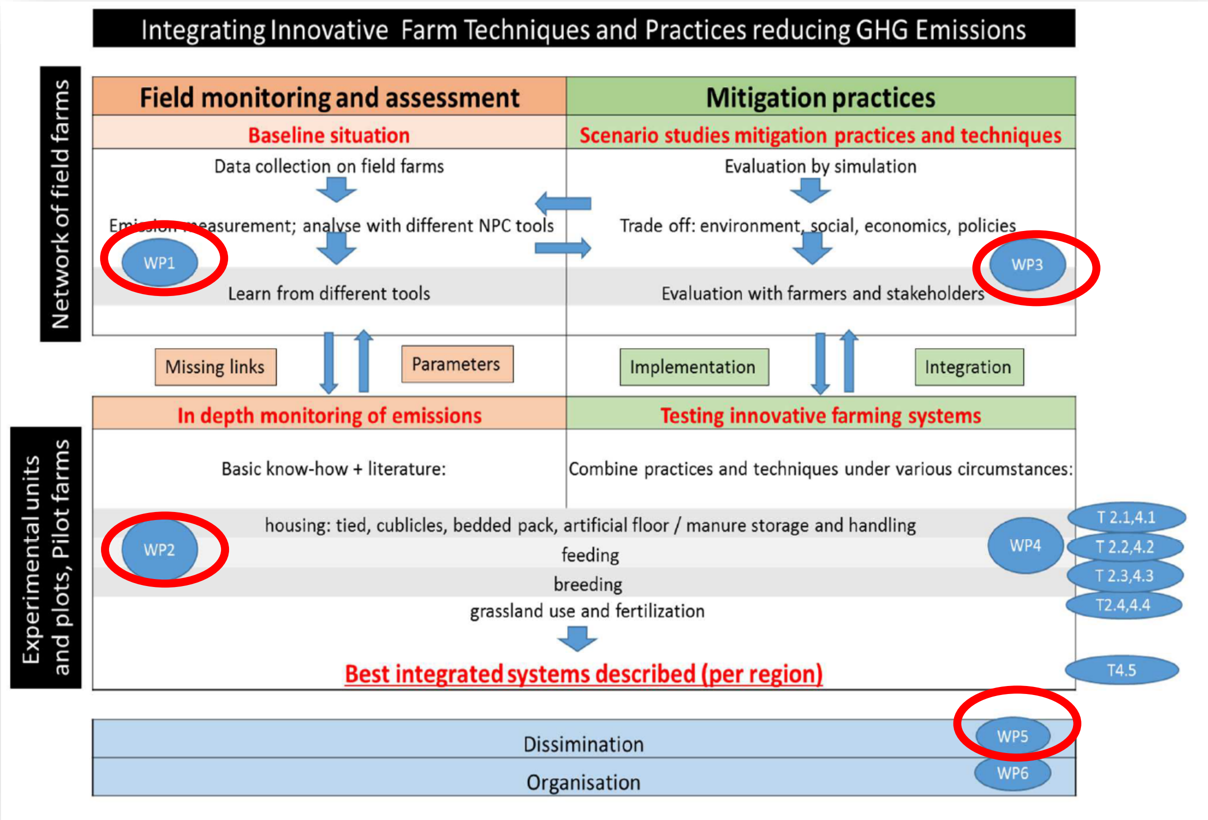


Figure 1 : Overview and relationships between work packages in the CCCFarming project and IDELE involment (red circles)

In this report, it has been decided to present first the work performed under the task where we (the Livestock Institute) were acting as partner (« Part I : CCCFarming Partnership ») and then the tasks carried out as leader (« Part II : On-farm emission measurements »). In the first part, « partnership » only IDELE was involved. In the second part we work jointly with INRAE UMR SAS.

Some of the WP were design to « inventory the use of measurement and sensor equipment and methods (WP1.2) » or dealt with « collecting general farm data (WP1.3) and « studying and monitoring innovative housing systems (WP2.1.1) ».
Since our specific task (WP1.5) involved the development and use of a measurement method based on « sensor equipment » and « general farm data » including farms having « innovative housing

systems », all of these tasks (WP1.2, WP1.3 and WP2.1.1) will be then included in the second section (Part II) and not the first and we will mention, whenever necessary, the link with the other WP involved.

1. Part I : CCCFarming partnership – (IDELE)

1.1. WP1: Field monitoring and assessment

This first work package gathers several tasks where IDELE was actively involved. We provided information and documents for all the following tasks in this WP:

- WP1.1: Selection and organization of field study farms
- WP1.2: Inventory and study of use ICT - measurement and sensor equipment and methods to deal with emissions
- WP1.3: Collect general farm data
- WP1.4: Apply NPC calculation tool
- WP1.5: Perform farm emission measurements
- WP1.6: Interact with farmers, consultants and stakeholders

As mentioned in the "Introduction", our participation in the tasks WP1.2 and WP1.3 will be mentioned under "Part II: On-farm emissions measurements" when the WP1.5 led by the Livestock Institute will be presented.

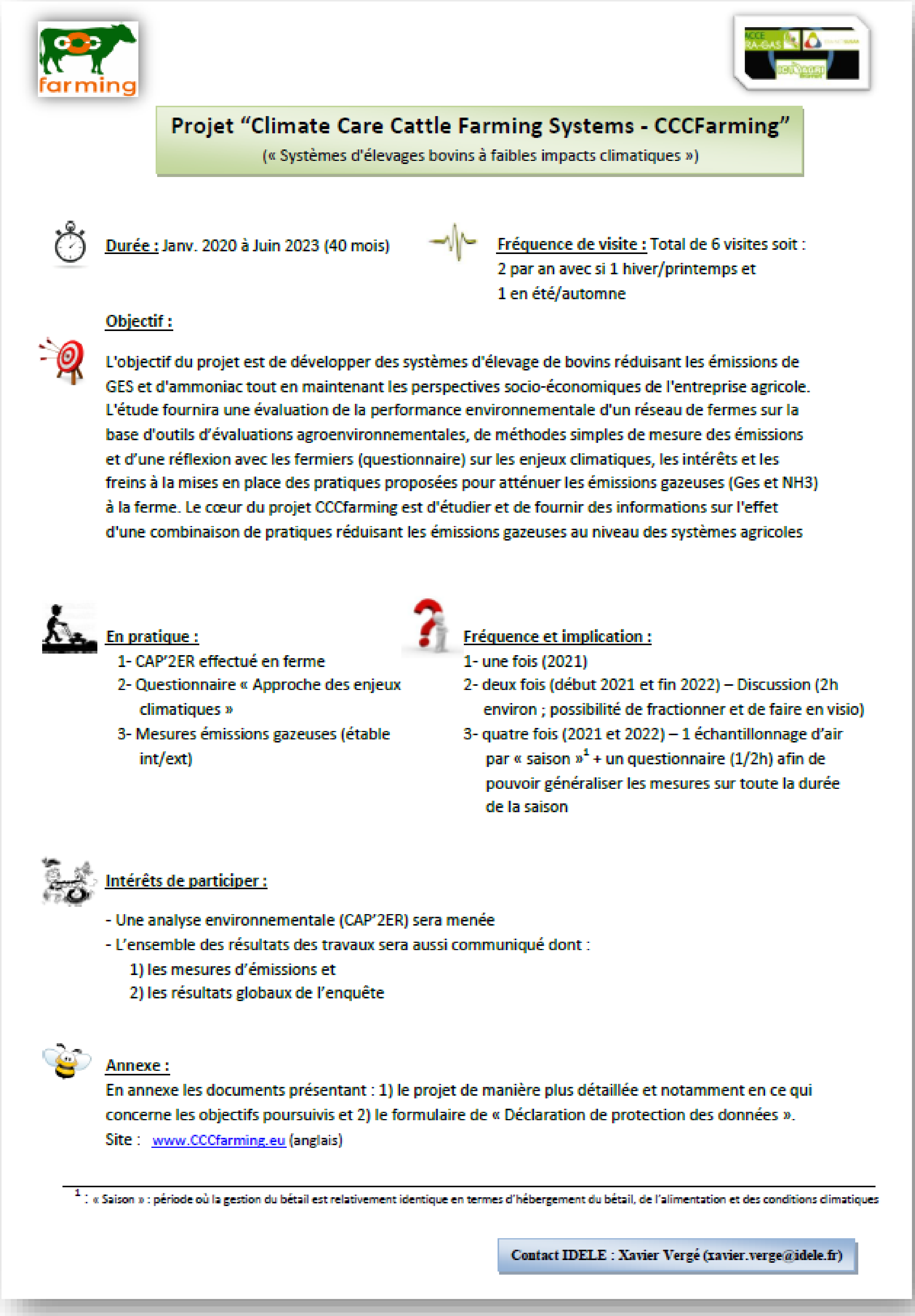
1.2. WP1.1: Selection and organization of field study farms

Eight dairy farms have been selected in France to support all studies under the CCCFarming program and especially the two on-farm work which are the gas measurements (WP 1.5) and the social questionnaire (WP 1.6).

- For farm selection the following flyer (Figure 2) has been developed specifically for France and sent to a large panel of farms. It completes the project presentation (cf. Annexes – "1. Farm selection") and gives an overview of the on-farm studies.

- The location and the ID number for each of the eight farms are presented Figure 3.

- Each of them has been described following a specific template. It is one page description gathering the main farm information. An example is presented Figure 4 and the eight farm factsheets are given in the annexes ("2. Farm factsheets")



Projet "Climate Care Cattle Farming Systems - CCCFarming"

(« Systèmes d'élevages bovins à faibles impacts climatiques »)

Durée : Janv. 2020 à Juin 2023 (40 mois)

Fréquence de visite : Total de 6 visites soit :
2 par an avec si 1 hiver/printemps et
1 en été/automne

Objectif :

L'objectif du projet est de développer des systèmes d'élevage de bovins réduisant les émissions de GES et d'ammoniac tout en maintenant les perspectives socio-économiques de l'entreprise agricole. L'étude fournira une évaluation de la performance environnementale d'un réseau de fermes sur la base d'outils d'évaluations agroenvironnementales, de méthodes simples de mesure des émissions et d'une réflexion avec les fermiers (questionnaire) sur les enjeux climatiques, les intérêts et les freins à la mises en place des pratiques proposées pour atténuer les émissions gazeuses (Ges et NH3) à la ferme. Le cœur du projet CCCfarming est d'étudier et de fournir des informations sur l'effet d'une combinaison de pratiques réduisant les émissions gazeuses au niveau des systèmes agricoles

En pratique :

1- CAP'2ER effectué en ferme
2- Questionnaire « Approche des enjeux climatiques »
3- Mesures émissions gazeuses (étable int/ext)

Fréquence et implication :

1- une fois (2021)
2- deux fois (début 2021 et fin 2022) – Discussion (2h environ ; possibilité de fractionner et de faire en visio)
3- quatre fois (2021 et 2022) – 1 échantillonnage d'air par « saison »[1] + un questionnaire (1/2h) afin de pouvoir généraliser les mesures sur toute la durée de la saison

Intérêts de participer :

- Une analyse environnementale (CAP'2ER) sera menée
- L'ensemble des résultats des travaux sera aussi communiqué dont :
  1) les mesures d'émissions et
  2) les résultats globaux de l'enquête

Annexe :

En annexe les documents présentant : 1) le projet de manière plus détaillée et notamment en ce qui concerne les objectifs poursuivis et 2) le formulaire de « Déclaration de protection des données ».
Site : www.CCCfarming.eu (anglais)

[1] : « Saison » : période où la gestion du bétail est relativement identique en termes d'hébergement du bétail, de l'alimentation et des conditions climatiques

Contact IDELE : Xavier Vergé (xavier.verge@idele.fr)

Figure 2 : Climate Care Cattle Farming (CCCFarming) project – French Flyer

The heights selected farms are presented in the following map (Figure 3):

