Update on sensor technologies for performance recording, management and welfare of small ruminants

(Abstract #42845)

Gerardo Caja (gerardo.caja@uab.es)
Group of Research in Ruminants (G2R), Department of Animal and Food Sciences,
Universitat Autònoma de Barcelona (UAB), Bellaterra, Barcelona (Spain)

Monday 28 August, Session 13: Innovation & technological advancements in small ruminants

G2R Grup Recerca Remugants

UAB Universitat Autònoma de Barcelona

TECH CARE
Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

European Commission | Horizon 2020 European Union funding for Research & Innovation

The small ruminant (SR) scenario for new technologies: 1/2

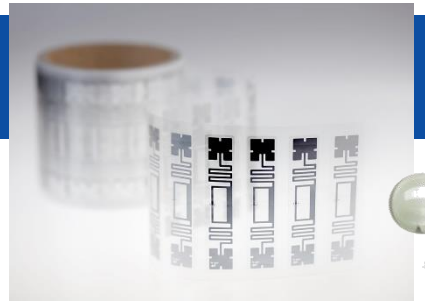
Small ruminants (SR) are:

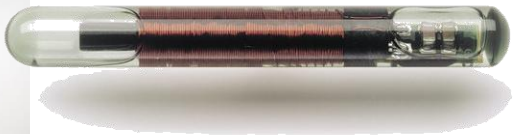
- The **largest 4-legged livestock population in the world**: 2,391 Mhead (sheep:goats = 53:47; FAOstat, 2023).
- Located on **poor resources and facilities'** areas, where they are key for **employment and capitalization** (*pecora = money*).
- Their products are **favorably considered by consumers** (e.g. Asian and Mediterranean countries) because health, quality and welfare.
- Their **farm size tends to increase** to compensate the rise of costs and the decline of profits.
- They need **new tools** for **performance recording, management and welfare assessment: PLF** (precision livestock farming)**.**

The small ruminant (SR) scenario for new technologies: 2/2

- **SR are fully e-ID (radio frequency)** in the EU and UK, because the BSE crisis (1996) and the EU Regulations on SR's ID (2005, 2015).
- Many cost-benefit studies proved the **benefits of e-ID based on transponders in SR** (Saa et al., 2005; Ait-Saidi et al., 2008, 2014ab; Morgan-Davies et al., 2018).
- **Transponders as a tool for PLF** implementation.
- **Currently low IoT** (Internet of things) **penetration in livestock (4%) and SR (<0.1%)**.
- Expected new **developments of PLF technologies using sensors** for monitoring the production and welfare of SR (Caja et al., 2020).
- Concept and differences: **transponder vs. sensor?**

