

Simplified method developed for estimating the on-farm GHG and NH₃ emissions **Presentation and Results**

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Road map...



- *I. Development of the “Simplified Method”*
- *II. Results based on an international study*
- *III. Interest and perspectives*



• I. Development of the “Simplified Method”

Objectives :

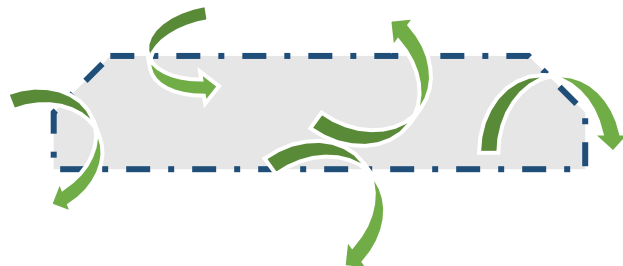
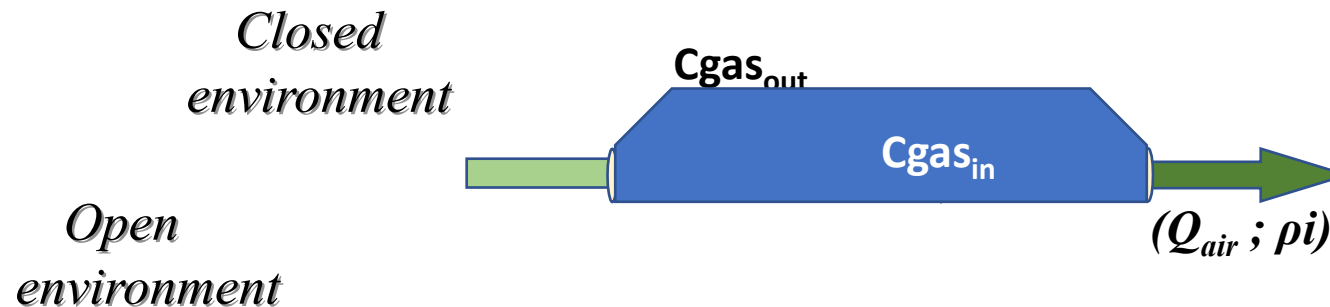
Gas emission estimates (NH_3 , CO_2 , CH_4 , N_2O) in open barns, for non-expert people, at low costs

The issue :

Calculations with air fluxes and gas concentration gradients :

$$\text{Emissions}_{\text{Gas}} = (Q_{\text{air}} \times \rho_i) \times (C_{\text{gas}_{\text{in}}} - C_{\text{gas}_{\text{out}}})$$

- Q_{air} : air flow rate
- ρ_i : air density
- C_{gas} : gas concentration



In open barns how to estimate the air flow rate in a simple way so that non-expert people can do it, and with acceptable costs ...?



• I. Development of the “Simplified Method”

Objective :

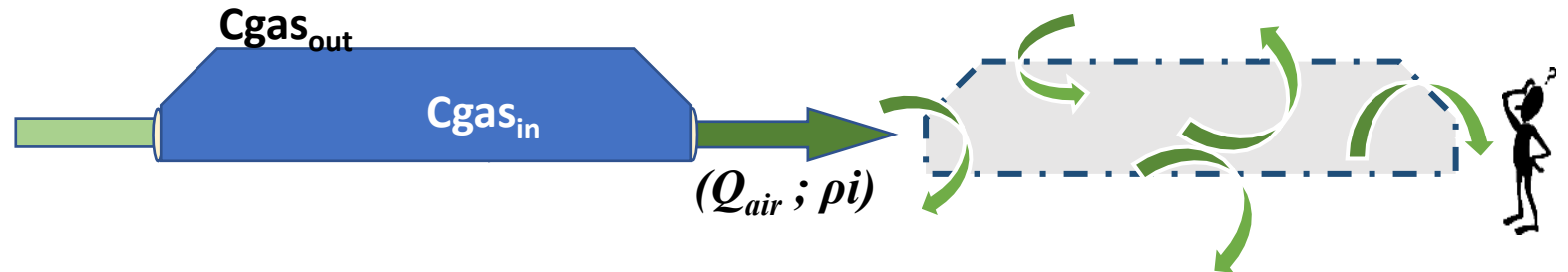
Gas emission estimates in open barns (NH_3 , CO_2 , CH_4 , N_2O)

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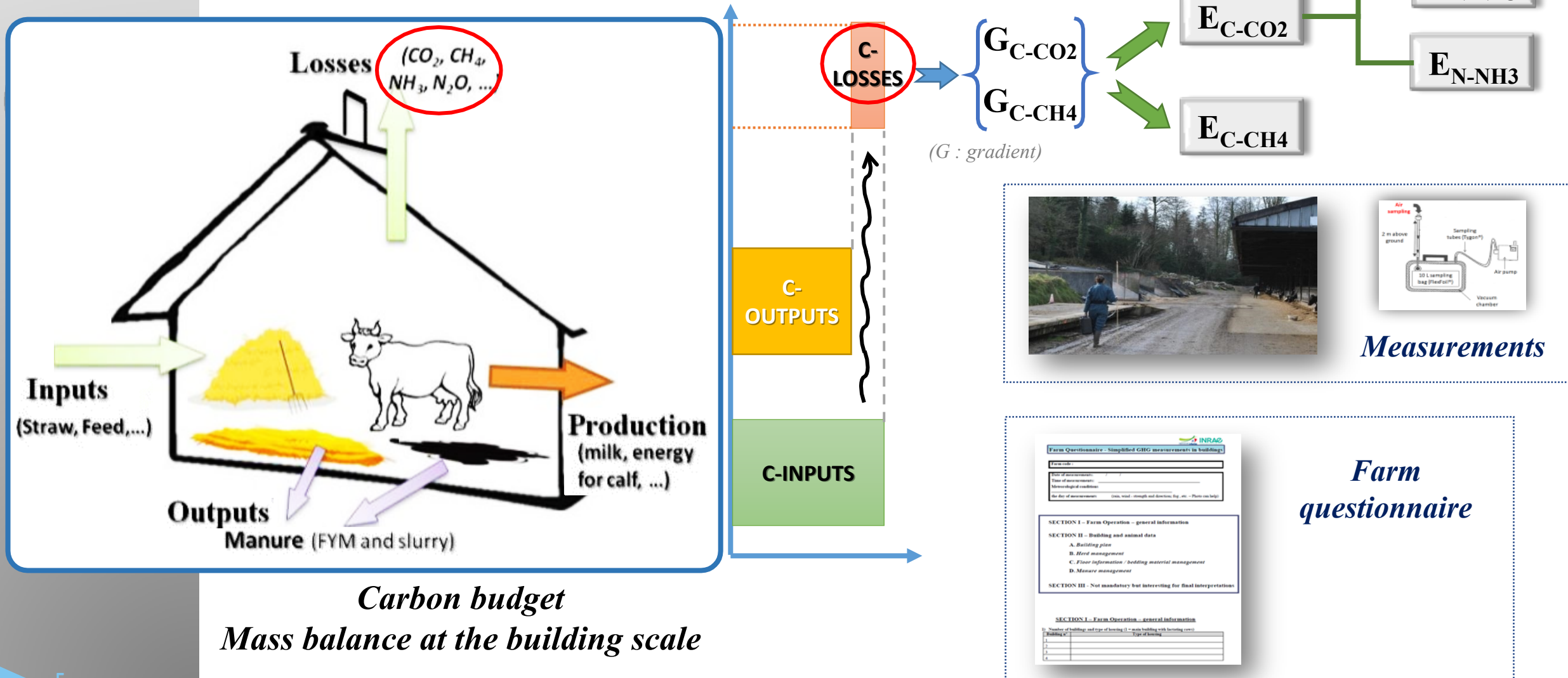