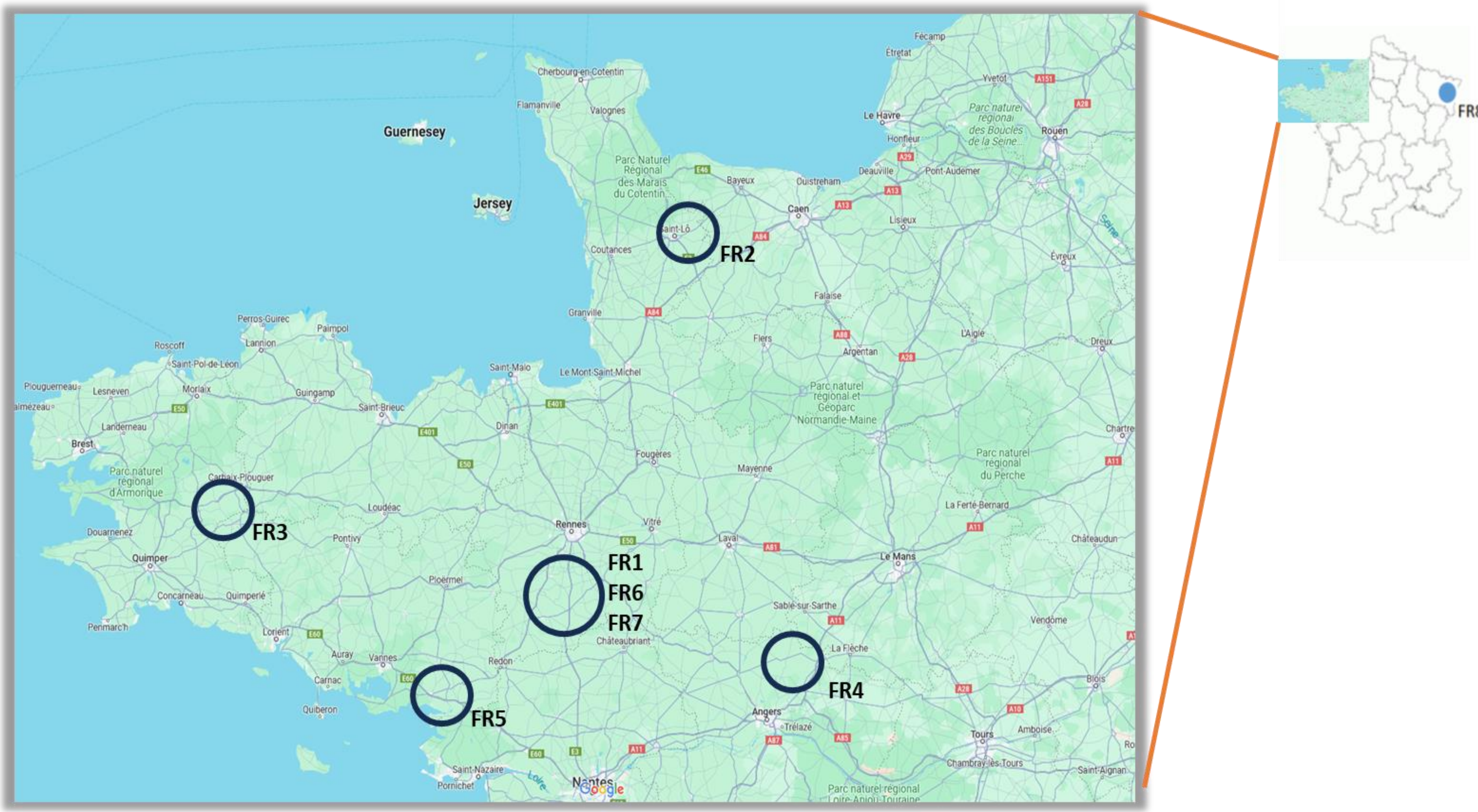


Figure 3 : Farm ID and locations in France

Farm ID : FR4

This farm created in 1974 is located on a sandy clay soil in the Pays de la Loire County, near from Angers. The farm carries out studies on animal feeding and fodder crops adapted to water shortages but also on animal welfare and production costs.

Landscape :	Lowland
Soil type :	mostly sandy soil
Farming system :	Conventional
Total lands :	
- Arable lands :	144 ha : 50 ha of irrigated sillage maize (15-16 T DM/ha) – 50 ha of grain maize (90 q / ha), 12 ha of triticale (55 q / ha), 29 ha of temporary grasslands and 3 ha of sorghum.
- Permanent grassland :	44 ha
- Other land types :	No
Dairy cow housing :	Cubicles
Bedding material :	Straw
Floor in walking alley :	Grooved concrete
Dairy herd :	137 dairy cows + 124 heifers
Breed :	Holstein
Herd production level :	9 400 l/cow/year
Milking system :	Rotary Milking parlour (28 places)
Feeding system :	TMR and individual feeding system (84 weighing troughs)
Dairy herd grazing :	No for dairy cows (only heifers on permanent grasslands)
Manure type :	Solid manure and slurry
Manure storage :	Open liquid manure tank Stockpile for solid manure
Other farming animals :	swine (Sows)

Highlights

- Speciliazed in the field of animal feeding
- All the animals are genotyped
- Weighing troughs allow to know precisely the consumption of each of the 84 cows on trial
- Studies on fodder production adapted to water shortages

Figure 4 : Example of farm factsheet – French Farm FR4

1.3. WP1.4: Apply NPC calculation tool

The Livestock Institute (IDELE) was well involved in this task since one of the three NPC tool considered was Cap'2ER®, a French certified assessment tool for evaluating the environmental burdens and farm sustainability.

- Common Data recording Sheet

The first level of the tool (Cap'2ER® niveau 1) was used and we participated in the development of a Common Data Recording Sheet under excel to help partners filling the tools. The developed spreadsheet is presented below (Figure 5). All relevant cells in the spreadsheets under ANCA (from The Netherlands) and Cap'2ER® were linked to AgreCalc which was used as the reference. Therefore, once the latter filled the other ones were automatically filled.

Specificities, such as animal breeds or administrative regions, which are used to choose some of the default values of the tools, made this exercise uneasy and several adaptations had to be done to be able to make the links between the calculators. **Generic calculation tools can be developed for homogeneous evaluation procedures, but accurate estimates require specific default values based on homogeneous categories identified and validated by local advisors.**

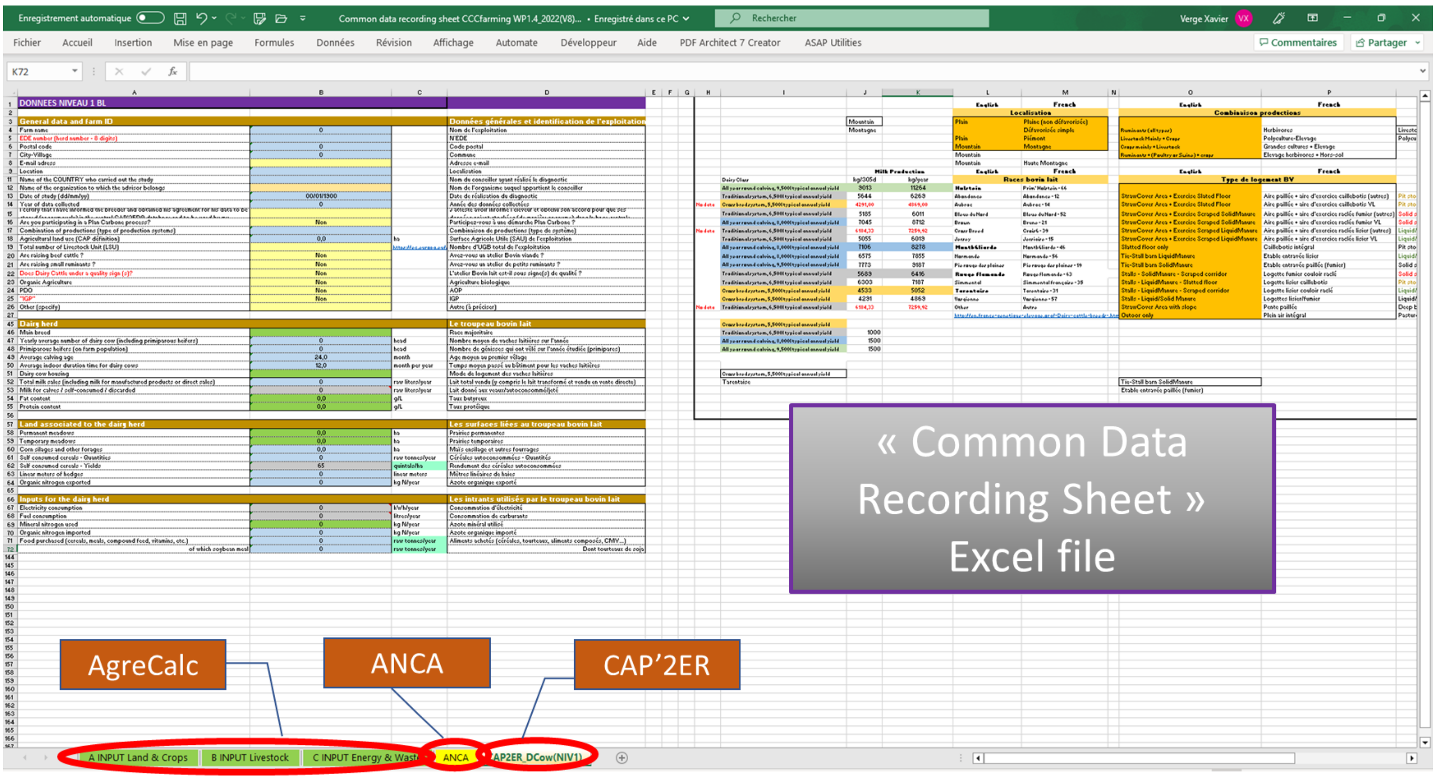


Figure 5 : common data recording sheet for the three NPC tools used

- CAP'2ER® calculations

Since CAP'2ER® is not freely open to public, we had also to perform all the calculations for all the farms of the partners. All results have been provided to the WP1.4 leader in an Excel file (cf. illustration Figure 6).

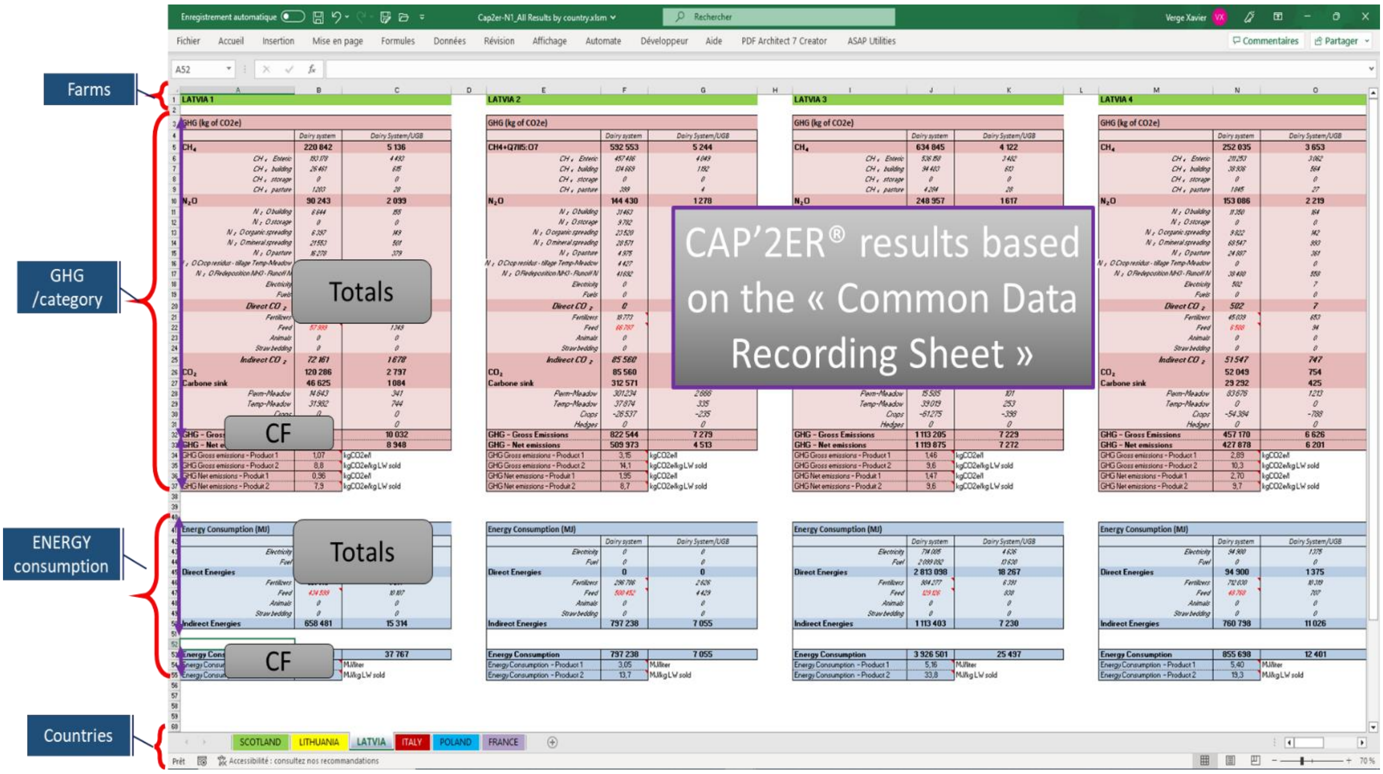


Figure 6 : Results obtained using CAP'2ER® and based on the "Common Data Sheet" developed for WP1.4

1.4. WP1.6: Interact with farmers, consultants and stakeholders

The objectives of this task were to investigate the farmers' current and planned strategies to mitigate GHG and NH_3 emissions and what were their opinions on these questions. A questionnaire related to the "characteristics of the farm and the farmer", "their information sources", "their future expectations and plans" and the "past, future and abandoned actions to reduce emissions" have been developed by the WP1.6 leader.