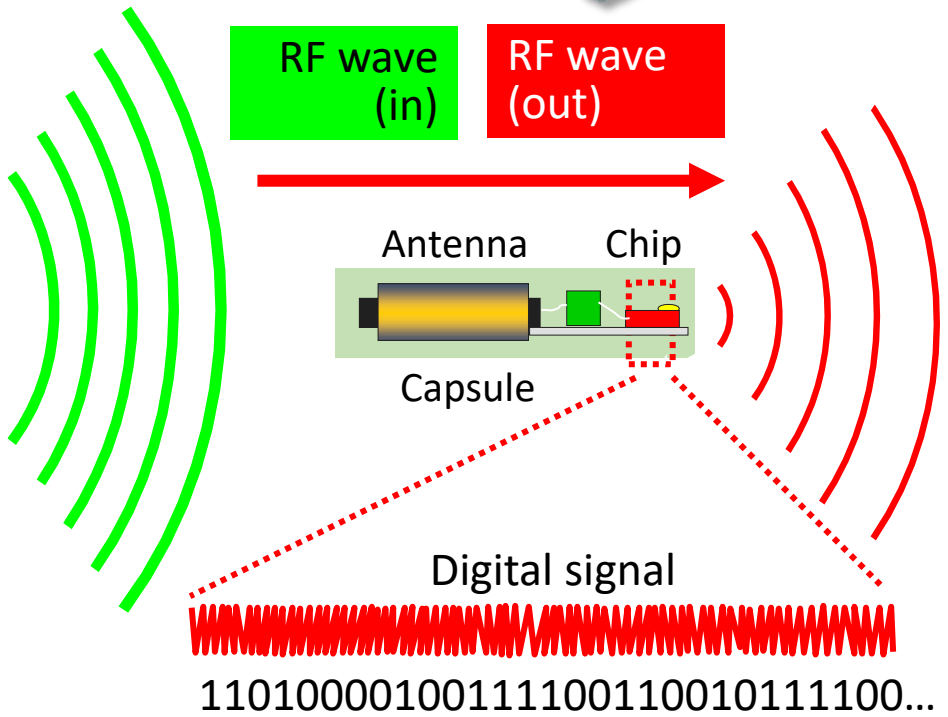
Transponders vs. Sensors: 1/2





- **Transponder (*Transmitter-responder*)**:
  So-named 'microchip': inject, eartag, bolus…
  Electronic device (e-ID) which uses radio-frequency (RF) for sending a **fix response**.

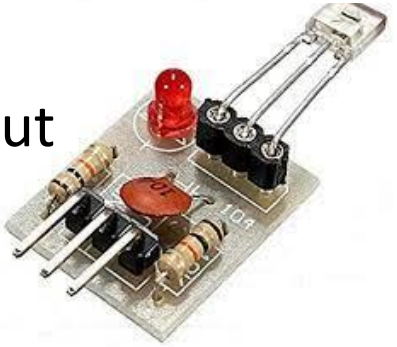
- **Typology:** Modifies their reading performances (key aspect)
  - Size: '**the greater the better**' (maximum?)
  - Power: **Passive** (no battery) vs. **Active** (with)
  - RF band:
    - **Low** (LF): 134.2 kHz (unreadable under collision)
    - **High** (HF): 13.56 MHz (printed tags)
    - **Ultra High** (UHF): 860-960 MHz (safety?)
  - RF technology (operational mode):
    - **Transmission mode**: **HDX** (Half-Duplex, 1-way) vs. **FDX** (Full-Duplex, 1 or 2-ways)
    - **Reading mode (collision)**: **LBT** (listen before talking) vs. **DRM** (dense reader mode)



Transponders vs. Sensors: 2/2

- **Sensor (*Transducer*)**:
  Input device which **produces an output** (**signal**) according to the **input quantity** (physical, chemical or biological).
  It is a part of a recording or control system.

- **Taxonomy** (NRC, 1995):
  - **Self generating sensors**: direct response (e.g. Faraday's thermistor)
  - **Modulating sensors**: able to vary their output according to a second input (e.g. fiberoptic magnetic-field, saver laser receiver…)
  - **Smart sensors**: their complexity concealed by an interface and on-chip signal (e.g. temperature controllers…)
  - Aim-related sensors: **12 main types** according to technology (Caja et al., 2020).
  - **Animal based** classification: **Wearables** or **non-wearables**



Animal based sensors: 1/2

- **Wearables:** on/in the animal (Caja et al., 2020)

Type	Technology	Indicator	Device	Usage
Transponder (not a sensor)	Radio frequency	Individual data	• Ear tag • Collar • Leg tag • Bolus • Inject	Identification, sorting, feeding, mating,…
Geographical positioning system (GPS/GNSS)	Satellite network	Position	• Collar	Virtual fencing, spatial location, grazing monitoring
	Bluetooth, LoRa	Relative distance	• Collar + ear tag	Mother-offspring relationship, feeding

Animal based sensors: 1/2

- **Wearables:** on/in the animal (Caja et al., 2020)