Solution :

Replacing air flow rate measurements
by estimating carbon budget in
livestock buildings



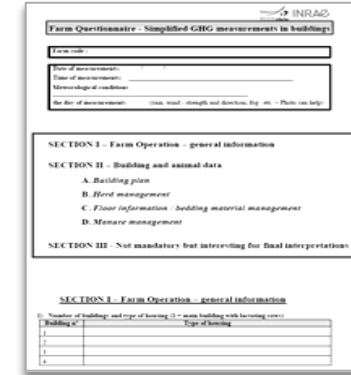
• I. Development of the “Simplified Method”



• *I. Development of the “Simplified Method”*

Quality Control

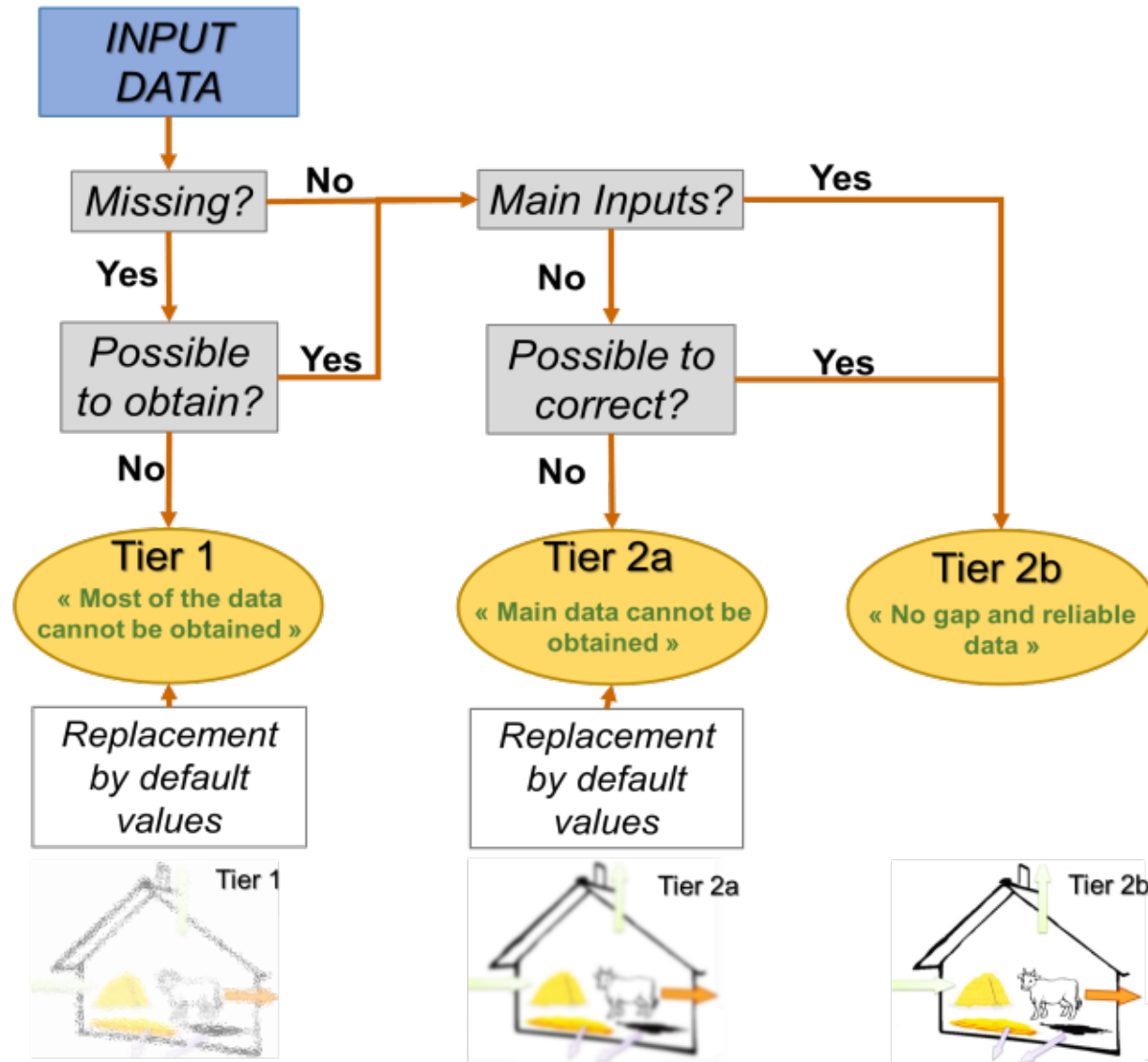
The first step of the method consist in checking all data input from the questionnaire



Depending on the level of data reliability three tiers have been defined:

- | | | |
|--|--------|--------------------------------|
| 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 |

• I. Development of the “Simplified Method”



Road map...



- *I. Development of the “Simplified Method”*
- *II. Results based on an international study*
- *III. Interest and perspectives*



• II. Results (ClimateCareCattleFarming 2020-2023)

CCCFarming is :

- 8 countries
- 60 dairy farms
- **264 measurements** and about 1 000 EF calculations
- With a wide range of dairy production systems :

Housing

- Cubicle, slatted floor
- Cubicle, sloping straw floor
- Cubicle, deep straw
- Cubicle with sand bedding and rubber floor
- Freewalk wood chips
- Compost bedded pack barn
- Compost barn, scraping alley
- Tie stall, deep straw
- Tie stall, scraping alley

Climate data	Temp. _{out}
	(°C)
Avg ± SD	13.6 ± 8.6
[min ; max]	[-3.2 ; 36.0]

In-barn Sampling	CO ₂	CH ₄	NH ₃	N ₂ O
	(mg.m ⁻³)	(mg.m ⁻³)	(mg.m ⁻³)	(mg.m ⁻³)
Avg ± SD	1121 ± 495	22.2 ± 39.4	0.60 ± 0.49	0.71 ± 0.44
[min ; max]	[116 ; 5155]	[0.4 ; 352.4]	[0.01 ; 2.83]	[0.34 ; 4.91]

Farm Characteristics	Area	Cows pop.	Weight	Feed	Milk	Fat	Protein
	(m ² .cow ⁻¹)	(anim.house ⁻¹)	(kg.cow ⁻¹)	(kg DM. cow ⁻¹)	(kg day ⁻¹)	(g.L ⁻¹)	(g.L ⁻¹)
Avg ± SD	11 ± 6	132 ± 127	678 ± 59	22 ± 3	29 ± 7	42 ± 4	34 ± 2
[min ; max]	[2 ; 51]	[11 ; 1009]	[450 ; 825]	[6 ; 31]	[10 ; 56]	[32 ; 52]	[30 ; 40]



• II. Results (ClimateCareCattleFarming 2020-2023)

The screenshot shows the 'CCCfarming_Emission_flyer_v10_uncertainty.xlsx' spreadsheet. The interface includes a menu bar (Fichier, Accueil, Insertion, etc.), a formula bar, and a grid of data. A yellow banner at the top reads 'DO NOT INSERT COLUMNS unless all formulas using this sheet are manually updated'. A green banner below it says 'processing: input data for uncertainty estimates'. The data table has columns for various inputs and outputs, including tier levels, bedding input, milk production, and gas concentrations. Annotations include:

- EF - Calculator**: A large blue box covering the top part of the data table.
- Tier 1 or 2_{A,B} applied**: A yellow speech bubble pointing to the 'tier level for DM feed input' column.
- Quality Control**: A yellow speech bubble pointing to the 'Simplified-Method_INPUT_3.0_Italy_farm3-season4.xlsx' row.
- Calculations**: A green speech bubble pointing to the 'Bedding input (kg/cow/day)' column.
- Results factsheet**: A blue speech bubble pointing to the 'milk production (kg/day cow)' column.
- Interpretation**: A grey speech bubble pointing to the 'Gaz concentration (mg/m3) INDOOR_N2O' column.