Our first task was to translate the whole questionnaire and then we collected all the answers face to face through on-farm visits. We processed all data and sent them to the WP leader in an Excel file. We also wrote two documents:

1- a "Discussion points" analysing the policy and agricultural background, the farm and farmer situations and the changes over time in the farm in general and more specifically concerning the GHG and NH3 emissions.
2- a 12 pages report analysing more deeply all the data collected in our 8 selected farms.

Both documents are reported in the Annexes (Section 3).

To complete this study, additional information has been asked and a questionnaire on the country policies and supply chains has been sent. Questions are presented Figure 7 and the filled form is given in the Annexes (Section 3).

Greenhouse gas and NH_3 policy and supply chain environment and common practices

TABLE 1	**What are the main government-driven regulations and support schemes which support/force farmers to implement GHG and NH_3 mitigation practices and which are the exact practices they promote?**

TABLE 2	**What are the main voluntary (dairy/agricultural driven) schemes which support farmers to implement GHG and NH_3 mitigation practices and which are the exact practices they promote?**

TABLE 3	**What are the main supply chain (processors, supermarkets) driven regulations which support/force farmers to implement GHG and NH_3 mitigation practices and which are the exact practices they promote?**

TABLE 4	**Describe how GHG and NH_3 reduction practices are promoted through the extension service or any other channels**

TABLE 5	**Are there any GHG and NH_3 reduction practices which are already commonly practiced in the country?**

Figure 7 : Questionnaire on the country policies and supply chains

1.5. WP2: In depth monitoring and research

The objective of the WP2 was “to *use experimental barn units, field plots and pilot farm designs to compare emissions from housing /manure techniques, and breeding, feeding and grassland practices and techniques in case that cannot be measured on the field study farms".* IDELE was well involved in the task WP2.2.2 led by INRAE: “Study and monitor novel feeding practices related to crops".

The effect of two different feeding modalities have been studied at the building, storage and field levels. IDELE was leading the storage part of this task.

We studied the gas emissions (GHG and NH_3) from manure coming from dairy cows in each of the feeding situations. Temperature, hygrometry, manure production and characteristics were monitored as well as gas emissions.

We used the aparatus presented below (Figure 8) with the INNOVA® 1412 analyser. For amonia emissions, we also completed the measurements with colorimetric tubes (Figure 9).

Figure 8 : Gas measurements from stored manure

Figure 9 : Colorimetric tubes used for ammonia emission measurements and the associated pump

Temperature and hygrometry were measured continuously. An example is presented Figure 11

Figure 10 : Thermo-hygrometers used

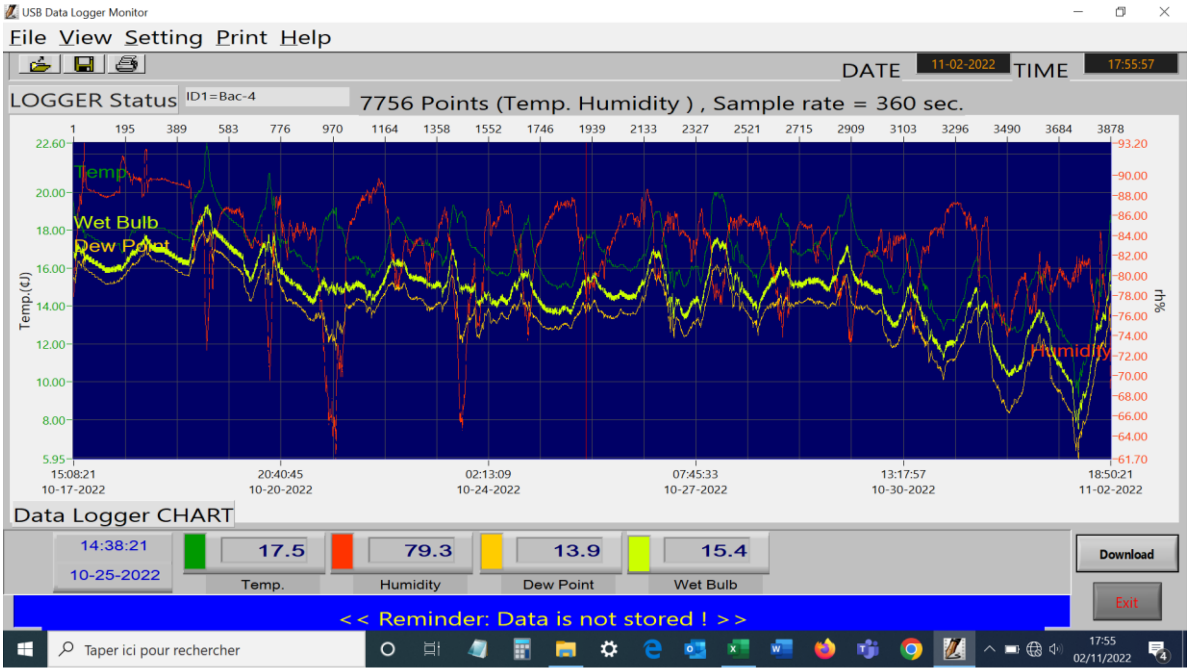


Figure 11 : Example of temperature and humidity measurements

Manure characteristics have been monitored from the excretion to the end of the experimentation. An example of the type of analysis and parameters followed is presented below (Figure 12).

The main results of this study have been sent to the task leader.

ANALYSE DE LA VALEUR AGRONOMIQUE D'UN ENGRAIS DE FERME - EFFLUENT D'ELEVAGE

N° ECHANTILLON HA22-36631
Date de prélèvement : 02/11/2022
Date de réception : 08/12/2022
Date d'édition : 16/12/2022
N° de Dossier : 000173535

ADMINISTRATION/TIERS ·		AGRICULTEUR/ELEVEUR/RAISON SOCIALE
TIERS : INSTITUT DE L'ELEVAGE Région/dépôt : Nom technicien :		INSTITUT DE L'ELEVAGE ROUTE D'EPINAY SUR ODON 14310 VILLERS BOCAGE
NUMERO de CLIENT LANO OU NUMERO D'ELEVAGE	16451	

CARACTERISTIQUES DE L'ECHANTILLON

NOM DE L'ECHANTILLON: 1CR I BAT 02/11/22

TYPE DE PRODUIT : Fumier Mou
ESPECE ANIMALE : Bovins Mixte
DUREE DE STOCKAGE/AGE "MOYEN" DE L'EFFLUENT : 1 mois

QUANTITE EPANDUE OU PREVUE/ha	Code typologique
Tonnes ou m3 /ha	FMBM

RESULTATS DES ANALYSES

DETERMINATION	RESULTATS	UNITE	DETERMINATION	RESULTATS	UNITE
Matières sèches (MS)	18,9	% mat. brute	pH	7,8	-
Humidité (HTE)	81,1	% mat. brute	**Rapport C/N**	13,1	-
Matières minérales (MM)	12,2	% mat. sèches	**Anhydride Phosphorique (P2O5)**	**1,88**	% mat. sèches
Matières organiques (MO)	87,8	% mat. sèches	**Potasse (K2O)**	**3,13**	% mat. sèches
Carbone organique (C org.)	43,9	% mat. sèches	**Chaux (CaO)**	**0,82**	% mat. sèches
Azote total (NtK)	**3,36**	% mat. sèches	**Magnesium (MgO)**	**0,98**	% mat. sèches
Azote ammoniacal (N-NH4)	0,57	% mat. sèches	Oxyde de sodium (Na2O)	0,40	% mat. sèches
Azote organique (N organique)	2,79	% mat. sèches	Cuivre total (Cu)	2	mg/kg MS
Rapport N-NH4/N total	**17,0**	%	Zinc total (Zn)	23	mg/kg MS
Rapport N organique/N total	83,0	%	Manganèse total (Mn)	27	mg/kg MS

VALEUR AGRONOMIQUE DU PRODUIT (épandu à l'humidité de l'échantillon analysé)

ELEMENT FERTILISANT OU AMENDANT	QUANTITE APPORTEE PAR Tonne OU m3 DE PRODUIT BRUT EPANDU	QUANTITE EFFICACE TOTALE APPORTEE POUR UN EPANDAGE DE 30 T OU m3/ha	UNITE	PART DISPONIBLE (coefficients déjà appliqués aux calculs, en % du total)
Matières organiques	166	4 980	kg/ha	-
Azote ammoniacal	1,1	32	kg/ha	La part disponible des fractions azotées dépend de très nombreux paramètres! (sol, culture, climat, épandage)
Azote organique	5,3	158	kg/ha	
Azote total (NtK)	**6,4**	**191**	kg/ha	
P2O5	**3,6**	**108**	kg/ha	**100**
K2O	**5,9**	**177**	kg/ha	**100**
CaO	**1,6**	**48**	kg/ha	**100**
MgO	**1,9**	**57**	kg/ha	**100**
Na2O	0,8	24	kg/ha	100
Cu	0	0	g/ha	70
Zn	4	120	g/ha	80
Mn	5	150	g/ha	-

ANALYSES COMPLEMENTAIRES ET REMARQUES

LABORATOIRE AGRONOMIQUE DE NORMANDIE - CS15208 - 50008 SAINT-LO CEDEX
TEL. 02.33.77.38.15 - Email : lano@lilano.asso.fr - SITE : www.lano.asso.fr
Laboratoire agréé par le Ministère de l'Agriculture français et l'ASP (ex AUP-ONIOL)
Laboratoire adhérent du GEMAS
Laboratoire des Chambres d'Agriculture et du CRIEL NORMANDIE LAIT

Figure 12 : Example of the manure characteristics controled for this study

1.6. WP3: mitigation practices and techniques

This WP was composed by the three following tasks:

- Task 3.1: Farmers' opinions concerning mitigation practices and techniques
- Task 3.2: Policy and ethical aspects of selected mitigation practices and techniques
- Task 3.3: Socio-economic and trade-off aspects of mitigation practices and techniques

We have been involved in the first and third task. Originally IDELE was chosen to lead the second one. However, our main task was on-farm measurements (WP1.5) and, due to the covid 19 situation, we faced many diffculties leading to delays. For example, the presentation of the method that each of the partners had to use was supposed to be done physically to show all material needed and how to use it, and this was not possible. Finding farms and visiting them was not possible either and had to be delayed. Also, the Brexit situation had impacts on the sendings between Scotland and France and notably the air samplings which were delayed too.

Finally, after dicsussions with the steering committee, it had been decided for France to focus on the work package WP1.5, to keep supporting all other tasks where France was involved in and to leave the leadership of the WP3.2 tasks. We would then support this WP only.

For the first task (WP3.1) we filled the template of the forms (section 1, 2, 3 and 7) designed to be used to describe each farm. An example is presented Figure 13, the other leaflets are provided in the Annexes (Section 4).

For the third task (WP1.3), we sent to the WP leader all inputs needed for the scenarii of two farms in order to estimate gas mitigations and economical impacts.

Farm plan reduction of emissions **Dairy farmer: Farm 5**

1. Description of farmers' future strategy on development of farm and reduction of emissions

The farmers considered to move to organic status but they abandoned the project fearing a market saturation. Instead, they embarked on the "High Environmental Value" (HEV) standard. It is now certified level 3 since 2020. Considering the manpower shortage and the need to gain time and efficiency, the farmers are investing to be more resilient and more adapted to societal expectations. For these reasons, as well as to save fuel and preserve biodiversity, they have been practicing no-till for 20 years. They produce biogas for 10 years yet which allows them to diversify their income. For them, they consider that they already optimized their production system in the environmental domain, by deploying many other levers: photovoltaic, drying of protein fodder, equipment for animal welfare, scraping blade instead of fushing, feed optimization... Therefore, they consider that they are at the limit of their possibilities to reduce GHG emissions or to increase carbon sequestration. Next potential project (study in progress): supplying and recycling energy, in synergy with a nearby data center.