Type		Technology	Indicator	Device	Usage
Transponder (not a sensor)		Radio frequency	Individual data	• Ear tag • Collar • Leg tag • Bolus • Inject	Identification, sorting, feeding, mating,…
Geographical positioning system (GPS/GNSS)		Satellite network	Position	• Collar	Virtual fencing, spatial location, grazing monitoring
		Bluetooth, LoRa	Relative distance	• Collar + ear tag	Mother-offspring relationship, feeding
Sensor	**Temperature**	Thermistor	Rectal, rumen or vaginal	• Ear tag • Bolus • Inject	Health (fever), stress, heat, drinking bouts
	pH	Voltage	Rumen pH	• Bolus	Feeding, rumen function (health)
	Pressure	Several	Rumen activity	• Bolus	Rumination
	Sound	Microphone	Sound	• Bolus • Halter	Heart rate, rumination, coughing
	Acceleration	3-axial piezoelectric	Motion	• Ear tag • Bolus • Collar • Leg pedometer	Behavior: Motion, resting, feeding, rumination, lameness (health)
	Biomarker	Several	Several	• Ear tag?	Metabolites (health?)

Animal based sensors: 2/2

- **Non-Wearable:** on/in the facilities (Caja et al., 2020)

Type	Technology	Indicator	Device	Usage
Cameras	Optical imaging	Shape	• Handheld or fixed camera	Behavior, growth, supervision, stress
	Infrared imaging (IR)	Temperature	• Handheld or fixed camera	Thermometric monitoring, udder health (mastitis), head and hoof health, stress (eye)
	Near infrared (NIR)	Milk flow	• Absorbance/reflectance meters	Milk volume and flow meters
	3D imaging	3D shape	• Fixed camera	Body reserves?
	Laser beam	Height	• Fixed laser	Size, growth
Microphones	Sound	Intensity and frequency	• Fixed microphone	Coughing, lambing, acute stress

https://www.cambridge.org/core/journals/journal-of-dairy-research/article/sensing-solutions-for-improving-the-performance-health-and-wellbeing-of-small-ruminants/27931C4E696F45D282D8DE8C8F1194F0

Animal based sensors: 2/2

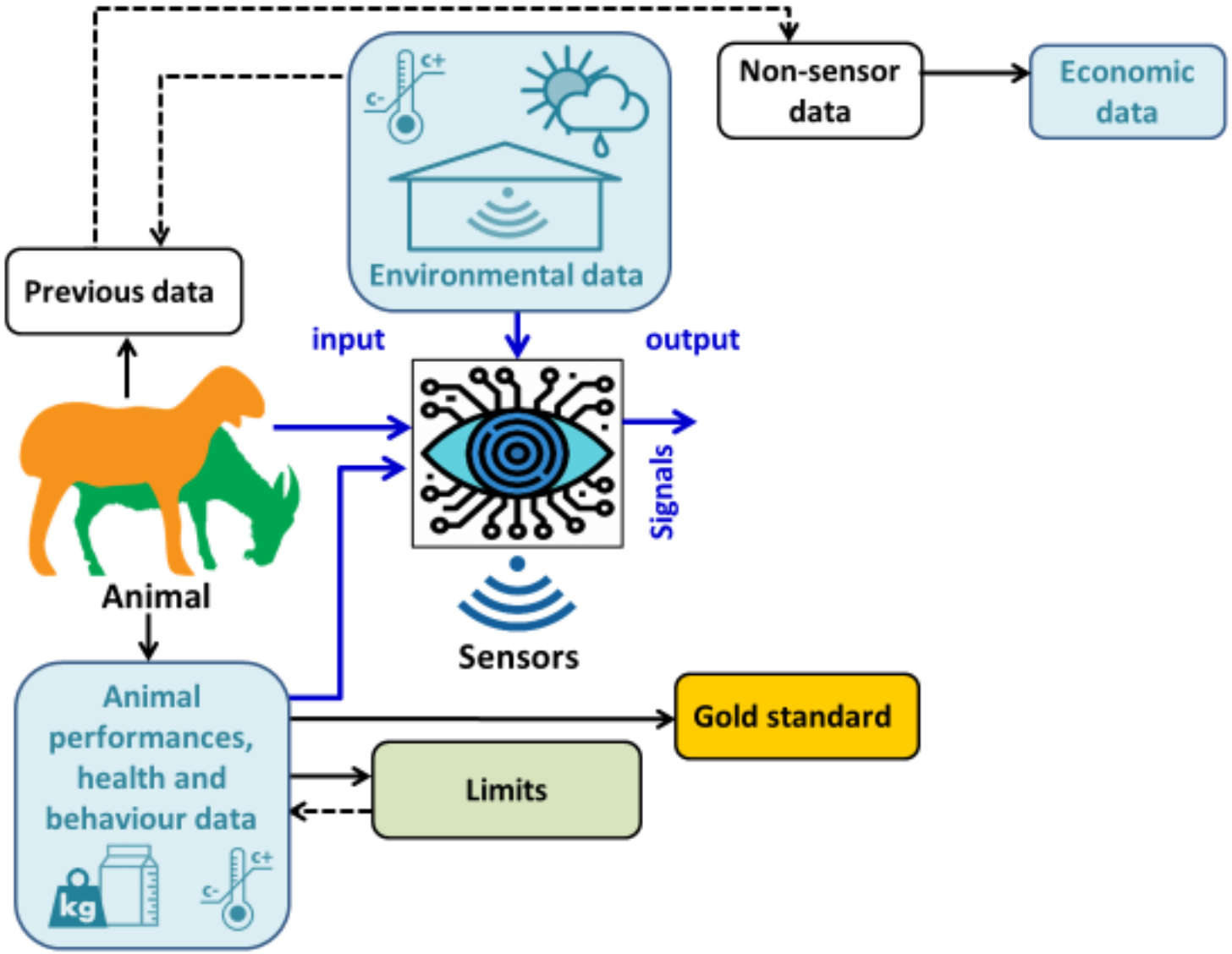
- **Non-Wearable:** on/in the facilities (Caja et al., 2020)