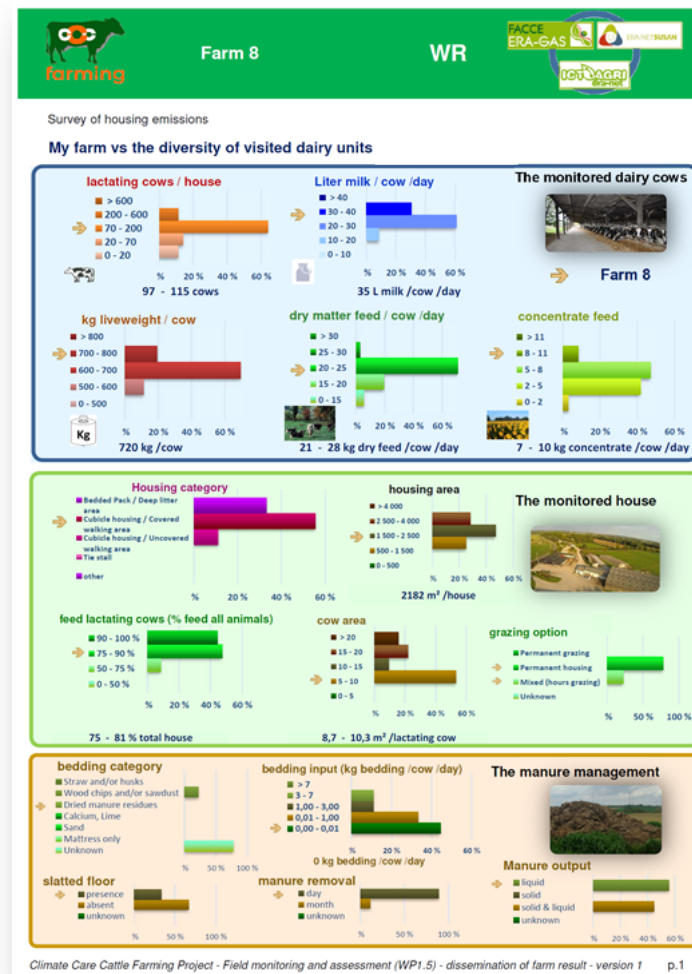
At the bottom, a red circle highlights the 'File Monitor', 'DataExtracted', 'Parameters', 'emissions', 'emission interval', 'Flyer Data', 'messages', 'Emission flyer', 'Freq_all_data', 'Freq_Country', and 'Freq' tabs.

Filename (date observation)	tier 3 feeding cows DM feed kg/cow/day	tier level for DM feed input	Bedding input (kg/cow/day)	tier level for total C input	milk production (kg/day cow)	Fat/milk (g/L)	Protein/milk (g/L)	Temp Outdoor (°C)	Gaz concentration (mg/m3) INDOOR_N2O	Gaz concentration (mg/m3) OUTDOOR_N2O	Gaz concentration (mg/m3) INDOOR_CO2	conc (m	
Simplified-Method_INPUT_3.0_Italy_farm3-season4.xlsx (2022-02-01)	700	23,0	23,0	3	3,5	3	0,5	45,0	37,2	8,3	0,780	0,8	1241
Simplified-Method_INPUT_3.0_Italy_farm4-season1.xlsx (2021-04-07)	750	24,0	24,0	3	1,4	3	0,7	41,3	35,5	13,6	0,645	0,6	1096
Simplified-Method_INPUT_3.0_Italy_farm4-season2.xlsx (2021-06-22)	775	23,0	23,0	3	0,8	3	0,7	39,2	35,1	32,7	0,615	0,6	906
Simplified-Method_INPUT_3.0_Italy_farm4-season3.xlsx (2021-08-14)	700	25,0	25,0	3	0,7	3	0,7	38,7	34,4	16,8	0,665	0,7	921
Simplified-Method_INPUT_3.0_Italy_farm4-season4.xlsx (2021-10-31)	750	22,7	22,7	3	0,8	3	0,7	42,6	47,2	9,2	0,766	0,8	1114
Simplified-Method_INPUT_3.0_Italy_farm4-season5.xlsx (2021-12-29)	670	22,2	22,2	3	0,5	3	0,7	37,4	38,6	12,1	0,657	0,6	1032
Simplified-Method_INPUT_3.0_Italy_farm5-season1.xlsx (2021-07-08)	780	18,4	18,4	3	0,5	3	0,7	37,4	38,6	30,4	0,633	0,6	1004
Simplified-Method_INPUT_3.0_Italy_farm5-season2.xlsx (2021-10-07)	750	22,7	22,7	3	0,5	3	0,7	42,6	47,2	9,2	0,766	0,8	1114
Simplified-Method_INPUT_3.0_Italy_farm5-season3.xlsx (2022-01-27)	750	22,7	22,7	3	0,5	3	0,7	42,6	47,2	9,2	0,766	0,8	1114
Simplified-Method_INPUT_3.0_Italy_farm5-season4.xlsx (2022-03-30)	750	22,7	22,7	3	0,5	3	0,7	42,6	47,2	9,2	0,766	0,8	1114
Simplified-Method_INPUT_3.0_Italy_farm5-season5.xlsx (2021-07-09)	750	22,7	22,7	3	0,5	3	0,7	42,6	47,2	9,2	0,766	0,8	1114
Simplified-Method_INPUT_3.0_Italy_farm5-season6.xlsx (2021-10-06)	700	25,1	25,1	3	0,7	3	0,7	37,4	38,6	12,1	0,657	0,6	1032
Simplified-Method_INPUT_3.0_Italy_farm5-season7.xlsx (2022-01-28)	700	25,1	25,1	3	0,7	3	0,7	37,4	38,6	12,1	0,657	0,6	1032
Simplified-Method_INPUT_3.0_Latvia_farm1-season1.xlsx (2021-05-13)	650	24,1	24,1	3	0,7	3	0,7	37,4	38,6	12,1	0,657	0,6	1032
Simplified-Method_INPUT_3.0_Latvia_farm1-season2.xlsx (2021-08-09)	650	24,1	24,1	3	0,7	3	0,7	37,4	38,6	12,1	0,657	0,6	1032