2. Which mitigation measures / practices were already taken?

1. No-till (since 20 years)
2. Methanization (10 years ago)
3. Photovoltaic
4. Drying of protein fodder
5. Investments for animal welfare (mats, water mattresses)
6. Scraping blade instead of flushing
7. Feeding optimization

4. Expected effects on emissions (based on tool calculations, see attachment)

1. Measure 1: ....
   .....
   ......
2. Measure 2: ....
   .....
   .....
3. Measure 3: .....
   .....
   .....

3. Which mitigation measures are planned to be implemented and how?

1. Synergy with a data center: payment for the supply of renewable energy by the farm to power/cool the data center + recycling of the heat produced by the data center for drying on the farm
2. The farmers consider they are at the end of what they could do to mitigate their environmental impacts

5. Equipment involved; Investment and economics?

1. ....
2. ....
3. ....

Economics:

7. Quote of farmer:

"Doing projects to get out of our comfort zone and keep the pleasure of working: it's in our DNA! "
"Nitrogen efficiency is 60 to 70% compared to 30% before methanization; the organic matter of our soils has increased by 1 to 1.5 points"
"Be careful not to go at the expense of dairy performance"

6. Attention points when implementing measures

1. ......
2. ....

farming

Joint call 2018 on novel technologies, solutions and systems to reduce GHG - ID 39274

FACCE ERA-GAS ERA-NET SUSAN ICT AGRI era-net

Figure 13 : Example of farm leaflet filled for the WP3.1

2. Part II: On-farm emissions measurements – (IDELE-INRAE UMR SAS)

2.1. Introduction

In this section we present the task lead by IDELE. We worked with INRAE-SAS which was leading the emission factor (EF) calculations.

The objectives of this task were:

1- To finalize the “Simplified Method” which had to be used by all partners/countries of the project, with the aim to adapt it to the international perspective.
2- To present both the principles and the specific material to use with this method
3- To do the French on-farm measurements and calculations
4- To collect the calculated GHG and NH_3 emission factors (EF) from all partners (60 farms x 4 measurement seasons)
5- To analyse all the results with the objective of characterizing the emission profile for the 60 farms in the 8 countries
6- To provide a farm document (leaflet) which can be used by each partner to go and see the farmers and to present the results in an easy and informative way.

The next sections present, first, the “Simplified Method” and how it had been transferred to partners; second, the encountered difficulties due to the Covid situation and what has been done to be able to keep working on this task and, finally, the results and final deliverables (leaflets) with a short discussion.

2.2. The Simplified Method

This section presents very briefly the method used in this project. More details are presented in the Annexes.

2.2.1. Principles

The Simplified Method has been developed by IDELE-INRAE to be able to estimate the GHG and NH_3 emission factors in open livestock buildings. It has been designed to be used by non-expert people and at low cost. The objective is to characterize the studied building in terms of emissions to be able to point out “hot spots” and/or to identify good practices, compared to average results (in our case the 60 farms), and finally to implement mitigation strategies.

To do so, a questionnaire is filled with the farmer to be able to estimate the carbon inputs and outputs in the studied building. The objective of this step is to estimate the carbon losses which are supposed to come from the CO_2 and CH_4 emissions.

To be able to identify how carbon is distributed in these two gases, air samplings are done outside and inside the building. A gas gradient is then calculated: $Gradient_{gas} = gas_{in} - gas_{out}$.

To transfer this method a document presenting the principles and the protocol of measurements (cf. Annexes) has been developed.

2.2.2. Material

For this method, specific material needs to be used. The list has been provided, as well as the suppliers, to make sure that all measurements will be done the same way.

The on-farm questionnaire has also been provided. It is presented section XX of the Annexes.

2.3. Adaptation to covid situation

Some of the steps presented in the Introduction have been very disturbed by the Covid situation and, for example, all physical meeting planned had to be cancelled. In this situation leading field works at an international level became extremely complex and challenging. To be sure that this task will nevertheless be filled we decided to simplify the work of each partner. But, with this reorientation, the workload for us (IDELE-INRAE) increased considerably.

The main adaptations:

2.3.1. Input data

1- We decided to do all the EF calculations (for all gases and all farms/seasons). Therefore, each partner had only to provide us the results from the questionnaires and from the gas analyses.

Since, it was not possible for us to transfer manually all the answers from all partners under Excel to be able to calculate the EF, we developed an Excel file gathering all the questions under several spreadsheets. (cf. Figure 14).

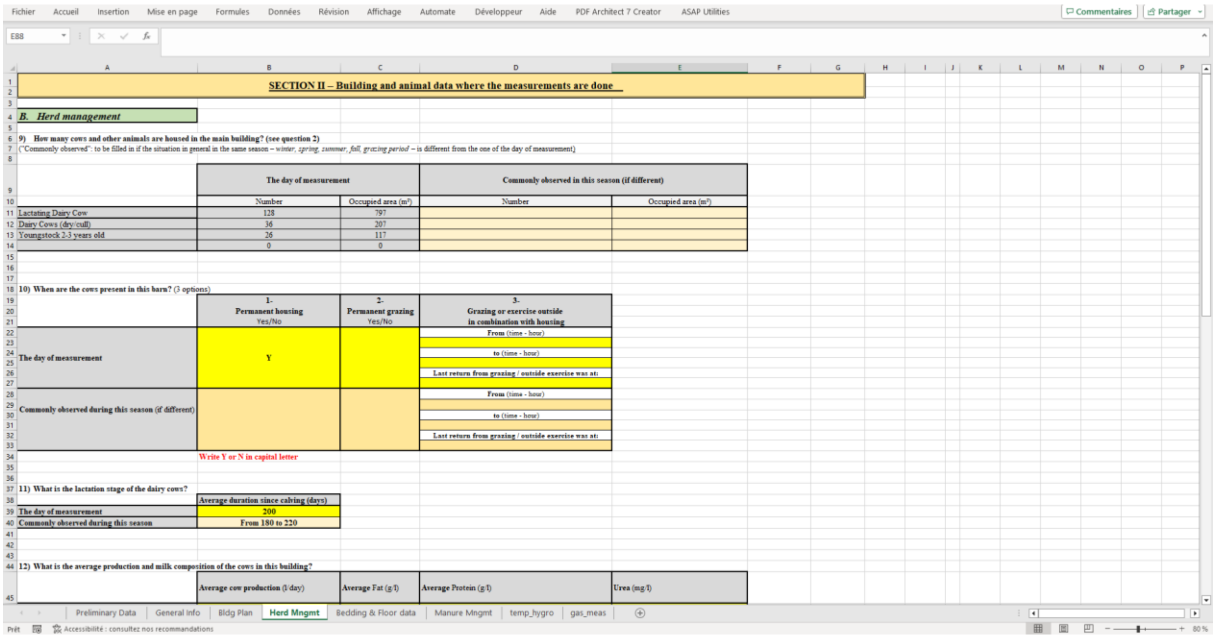
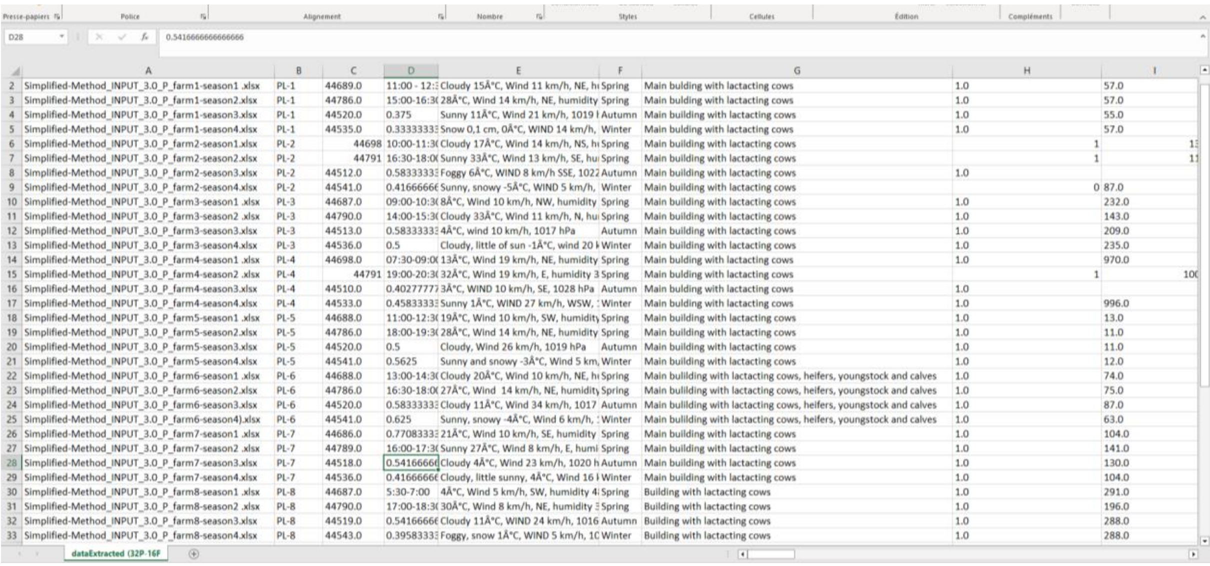


Figure 14 : Input file for on-farm questionnaire

2- To be able to use efficiently all the collected data ("input files") a program has been developed to gather and reorganize all the necessary data for the EF calculations. It has been written under "R" and provides all data (columns) per country-farm-season (rows) (cf. Figure 15).