Type	Technology	Indicator	Device	Usage
Cameras	Optical imaging	Shape	• Handheld or fixed camera	Behavior, growth, supervision, stress
	Infrared imaging (IR)	Temperature	• Handheld or fixed camera	Thermometric monitoring, udder health (mastitis), head and hoof health, stress (eye)
	Near infrared (NIR)	Milk flow	• Absorbance/reflectance meters	Milk volume and flow meters
	3D imaging	3D shape	• Fixed camera	Body reserves?
	Laser beam	Height	• Fixed laser	Size, growth
Microphones	Sound	Intensity and frequency	• Fixed microphone	Coughing, lambing, acute stress
Weighing cells	Electromagnetic force restoration	Weight	• Electronic scales • Autodrafter scale • Walk-over-weighing • Watering-weighing	Weight, growth, intake, water, gait recording (lameness)
Ambient sensors	Several	Environmental data	• Temperature/humidity • Air quality • Soil humidity	Comfort and health monitoring, bedding

https://www.cambridge.org/core/journals/journal-of-dairy-research/article/sensing-solutions-for-improving-the-performance-health-and-wellbeing-of-small-ruminants/27931C4E696F45D282D8DE8C8F1194F0

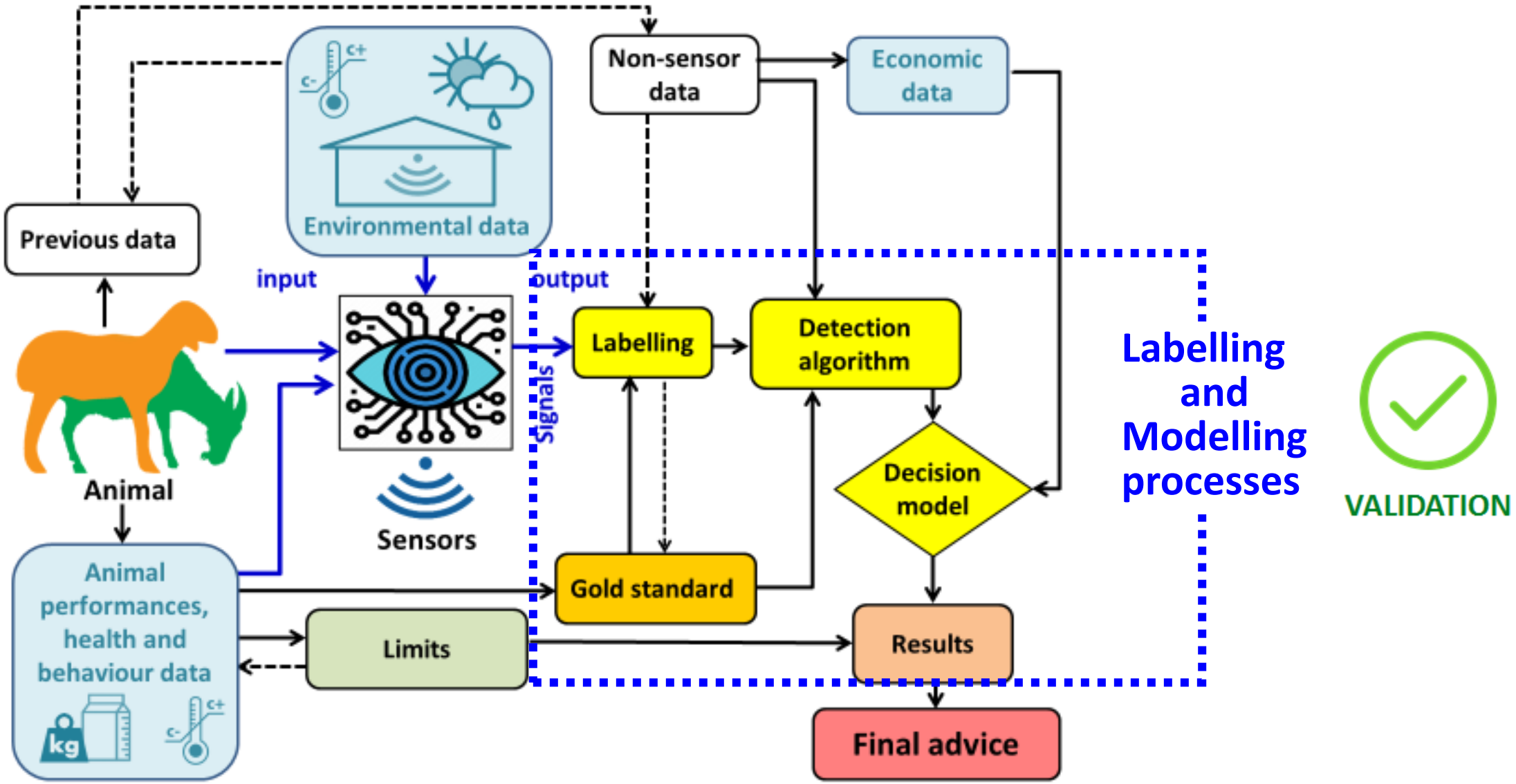
Implementation of a PLF sensor system on farm conditions

(Caja et al., 2020)



Implementation of a PLF sensor system on farm conditions

(Caja et al., 2020)



Wearable: Accelerometer responses according to body site attachment in sheep (Barwick et al., 2020)