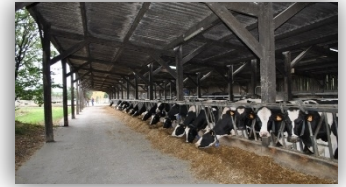
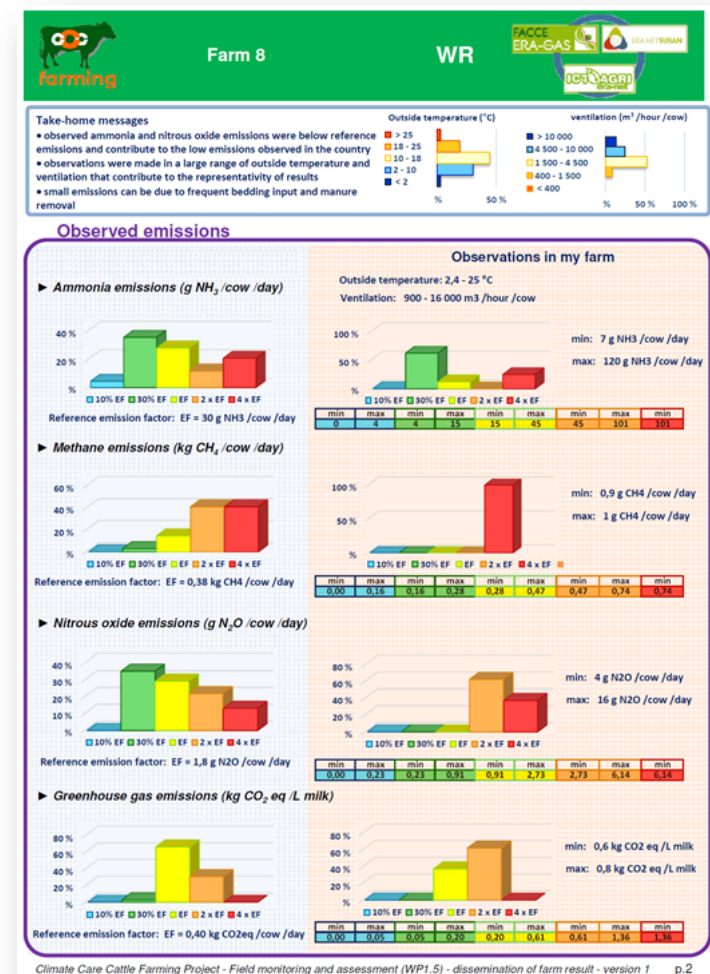
• II. Results (CCCFarming 2020-2023)

Overview of the results

Horizontal bars are for farm description



Vertical bars are for EF calculations



• II. Results (CCCFarming 2020-2023)

Graphs are for the
reference situation

Presentation of the
farm situation

Liter milk / cow /day

■ > 40

■ 30 - 40

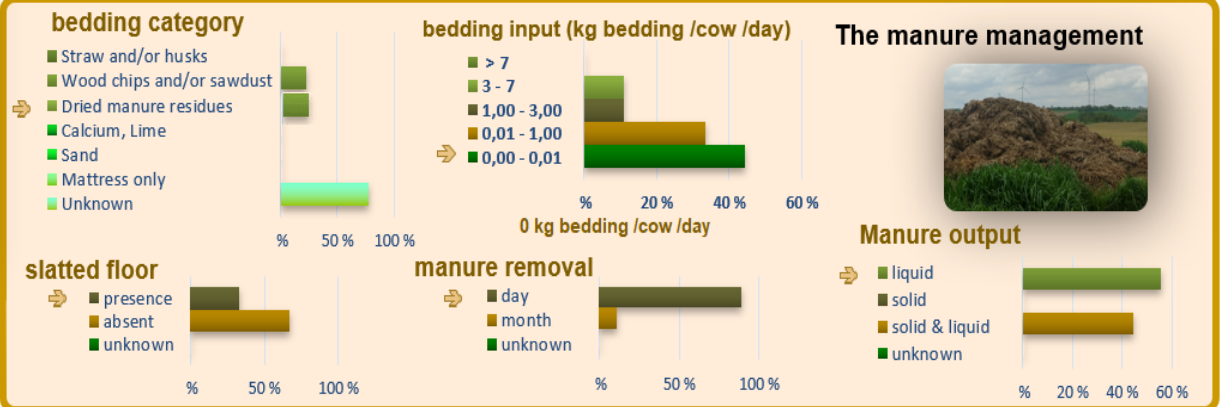
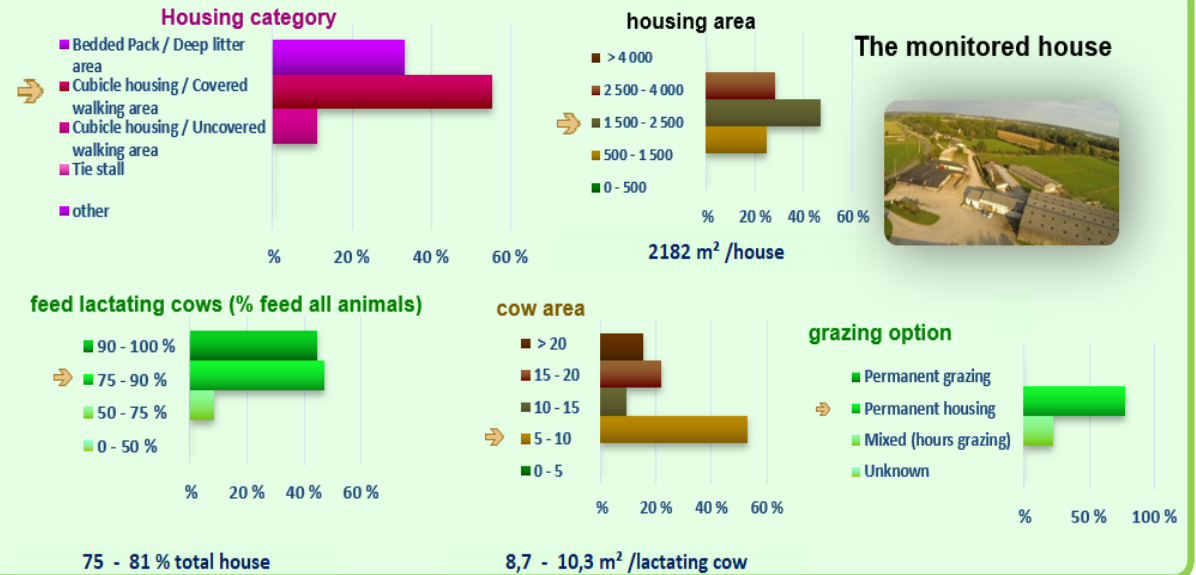
■ 20 - 30