D28 | 0.541666666666666

	A	B	C	D	E	F	G	H	I
2	Simplified-Method_INPUT_3.0_P_farm1-season1 .xlsx	PL-1	44689.0	11:00 - 12:3	Cloudy 15Å°C, Wind 11 km/h, NE, hı	Spring	Main bulding with lactacting cows	1.0	57.0
3	Simplified-Method_INPUT_3.0_P_farm1-season2.xlsx	PL-1	44786.0	15:00-16:3(	28Å°C, Wind 14 km/h, NE, humidity	Spring	Main bulding with lactacting cows	1.0	57.0
4	Simplified-Method_INPUT_3.0_P_farm1-season3.xlsx	PL-1	44520.0	0.375	Sunny 11Å°C, Wind 21 km/h, 1019 I	Autumn	Main building with lactacting cows	1.0	55.0
5	Simplified-Method_INPUT_3.0_P_farm1-season4.xlsx	PL-1	44535.0	0.3333333:	Snow 0,1 cm, 0Å°C, WIND 14 km/h,	Winter	Main bulding with lactacting cows	1.0	57.0
6	Simplified-Method_INPUT_3.0_P_farm2-season1.xlsx	PL-2	44698	10:00-11:3(	Cloudy 17Å°C, Wind 14 km/h, NS, hı	Spring	Main building with lactacting cows	1	1[illegible]
7	Simplified-Method_INPUT_3.0_P_farm2-season2.xlsx	PL-2	44791	16:30-18:0(	Sunny 33Å°C, Wind 13 km/h, SE, hu	Spring	Main building with lactacting cows	1	11
8	Simplified-Method_INPUT_3.0_P_farm2-season3.xlsx	PL-2	44512.0	0.5833333:	Foggy 6Å°C, WIND 8 km/h SSE, 1022	Autumn	Main building with lactacting cows	1.0	
9	Simplified-Method_INPUT_3.0_P_farm2-season4.xlsx	PL-2	44541.0	0.4166666(	Sunny, snowy -5Å°C, WIND 5 km/h,	Winter	Main building with lactacting cows	0	87.0
10	Simplified-Method_INPUT_3.0_P_farm3-season1 .xlsx	PL-3	44687.0	09:00-10:3(	8Å°C, Wind 10 km/h, NW, humidity	Spring	Main building with lactacting cows	1.0	232.0
11	Simplified-Method_INPUT_3.0_P_farm3-season2 .xlsx	PL-3	44790.0	14:00-15:3(	Cloudy 33Å°C, Wind 11 km/h, N, hu	Spring	Main building with lactacting cows	1.0	143.0
12	Simplified-Method_INPUT_3.0_P_farm3-season3.xlsx	PL-3	44513.0	0.5833333:	4Å°C, wind 10 km/h, 1017 hPa	Autumn	Main building with lactacting cows	1.0	209.0
13	Simplified-Method_INPUT_3.0_P_farm3-season4.xlsx	PL-3	44536.0	0.5	Cloudy, little of sun -1Å°C, wind 20 k	Winter	Main building with lactacting cows	1.0	235.0
14	Simplified-Method_INPUT_3.0_P_farm4-season1 .xlsx	PL-4	44698.0	07:30-09:0(	13Å°C, Wind 19 km/h, NE, humidity	Spring	Main bulding with lactacting cows	1.0	970.0
15	Simplified-Method_INPUT_3.0_P_farm4-season2 .xlsx	PL-4	44791	19:00-20:3(	32Å°C, Wind 19 km/h, E, humidity 3	Spring	Main bulding with lactacting cows	1	10[illegible]
16	Simplified-Method_INPUT_3.0_P_farm4-season3.xlsx	PL-4	44510.0	0.4027777	3Å°C, WIND 10 km/h, SE, 1028 hPa	Autumn	Main bulding with lactacting cows	1.0	
17	Simplified-Method_INPUT_3.0_P_farm4-season4.xlsx	PL-4	44533.0	0.4583333:	Sunny 1Å°C, WIND 27 km/h, WSW, :	Winter	Main bulding with lactacting cows	1.0	996.0
18	Simplified-Method_INPUT_3.0_P_farm5-season1 .xlsx	PL-5	44688.0	11:00-12:3(	19Å°C, Wind 10 km/h, SW, humidity	Spring	Main building with lactacting cows	1.0	13.0
19	Simplified-Method_INPUT_3.0_P_farm5-season2.xlsx	PL-5	44786.0	18:00-19:3(	28Å°C, Wind 14 km/h, NE, humidity	Spring	Main building with lactacting cows	1.0	11.0
20	Simplified-Method_INPUT_3.0_P_farm5-season3.xlsx	PL-5	44520.0	0.5	Cloudy, Wind 26 km/h, 1019 hPa	Autumn	Main building with lactacting cows	1.0	11.0
21	Simplified-Method_INPUT_3.0_P_farm5-season4.xlsx	PL-5	44541.0	0.5625	Sunny and snowy -3Å°C, Wind 5 km,	Winter	Main building with lactacting cows	1.0	12.0
22	Simplified-Method_INPUT_3.0_P_farm6-season1 .xlsx	PL-6	44688.0	13:00-14:3(	Cloudy 20Å°C, Wind 10 km/h, NE, hı	Spring	Main builiding with lactacting cows, heifers, youngstock and calves	1.0	74.0
23	Simplified-Method_INPUT_3.0_P_farm6-season2.xlsx	PL-6	44786.0	16:30-18:0(	27Å°C, Wind 14 km/h, NE, humidity	Spring	Main builiding with lactacting cows, heifers, youngstock and calves	1.0	75.0
24	Simplified-Method_INPUT_3.0_P_farm6-season3.xlsx	PL-6	44520.0	0.5833333:	Cloudy 11Å°C, Wind 34 km/h, 1017	Autumn	Main builiding with lactacting cows, heifers, youngstock and calves	1.0	87.0
25	Simplified-Method_INPUT_3.0_P_farm6-season4).xlsx	PL-6	44541.0	0.625	Sunny, snowy -4Å°C, Wind 6 km/h, :	Winter	Main builiding with lactacting cows, heifers, youngstock and calves	1.0	63.0
26	Simplified-Method_INPUT_3.0_P_farm7-season1 .xlsx	PL-7	44686.0	0.7708333:	21Å°C, Wind 10 km/h, SE, humidity	Spring	Main building with lactacting cows	1.0	104.0
27	Simplified-Method_INPUT_3.0_P_farm7-season2 .xlsx	PL-7	44789.0	16:00-17:3(	Sunny 27Å°C, Wind 8 km/h, E, humi	Spring	Main building with lactacting cows	1.0	141.0
28	Simplified-Method_INPUT_3.0_P_farm7-season3.xlsx	PL-7	44518.0	0.5416666(	Cloudy 4Å°C, Wind 23 km/h, 1020 h	Autumn	Main building with lactacting cows	1.0	130.0
29	Simplified-Method_INPUT_3.0_P_farm7-season4.xlsx	PL-7	44536.0	0.4166666(	Cloudy, little sunny, 4Å°C, Wind 16 I	Winter	Main building with lactacting cows	1.0	104.0
30	Simplified-Method_INPUT_3.0_P_farm8-season1 .xlsx	PL-8	44687.0	5:30-7:00	4Å°C, Wind 5 km/h, SW, humidity 4	Spring	Building with lactacting cows	1.0	291.0
31	Simplified-Method_INPUT_3.0_P_farm8-season2 .xlsx	PL-8	44790.0	17:00-18:3(	30Å°C, Wind 8 km/h, NE, humidity 3	Spring	Building with lactacting cows	1.0	196.0
32	Simplified-Method_INPUT_3.0_P_farm8-season3.xlsx	PL-8	44519.0	0.5416666(	Cloudy 11Å°C, WIND 24 km/h, 1016	Autumn	Building with lactacting cows	1.0	288.0
33	Simplified-Method_INPUT_3.0_P_farm8-season4.xlsx	PL-8	44543.0	0.3958333:	Foggy, snow 1Å°C, WIND 5 km/h, 1C	Winter	Building with lactacting cows	1.0	288.0

dataExtracted (32P-16F

Figure 15 : Farm inputs reorganized

3- This reorganized database was then checked for consistencies, for example, too high milk productions due to input mistakes, number appearing as text because of the use of coma instead of points, etc. Based on this quality control stage three tiers have been developed depending on the level of data that has to be replaced by default values (cf. Figure 16)

Tier 1: mainly based on default values → ***Very Low*** *farm precision*

Tier 2a: important inputs based on default values → ***Low*** *farm precision*

Tier 2b: no default value → ***Good*** *farm precision*

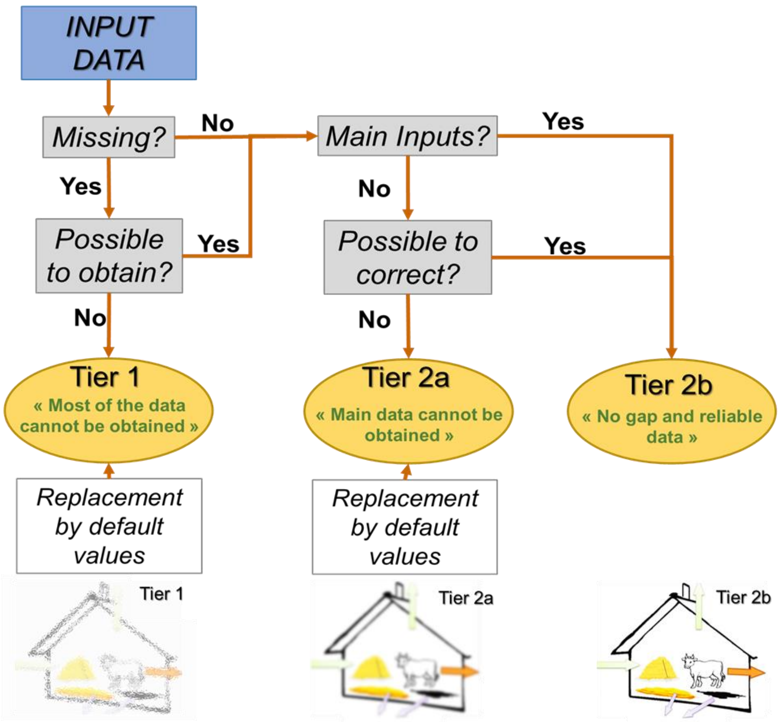


Figure 16 : Data quality control – Method for tier identifications

2.3.2. Calculator

The Excel based EF calculator has been totally rewritten. It is now specifically adapted to the new data organization and format. It is presented below Figure 17.

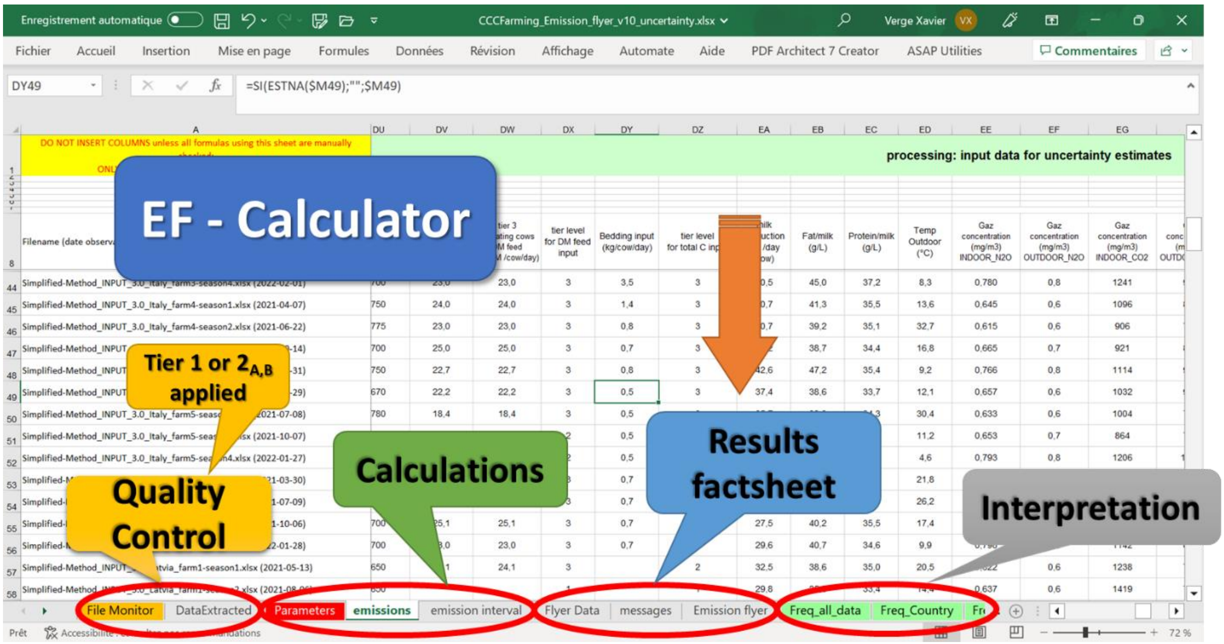


Figure 17 : Overview of the Excel based EF calculator

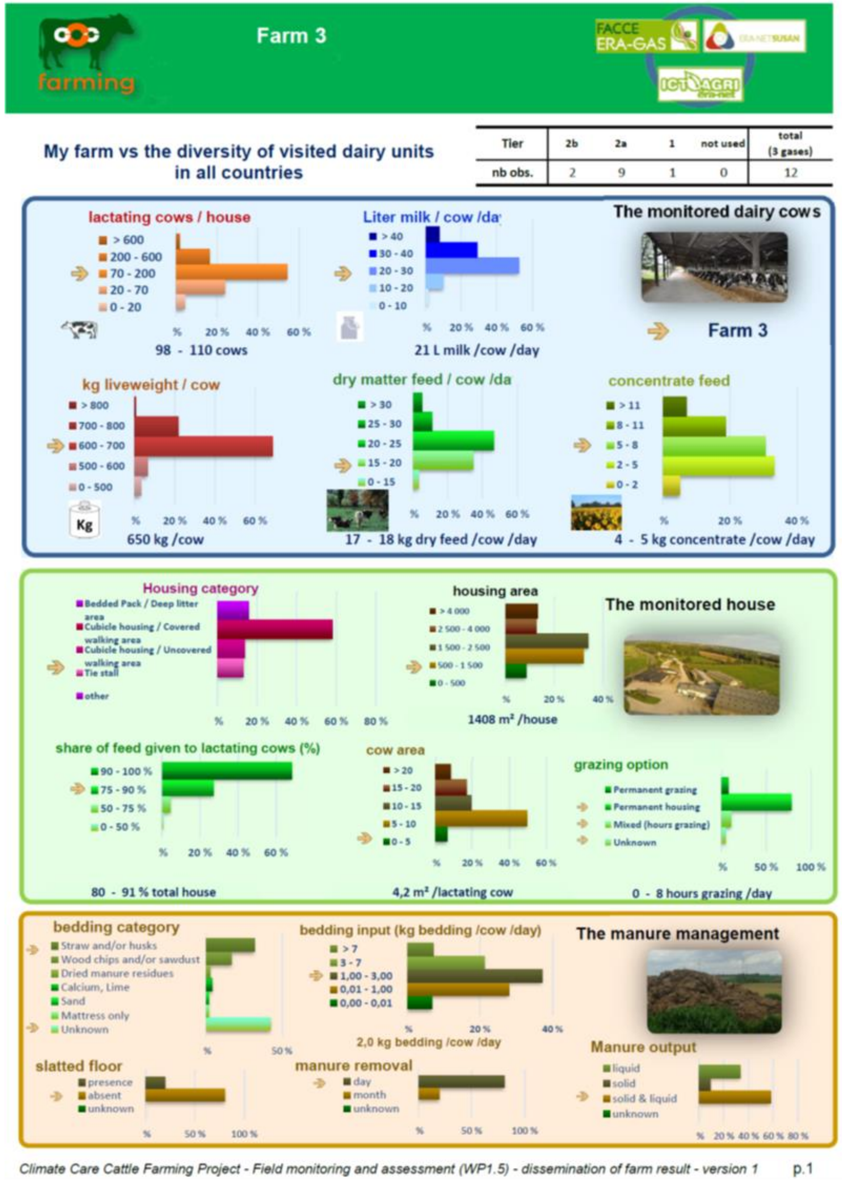
The first spreadsheets are used for quality control purposes, then calculations are performed and the results are presented in factsheets. Once printed, these results are designed to be presented to farmers. The last spreadsheets are used as a help for result interpretations.