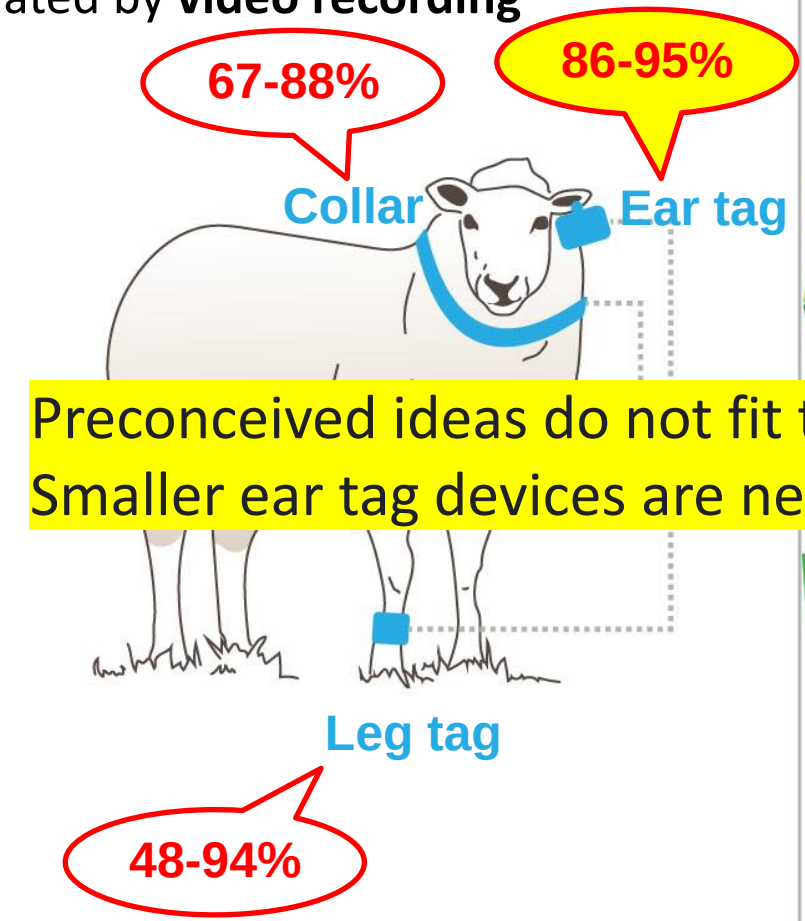
Behavior study:

- Grazing
- Standing*
- Walking
- Laying*

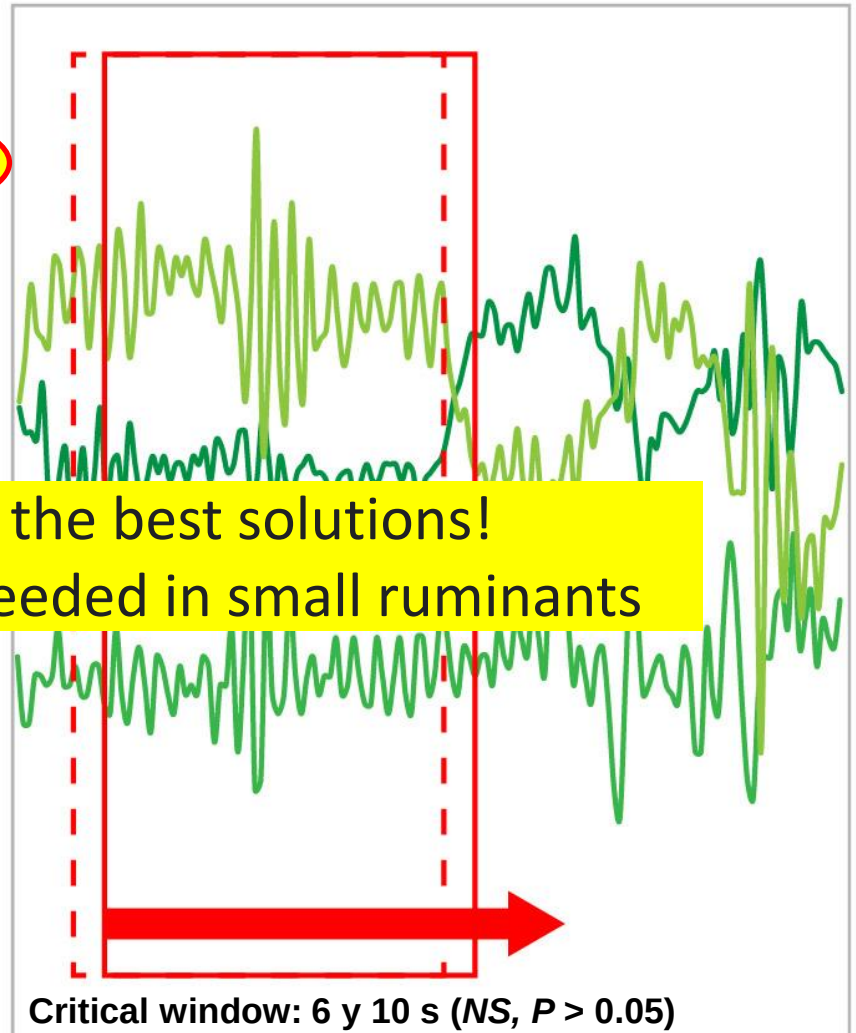
* = includes rumination

Merino x Poll Dorset (n = 5) with GCDC X16-mini accelerometers (50x25x12 mm, **18 g**)
Validated by **video recording**

Research in goats is needed!!!