■ 10 - 20

■ 0 - 10

% 20 % 40 % 60 %

35 L milk /cow /day

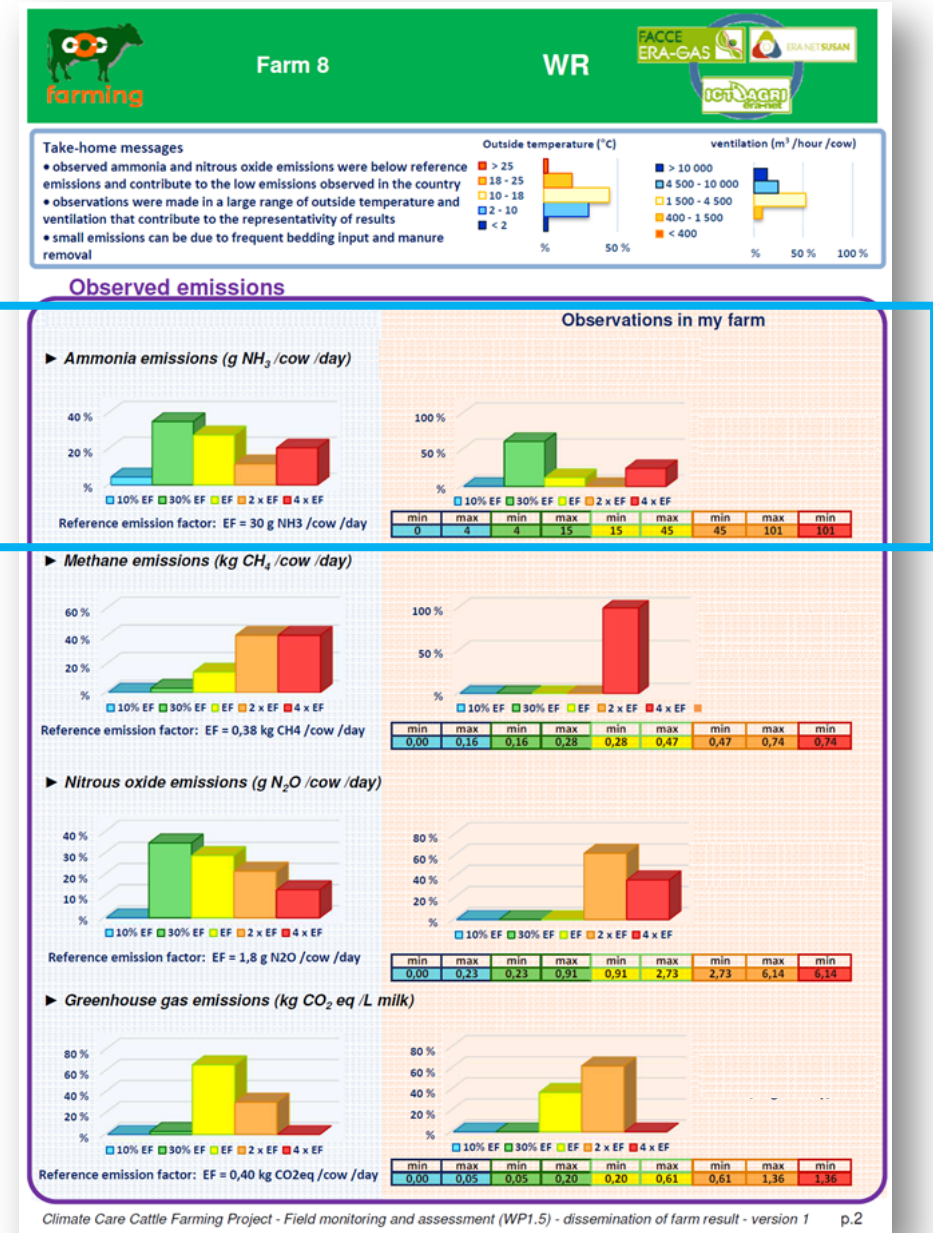


• II. Results (CCCFarming 2020-2023)



Left graphs show the country situation

Right graphs show the farm situation



• II. Results (CCCFarming 2020-2023)

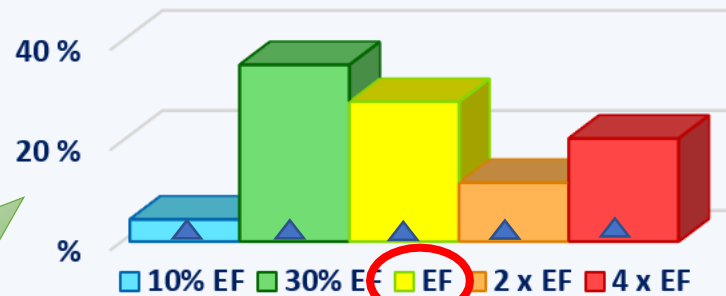
The farm (or country) is **NOT** characterized by only one EF for a specific year

BUT by the EF distribution over the year



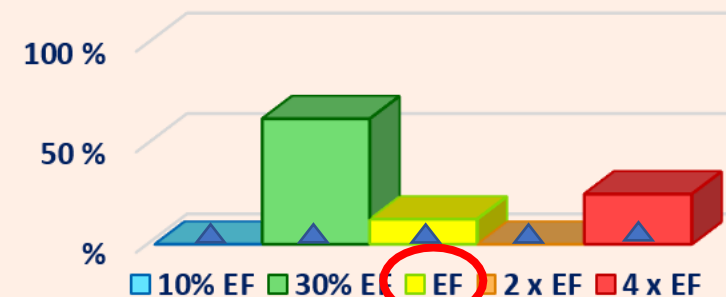
Observations

► Ammonia emissions (g NH₃ /cow /day)



Frequency

Observations in my farm



min	max	min	max	min	max	min	max	min
0	4	4	15	15	45	45	101	101

EFs distributed in 5 classes :

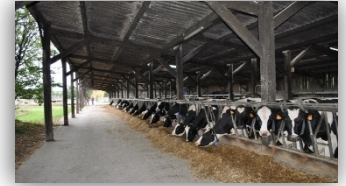
- 10% EF — Much lower
- 30% EF — Lower
- EF — Neutral
- 2x EF — Higher
- 4x EF — Much higher

It represents the « **signature** » of the farm over the year

- *II. Results (CCCFarming 2020-2023)*

OBJECTIVE

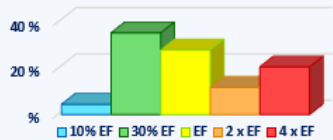
The objective of this method is to **point out « hot spots »** or **good practices**, compared to average results, to help implementing mitigation strategies



• II. Results (CCCFarming 2020-2023)

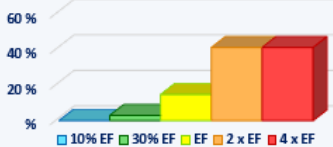
Observed emissions

► Ammonia emissions (g NH₃/cow /day)



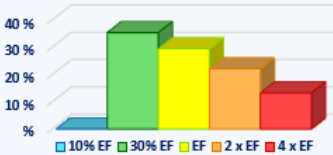
Reference emission factor: EF = 30 g NH₃ /cow /day

► Methane emissions (kg CH₄/cow /day)



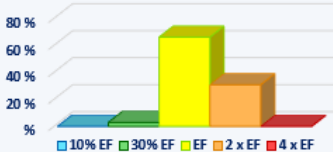
Reference emission factor: EF = 0,38 kg CH₄ /cow /day

► Nitrous oxide emissions (g N₂O /cow /day)



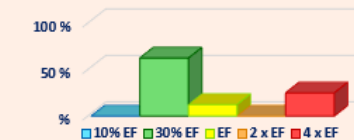
Reference emission factor: EF = 1,8 g N₂O /cow /day

► Greenhouse gas emissions (kg CO₂ eq /L milk)



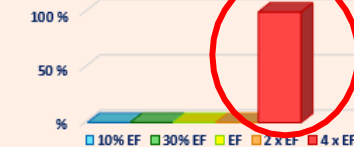
Reference emission factor: EF = 0,40 kg CO₂eq /cow /day