With all of these modifications we were able to handle all the files from all the partners (264 files) and calculate all the EF (more than 1050) and finally obtain a factsheet for each of the 60 farms where the text can be easily adapted to each country language.

An example is presented Figure 18. All factsheets are gathered at the end of the Annexes.

- The left page presents the farm situation. It is based on the questionnaire. All horizontal graphs correspond to the international average and the arrow, and the numbers below the graphs, present the situation of the farm. The farm is then compared to the averages of this project.
- At the right, all the EF calculations are presented. The left graphs (blue side) correspond to the international (project) average and the right graphs (orange side) present the farm results. The observed emissions are presented for the NH_3, CH_4 and N_2O gas and in CO_2 equivalent (combination of the CH_4 and N_2O gases, reported as kg CO_2eq per Liter of milk). At the top of the leaflet, the “Take home” message can be included by the farm adviser.

It is important to note that we do not present only one EF per farm and per year, but all the EF calculated for each specific farms distributed under five classes. This presentation takes into account the evidence that the emissions are observed with an uncertainty and that accurate observations should necessarily change over the year due to climate, animals and/or management issues. This graph has been called the “Signature” of the farm (cf.Figure 20).



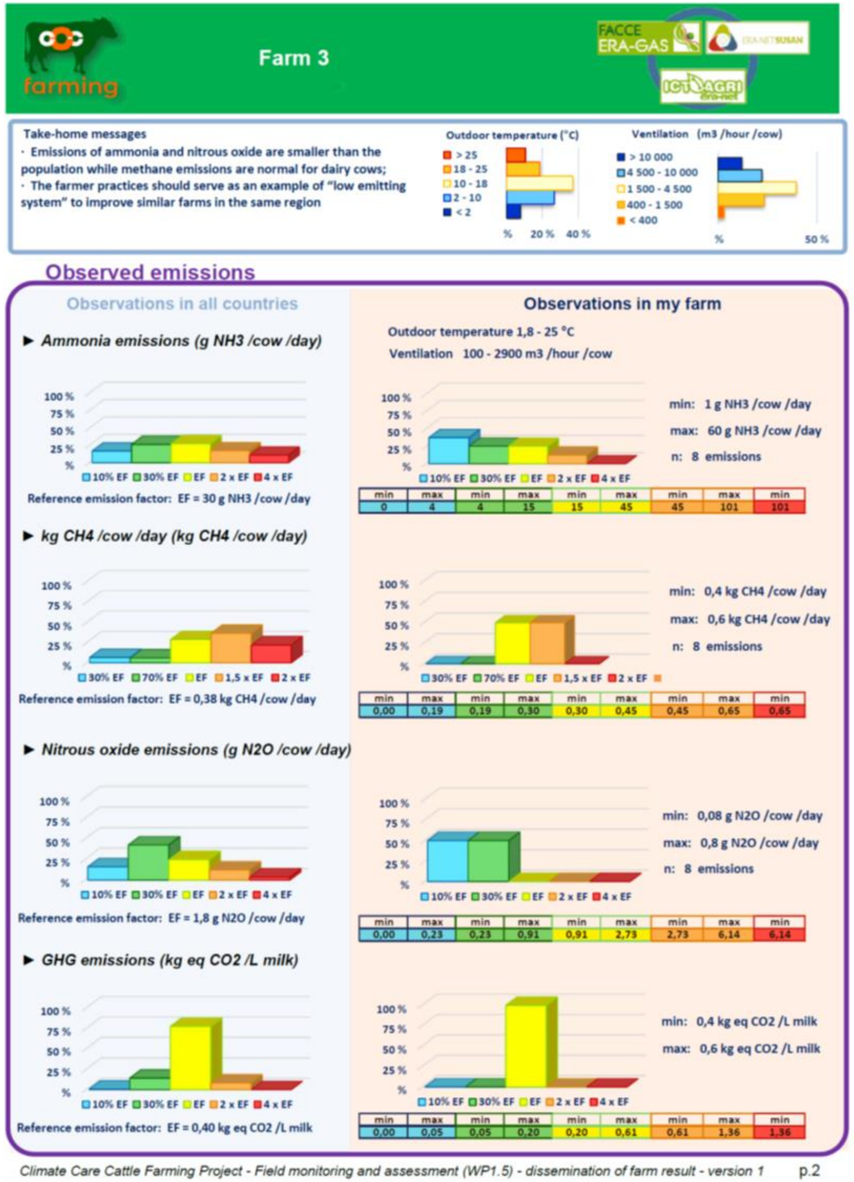


Figure 18 : Results - Farm factsheet

Finally, to be able to present the results to the farmers, we also developed the two pages presented below. They complete the factsheets and correspond to the front page (Figure 19) and back page (Figure 20) of the folded A3 leaflet.

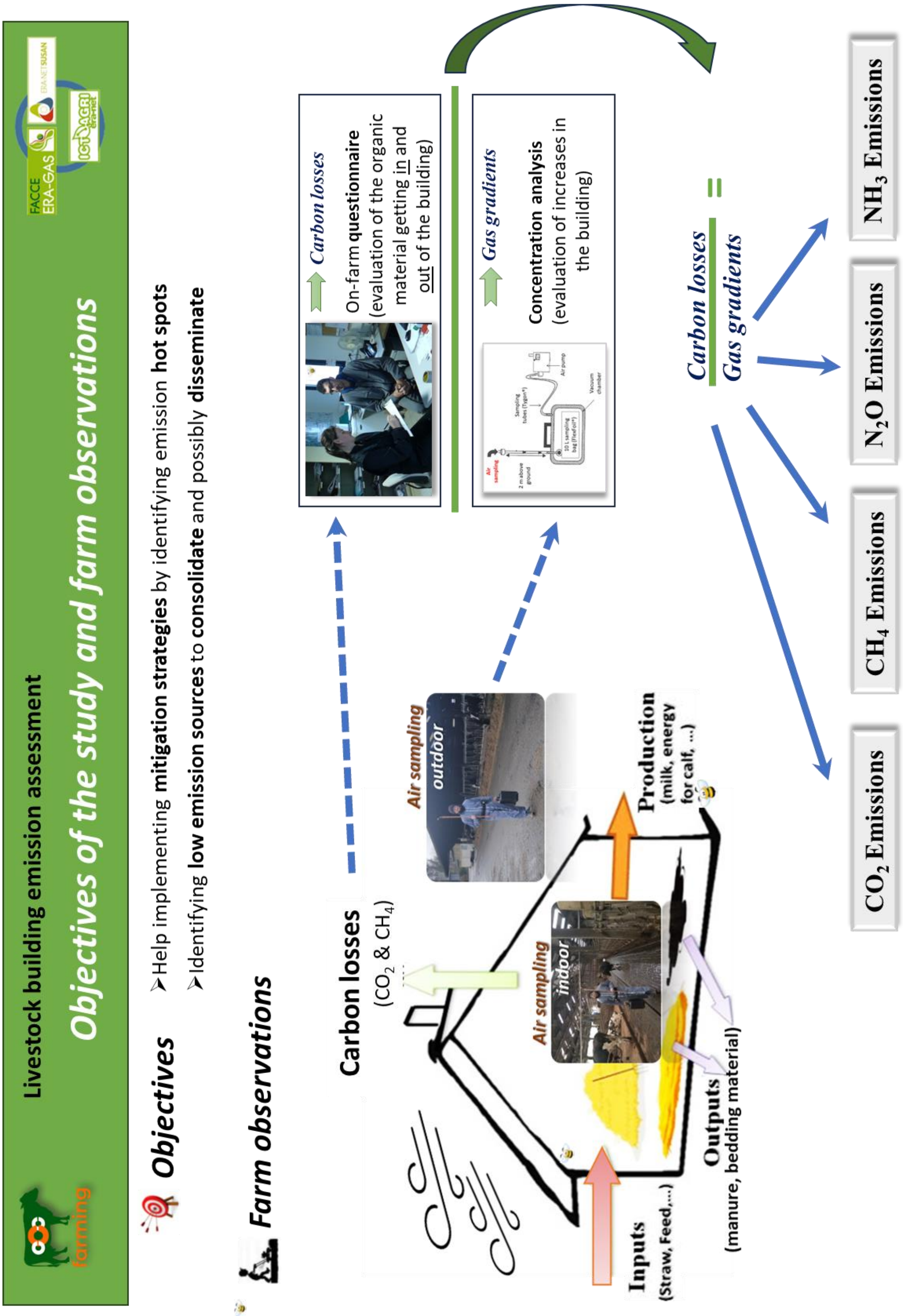


Figure 19 : Farm leaflet – page 1 (front page)

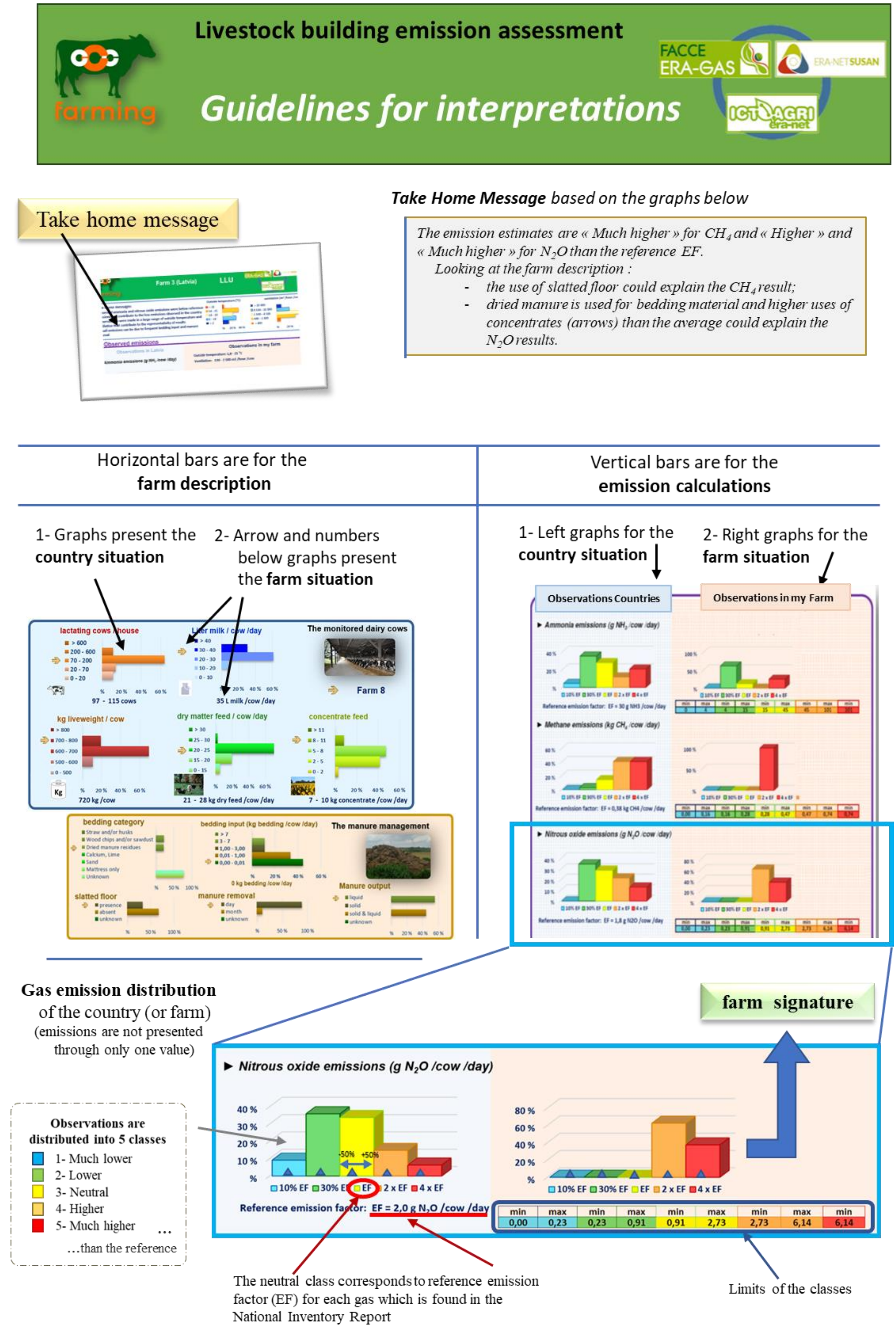


Figure 20 : Farm leaflet – page 4 (back page)

2.4. Results

2.4.1. Emission categories

The emission analyses lead to the identification of 12 categories (Table 1) where the ammonia, methane or nitrous oxide emissions frequencies, were similar, lower or higher than the average of all the livestock building studied. They were ranked from the least (n°1) to the highest (n°12) emissions, considering the three gases. In the case of Germany, the farms could not be classified because available data allowed calculations only on ammonia emissions.