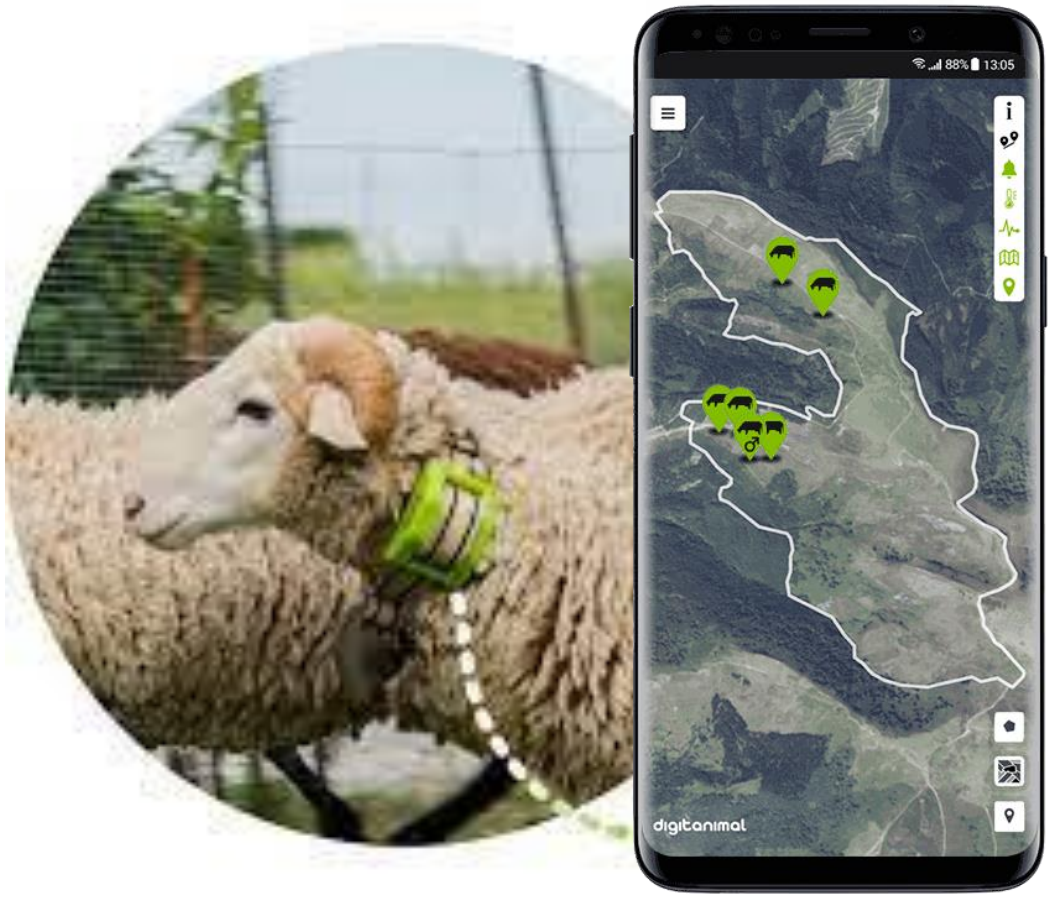
Preconceived ideas do not fit the best solutions!
Smaller ear tag devices are needed in small ruminants