Observations in my farm



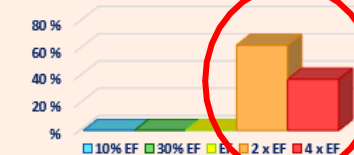
min max min max min max min max min

0 4 4 15 15 45 45 101 101



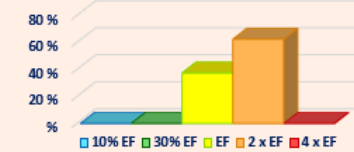
min max min max min max min max min

0,00 0,16 0,16 0,28 0,28 0,47 0,47 0,74 0,74



min max min max min max min max min

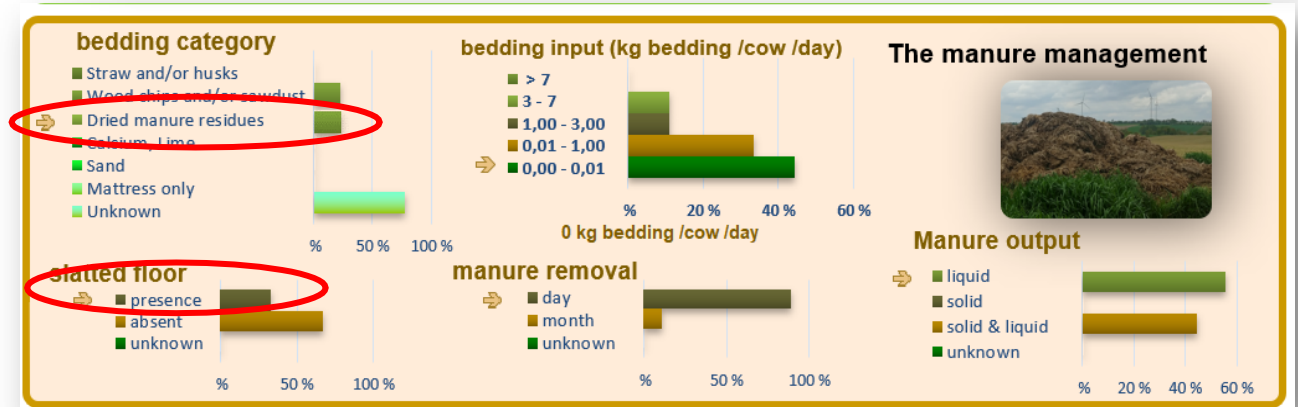
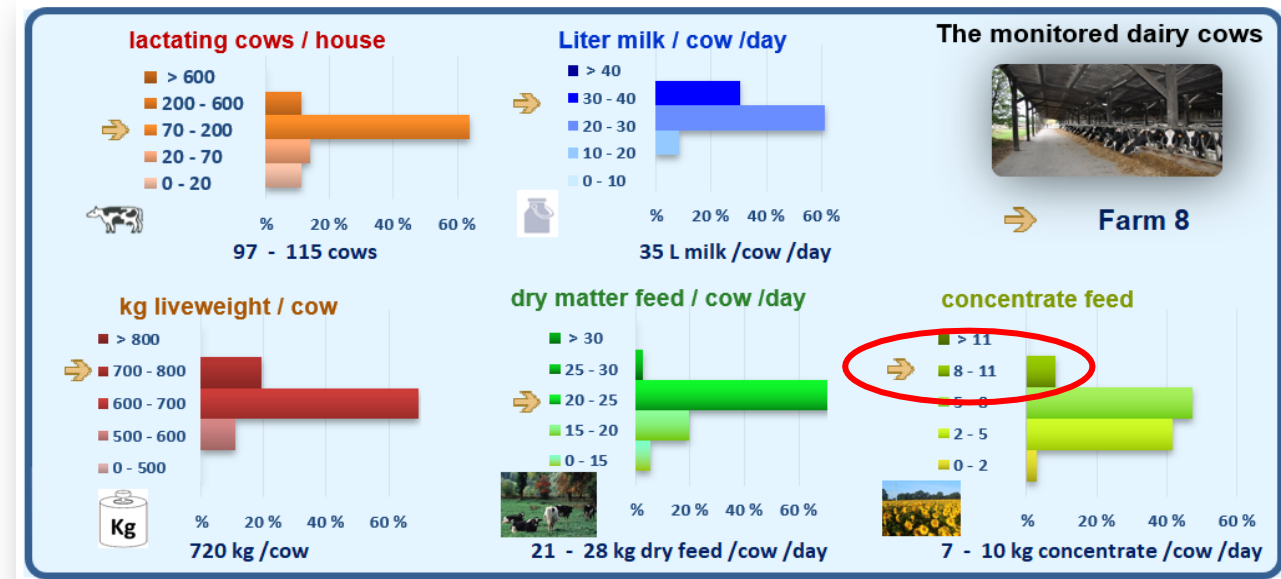
0,00 0,23 0,23 0,91 0,91 2,73 2,73 6,14 6,14



min max min max min max min max min

0,00 0,05 0,05 0,20 0,20 0,61 0,61 1,36 1,36

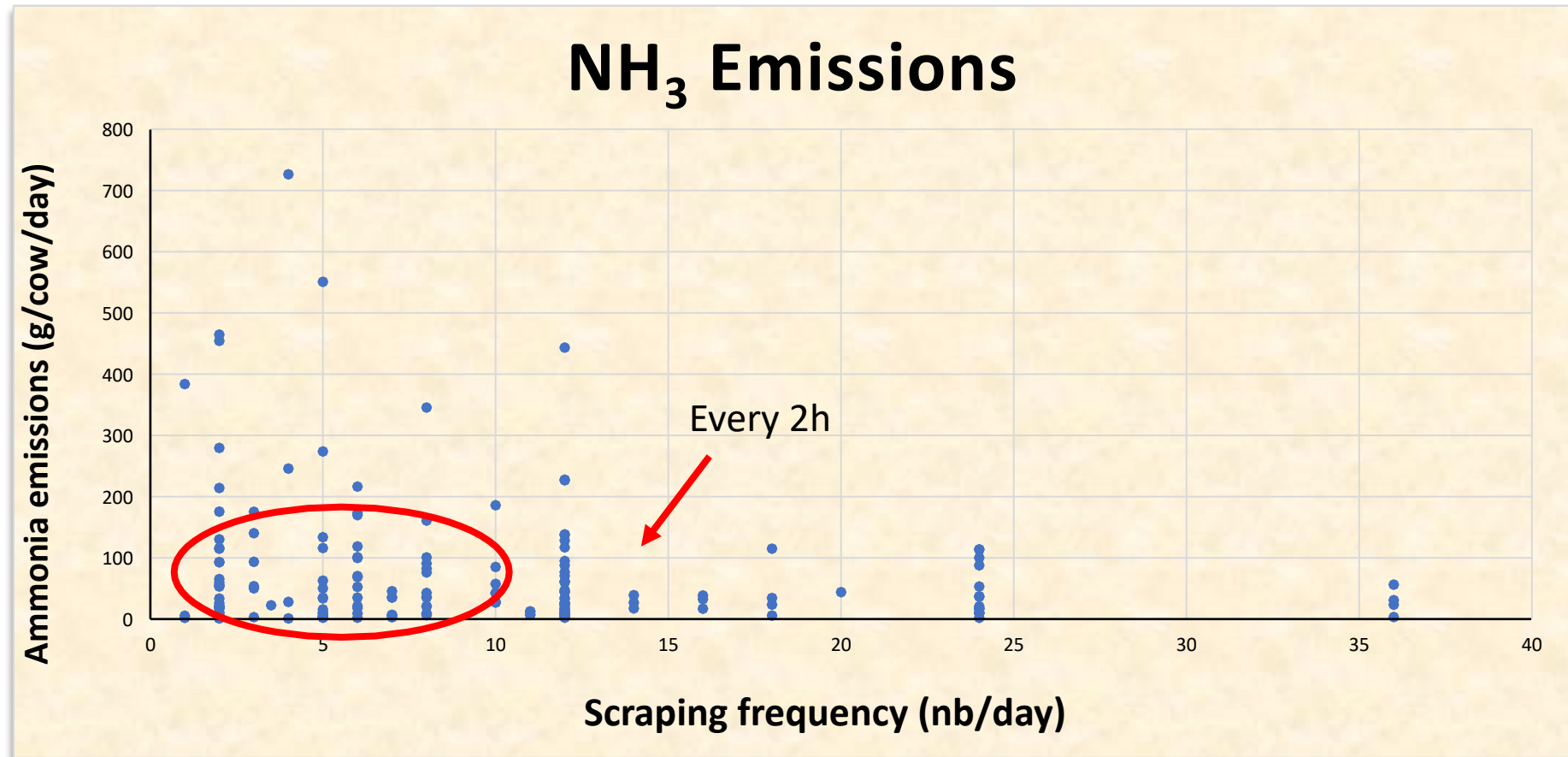
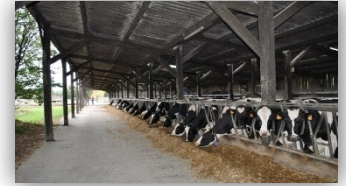
EXAMPLE « HOT SPOT »