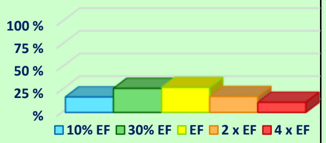
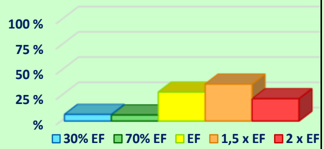
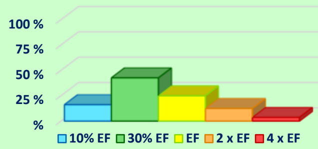
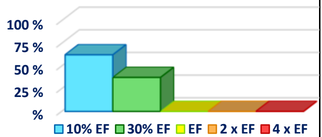
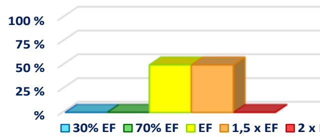
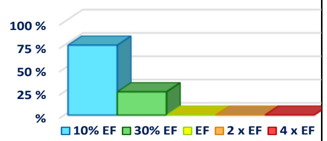
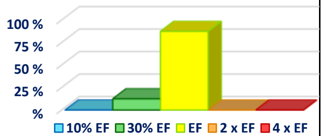
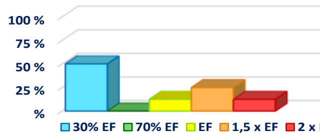
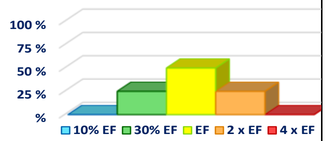
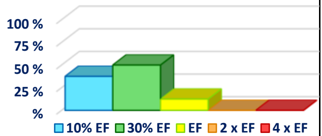
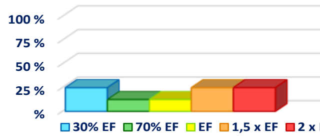
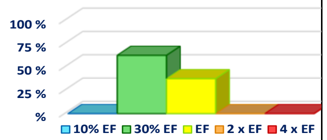
In each of the category, the emissions were considered similar but the link between emissions and specific features of the housing was unclear: animal number, feeding, grazing, housing type (e.g. cubicles, tie stall, deep litter) or area per cow, manure management (liquid and/or solid) or bedding input were heterogeneous between farms within the same category. Each category included a variable number of farms and no link related to country could be established except for Lithuania where the four farms belonged to category 1.

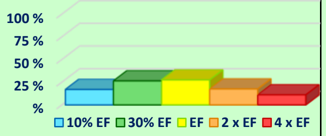
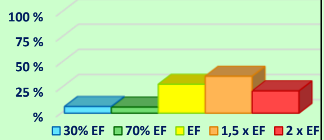
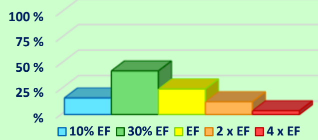
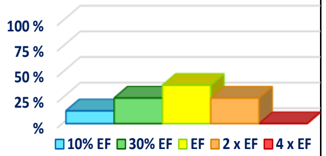
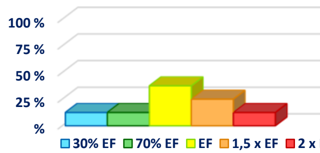
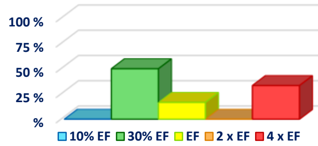
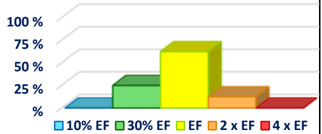
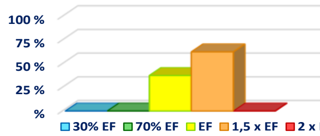
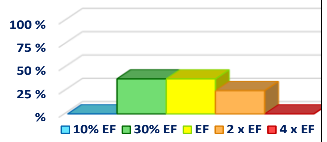
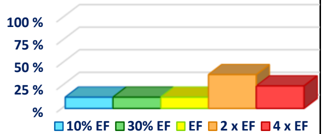
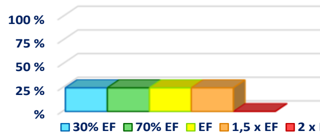
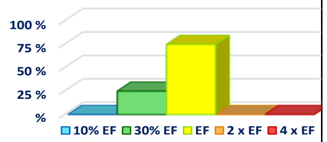
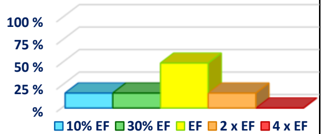
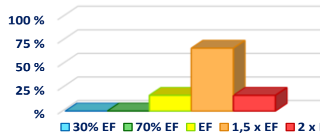
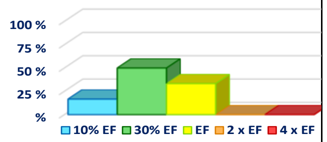
Three categories had 9 or 10 farms (categories 1, 3, 11) representing around 20% of the total number of farms. Three categories had 3 to 7 farms (categories 5, 8, 12) that means around 10% of the total number of farms. For the 6 other categories (n° 2, 4, 6, 7, 9, 10), only 1 or 2 farms were in each category (less than 5% of the total). In all these categories, the limited number of farms limited the possibility to analyze a possible link between emissions and housing type or management.

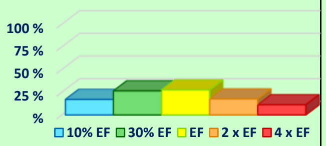
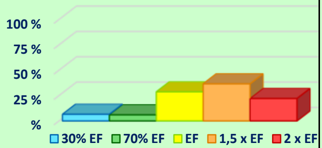
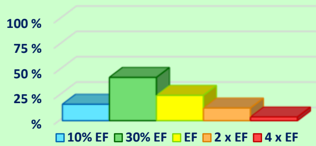
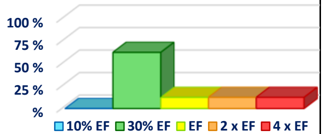
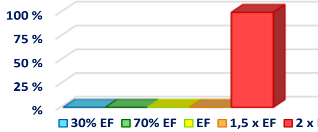
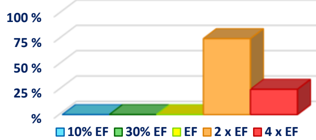
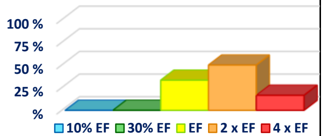
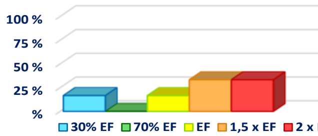
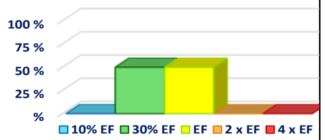
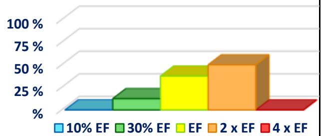
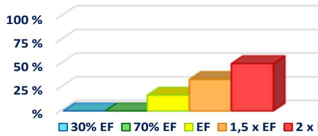
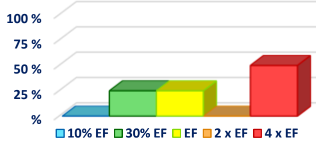
Links with animal number, feeding, grazing, housing type (e.g. cubicles, tie stall, deep litter) or area per cow, manure management (liquid and/or solid) or bedding input could not be established. This was due to the fact that most of the parameters for calculations were very diversified between farms (feeding, production, amount of bedding material, etc.). Even the temperature effect on ammonia emission was not observed despite the high range in temperature (outside temperature from −3.2 to +36.0 °C). In such situation, finding correlations with specific parameters would require having a larger farm sampling and more on-farm measurements.

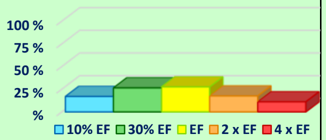
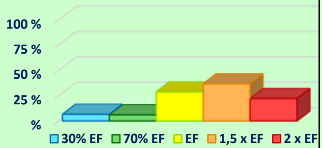
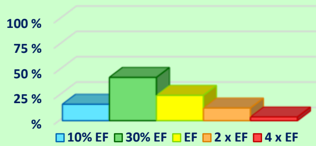
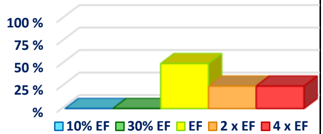
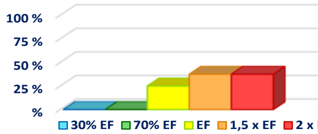
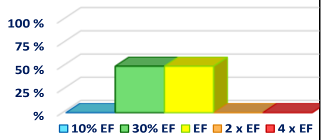
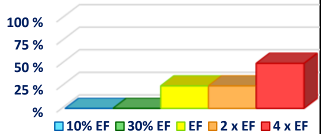
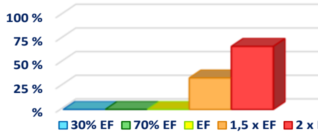
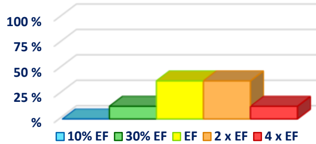
Almost all countries had farms in the "high emission categories" (n° 11 or 12) or in the "low emission categories" (n° 1 or 2). **Therefore, the proposed measuring method can help to support a strategy of emission reduction provided the observed results are integrated in national emission inventories**.

Table 1: farm distribution according to the gas emission levels

Category	House Signature			NH_3	CH_4	N_2O	Farm Id	Proposed message
population (reference for message)	 NH_3	 CH_4	 N_2O	–	–	–	all	
1	 NH_3	 CH_4	 N_2O	– –	–	– –	LV 2, LV 3, LV 6, FR 8, NL 1, IT 8, LT 1, LT 2, LT 3, LT 4	• Emissions of ammonia and nitrous oxide are smaller than the population while methane emissions are normal for dairy cows; • The farmer practices should serve as an example of “low emitting system” to improve similar farms in the same region
2	 NH_3	 CH_4	 N_2O	–	–	–	IT 4, SC 5	• Emissions of ammonia, methane and nitrous oxide are similar to the population; • Methane emissions higher than emission factor can be due to the manure management
3	 NH_3	 CH_4	 N_2O	– –	+	– –	LV 1, LV 4, LV 8, IT 7, NL 3, NL 6, SC 6, SC 7, SC 8	• Emissions of ammonia and nitrous oxide are lower than the population; • The reasons of occasional higher methane emissions should be understood to further improve the overall good quality of emissions

Category	House Signature			NH_3	CH_4	N_2O	Farm Id	Proposed message
population (reference for message)	 NH_3	 CH_4	 N_2O	–	–	–	all	
4	 NH_3	 CH_4	 N_2O	–	–	+	FR 1	• Emissions of ammonia and methane are similar to the population; • The risk of occasionally high nitrous oxide emission should be further studied
5	 NH_3	 CH_4	 N_2O	–	+	–	LV 5, NL 9, PL 1, PL 2, IT 2, IT 5, IT 6	• Emissions of ammonia and nitrous oxide are similar to the population; • Manure management could be tuned to decrease the occurrence of methane (or ammonia) emissions higher than the emission factor
6	 NH_3	 CH_4	 N_2O	+	–	–	FR 4, PL 4	• Emissions of ammonia are higher than the population; • Emissions of methane are lower than the population and nitrous oxide emissions similar; • Manure management could be tuned to decrease ammonia emissions
7	 NH_3	 CH_4	 N_2O	–	+ +	–	FR 5, PL 6	• Emissions of ammonia and nitrous oxide are similar to the population; • Methane emissions higher than emission factor can be due to the manure management