- *II. Results (CCCFarming 2020-2023)*

EXAMPLE
« GOOD PRACTICES »

High Scraping frequency decrease the risk of having high NH_3 emissions



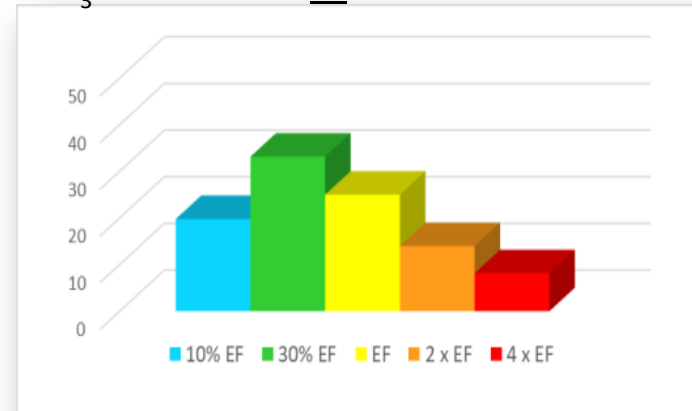
• II. Results (CCCFarming 2020-2023)

EXAMPLE « GOOD PRACTICES »

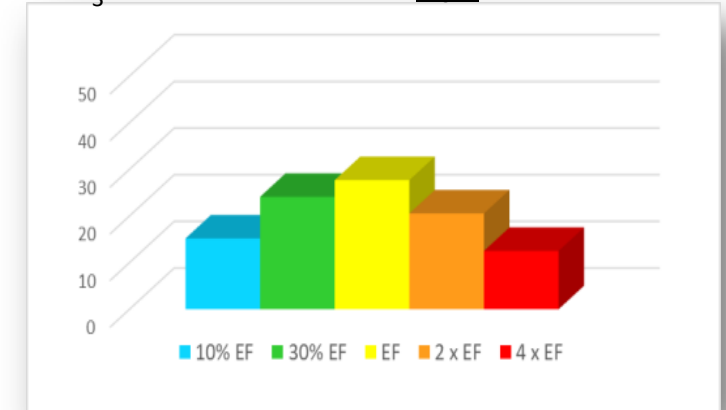
Presence of Mattress

All buildings with mattress showed low NH₃ emissions

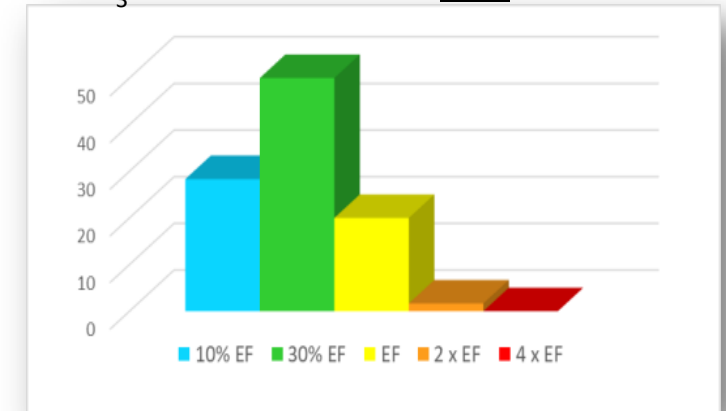
NH₃ emissions for **all** selected farms



NH₃ emissions for farms **w/o** mattress



NH₃ emissions for farms **with** mattress



Criteria for farm selection:

similar housing:

- ratio resting /walking area: 0,5 - 3 m² resting / m² walking
- slatted floor : excluded (absent or unknown)
- bedding: 0 - 5 kg litter /cow /day
- permanent housing (no grazing)

similar herd data:

- cow population: 20 - 220 dairy cow / house
- milk production: 20 - 45 L milk/day
- feed: 12 - 22 kg DMI/day



Road map...



- *I. Development of the “Simplified Method”*
- *II. Results based on an international study*
- *III. Interest and perspectives*



• *III. Interest and perspectives*

1. The “Simplified Method” uses Carbon budget instead of air flow rate

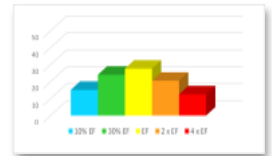


2. Designed to be used by non-expert people and for acceptable costs

3. Robust method applied to a high number and diversity of farming systems

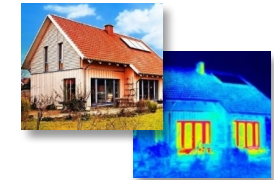


4. The “farm signature” is based on the EF occurrence within classes of values



5. Objectives are to bring out « hot spots » or better management practices, ie:

- decreasing the value and frequency of high emissions
- increasing frequency of low emissions and disseminating to other farms



• *III. Interest and perspectives*



There is a need to do as many on-farm measurements as possible to obtain a reliable “farm signature” and to evaluate as many farm as possible at the national level to set the most reliable “country signature” (which is used as reference).

Since it has been designed to be used by non-expert people and at low cost, it is achievable.



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Paul Robin : paul.robin@inrae.fr

Thank you for your attention

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idele.fr







ANNEXES



Annexes – Method development

$$Emissions_{Gas} = (Q_{air} \times \rho_i) \times (C_{gas_{in}} - C_{gas_{out}})$$

- Q_{air} : air flow rate
- ρ_i : air density
- C_{gas} : gas concentration

$$Emissions_{Gas} = A \times G_{gas}$$

$$A = \frac{E_{C-CH_4}}{G_{C-CH_4}} = \frac{E_{C-CO_2}}{G_{C-CO_2}} = \frac{E_{N-N_2O}}{G_{N-N_2O}} = \frac{E_{N-NH_3}}{G_{N-NH_3}}$$