Category	House Signature			NH_3	CH_4	N_2O	Farm Id	Proposed message
population (reference for message)	 NH_3	 CH_4	 N_2O	–	–	–	all	
8	 NH_3	 CH_4	 N_2O	–	+	+	NL 8, FR 2, FR 3	• Emissions of ammonia are lower than in most farms; • However, high methane and nitrous oxide are observed which can be due to the manure management (e.g. 1: reusing dried manure with moist litter; e.g. 2: moist litter for methane; e.g. 3: frequent turning for nitrous oxide)
9	 NH_3	 CH_4	 N_2O	+	+	–	SC 2, SC 3	• Emissions of ammonia and methane are higher than the population; • Manure management could be tuned to decrease these emissions
10	 NH_3	 CH_4	 N_2O	+	+	+	FR 6, NL 4	• Emissions of ammonia, methane and nitrous oxide are higher than the population; • Changes in manure management should be studied to decrease these emissions

Category	House Signature			NH_3	CH_4	N_2O	Farm Id	Proposed message
population (reference for message)	 NH_3	 CH_4	 N_2O	–	–	–	all	
11	 NH_3	 CH_4	 N_2O	+	+ +	–	SC 1, SC 4, PL 3, PL 5, PL 7, PL 8, NL 2, NL 7, LV 7	• Emissions of ammonia and methane higher than the population are occasionally observed; • Conditions of these high emissions should be identified to decrease there occurrence while maintaining small nitrous oxide emissions
12	 NH_3	 CH_4	 N_2O	+ +	+ +	+ +	FR 7, IT 1, IT 3, NL 5	• Emissions of ammonia, methane and nitrous oxide higher than the population are repeatedly observed; • Changes in manure or cow management can induce significant decrease in polluting emissions
13	only NH_3 available						DE 1, DE 2, DE 3, DE 4, DE 5, DE 6, DE 7, DE 8, DE 9, DE 10, DE 11, DE 12, DE 13	the “house signature” could not be observed; when high ammonia emissions were repeatedly observed, improvements in manure management could be tested

2.4.2. Ammonia emissions

Scraping frequencies

Hypothesis of the effect of increasing scrapping frequency on ammonia emission decrease was partially confirmed.

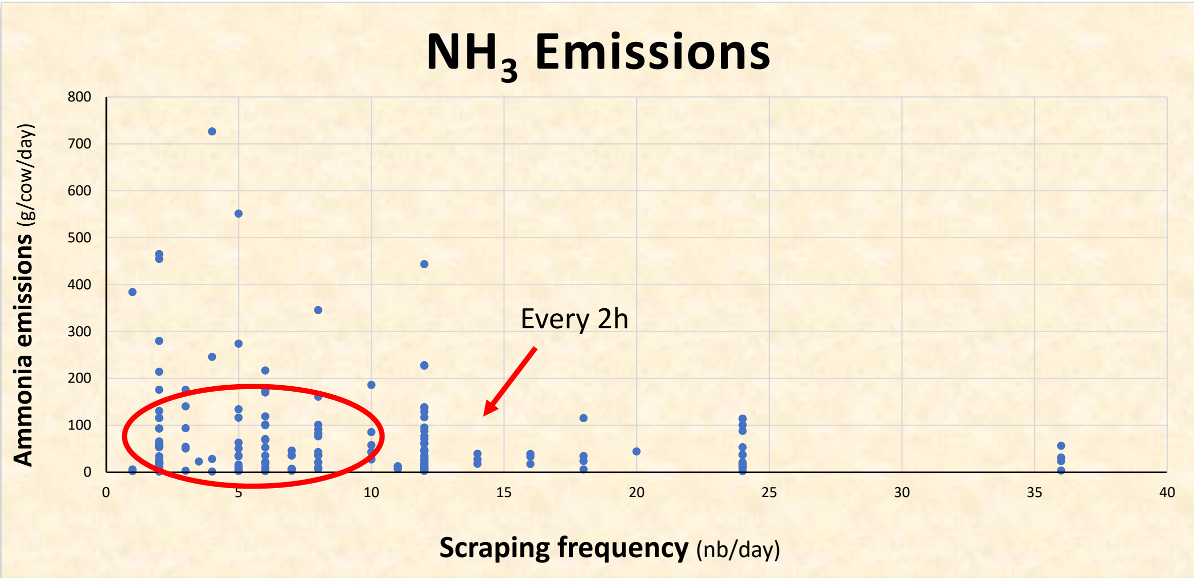


Figure 21 : effect of scraping frequency on ammonia emissions

As expected, with high scraping frequency the risk of having high ammonia emissions was low or non-existent (Cf. Figure 21). The threshold found in this project was a frequency of 12 time a day or every 2 hours.

However, this does not mean that low scraping frequencies, such as one per day, would necessarily induce high ammonia emissions in all the studied livestock buildings. Indeed, even in this case, emissions below 30 g NH_3 cow^{-1} day^{-1} were observed. **This means that practical observations can reveal the farms where the default EF should be replaced by a lower value because lower emissions are repeatedly observed**.

Use of innovative materials

We observed that in all buildings where mattresses were used for animal bedding smaller ammonia emissions were measured (Cf. Figure 22).

On the left, the graph presents the emission "signature" of all farms regardless the type of animal bedding used. On the right the same group of farms are divided into two sub-groups: the first one without mattresses (at the top) and the second one with farms using mattresses as animal bedding. One therefore observes that the emission signature is shifting on the right for the first group compared to the reference graph which means that these farms have, on average, more NH_3 emissions (the EF frequency was shifting towards higher emission classes). And for farms having such type of mattress there is a clear shift to the left with most of the EF distributed in the low emission classes.

This effect is not well understood yet and will require further investigations. This result illustrates fairly well the interest and the strength of the Simplified Method which has been developed as a tool observing the farm situation in terms of gas emissions and revealing the weaknesses ("hot spots") or the strengths (with low EF), which is the case here, of specific practices.

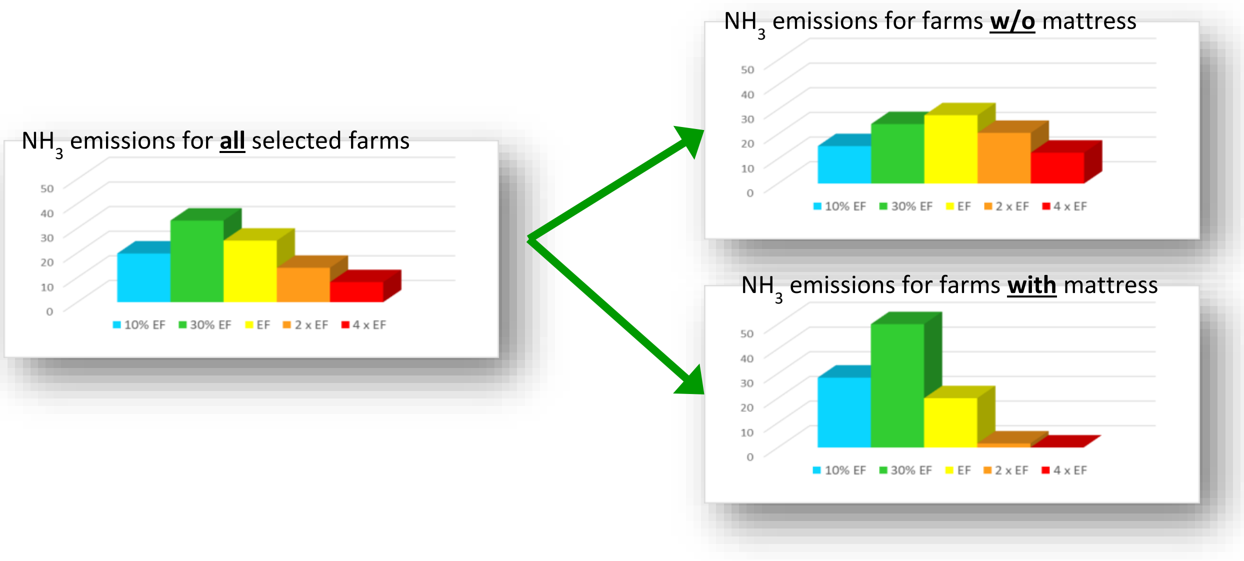


Figure 22 : Effect of having mattress as livestock bedding on ammonia emissions

2.4.3. Methane emissions

Accuracy of the measuring method could not allow distinguishing between herds where animals would have lower methane emissions.

Dispersion of the observed methane emissions showed that clear links with liquid or manure management could not be established: in all types of manure management systems, both high and low emitting houses where observed.

2.4.4. Nitrous oxide emissions

In most farms nitrous oxide emissions were in the range predicted by average emission factor.

In one case (category 8 - Table 1) high nitrous oxide emissions were repeatedly observed in the house. A clear explanation could not be found. We hypothesize that in one case it was due to reuse of dried manure as bedding, associated with a moist litter that could stimulate the denitrification processes on the floor. In another case it could be due to frequent turning of the litter, associated with a limited input of bedding material, leading to denitrification processes more intense than immobilization of excreted nitrogen as stable organic compounds.

In one case (category 1 - Table 1) low nitrous oxide emissions were repeatedly observed in the house. It showed that decreasing these emissions are feasible through transferring good farmer practices between similar farms in the same region and checking the results with the current method.

2.5. Discussion

2.5.1. Decreasing emissions at country or farm scale?

Observed emissions were highly variable and hardly predictable. We hypothesize that current models of ammonia, methane or nitrous oxide emission are too simple to integrate all interactions between climate, animal specificities, building characteristics and farmer practices. Such models can certainly be developed but the cost of recording all input parameters for all types of farms in all countries might be high. In addition, the time and cost of development and validation of such models for all farms might be high as well. Therefore, their development could be prioritized to the systems that mostly contribute to country emission. In this case they could be used to anticipate the effect of future technical changes (animals, feeding, manure, climate, etc.) on emissions and limit the risk of future increases at country scale. On the contrary, in livestock farming systems that have a high complexity and a low contribution to the country emission, the cost of such model development could appear excessive. In this case, the multiplication of emission estimates can both help to a better knowledge in country emissions and a pragmatic transfer of good practices between similar farms in the same region, having a similar technical and economic environment. This is why this low-cost method usable by non-expert people has been developed.

2.5.2. Perspectives

From current results, the high variability of observed emissions shows that even the tier 1 approach, based on gaseous measurements without an accurate knowledge in the livestock building carbon budget, can help identify good practices and "hot spots" of gas emissions at the building scale.

The limited cost of this approach can help develop surveys and databases that will then lead to both a better knowledge in actual emission factors and to the development and optimization of the strategies to reduce gas emissions.

In those farms where opportunities of gas emission decreases are identified, the tier 2 approach will be best suited to develop understanding of the high emissions and confirm the decrease in emissions after changes in terms of material and/or practices.

Acknowledgements

The authors want to thank all partners and people who contacted the farmers, performed all on-farm measurements and were involved more less directly in the WP1.5. task ensuring, in doing so, the success of this study:

- Becciolini V., University of Florence, Via san Bonaventura 13, 50145 Firenze, Italy
- Cieślak A. Poznan University, Wolynska 33, 60-637 Poznan, Poland
- Fehmer L., Justus Liebig Universität, Ludwigstraße 21 b 35390 , 35390 Gießen, Germany
- Galama P., Wageningen Livestock Research, De Elst 1, 6708 WD Wageningen, the Netherlands
- Hargreaves P., SRUC, Barony Campus, Parkgate, DG1 3NE Dumfries, United Kingdom
- Juškienė V., Lithuanian University of Health Sciences , R. Zebenkos, 1282317 Baisogala, Lithuania
- Kadžiene G., Lithuanian University of Health Sciences , R. Zebenkos, 1282317 Baisogala, Lithuania
- Leso L., University of Florence, Via san Bonaventura 13, 50145 Firenze, Italy
- Priekulis J., Latvia University of Life Sciences and technologies, Faculty of Engineering, 5 J. Cakstes Blvd., Jelgava, Latvia LV-3001
- Rees B., SRUC, Barony Campus, Parkgate, DG1 3NE Dumfries, United Kingdom
- Ruska D., Latvia University of Life Sciences and technologies, Faculty of Agriculture, Institute of Animal Sciences, 2 Liela street, Jelgava, Latvia, LV – 3001
- Schilder H., Wageningen Livestock Research, De Elst 1, 6708 WD Wageningen, the Netherlands
- Szumacher-Strabel M., Poznan University, Wolynska 33, 60-637 Poznan, Poland