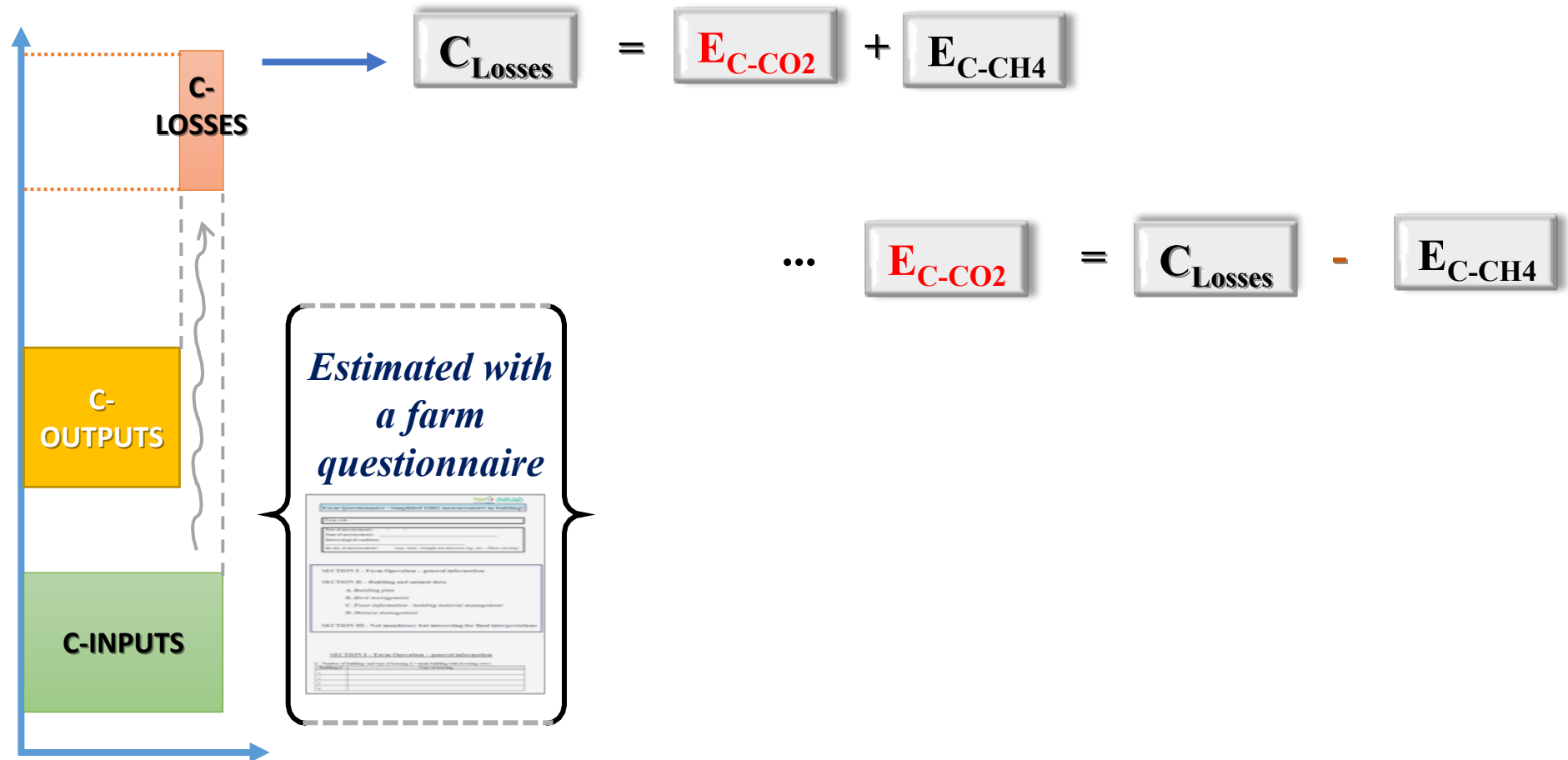


$$E_{C-CH_4} = E_{C-CO_2} \times \frac{G_{C-CH_4}}{G_{C-CO_2}}$$

$$E_{N-N_2O} = E_{C-CO_2} \times \frac{G_{N-N_2O}}{G_{C-CO_2}}$$

$$E_{N-NH_3} = E_{C-CO_2} \times \frac{G_{N-NH_3}}{G_{C-CO_2}}$$

Annexes – Method development



$$A = \frac{E_{\text{C-CH}_4}}{G_{\text{C-CH}_4}} = \frac{E_{\text{C-CO}_2}}{G_{\text{C-CO}_2}} = \dots \quad E_{\text{C-CH}_4} = E_{\text{C-CO}_2} \times \frac{G_{\text{C-CH}_4}}{G_{\text{C-CO}_2}}$$

Annexes – Method development

Since :

$$E_{C-CO_2} = C_{Losses} - E_{C-CH_4}$$



And :

$$E_{C-CH_4} = E_{C-CO_2} \times \frac{G_{C-CH_4}}{G_{C-CO_2}}$$



Then ...

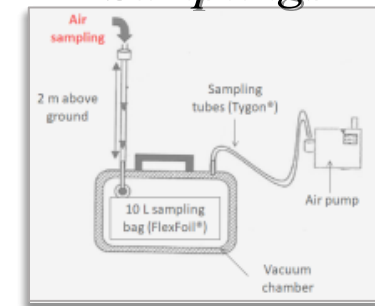
$$E_{C-CO_2} = \frac{C_{Losses}}{\left(1 + \frac{G_{C-CH_4}}{G_{C-CO_2}}\right)}$$

=

Questionnaire

The questionnaire form includes sections for:

- SECTION 1 - Farm Operation - general information
- SECTION 2 - Building and animal data
 - A. Building plan
 - B. Animal management
 - C. Floor information - building material management
 - D. Manure management
- SECTION 3 - Not mandatory but interesting for final interpretation
- SECTION 4 - Farm Operation - general information

Samplings

Annexes – Method development

$$Emissions_{Gas} = (Q_{air} \times \rho_i) \times (C_{gas_{in}} - C_{gas_{out}})$$

$$Emissions_{Gas} = A \times G_{gas}$$

$$A = \frac{E_{C-CH_4}}{G_{C-CH_4}} = \frac{E_{C-CO_2}}{G_{C-CO_2}} = \frac{E_{N-N_2O}}{G_{N-N_2O}} = \frac{E_{N-NH_3}}{G_{N-NH_3}}$$

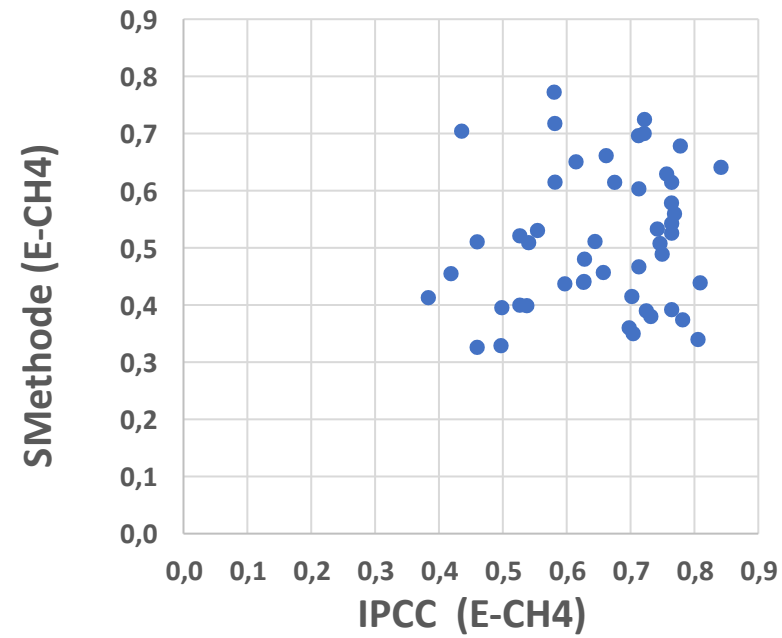


$$E_{C-CH_4} = E_{C-CO_2} \times \frac{G_{C-CH_4}}{G_{C-CO_2}}$$

$$E_{N-N_2O} = E_{C-CO_2} \times \frac{G_{N-N_2O}}{G_{C-CO_2}}$$

$$E_{N-NH_3} = E_{C-CO_2} \times \frac{G_{N-NH_3}}{G_{C-CO_2}}$$

CH₄ (Efmt+Mnre) emissions - SMethode/IPCC (kg/cow/day)



Method	Max	Min	Average	Median
Simplified Method	0.77	0.33	0.51	0.51
IPCC methodology	0.84	0.38	0.65	0.70
Difference	-0,07	-0,06	-0,14	-0,19