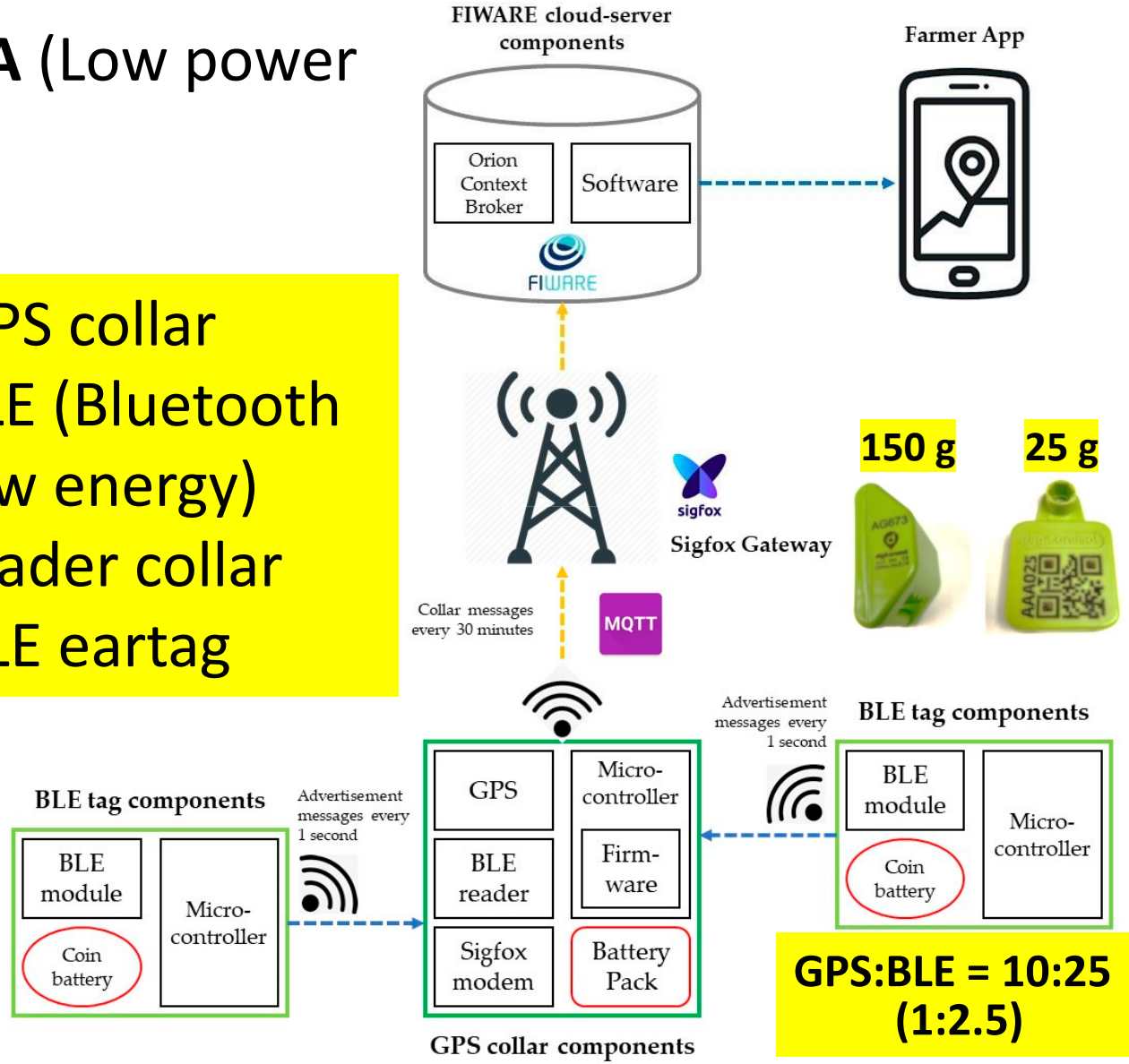
Results:
The accuracy of behavior devices varies according to the body site attachment (*P* < 0.05)

Wearable: Virtual tracking by Global Positioning System (GPS) without or with BLE (Maroto-Molina et al., 2019)

- **GPS sensor** with **GSM** (6 mo) or **LPWA** (Low power wide area: LoRa or Sigfox, 18 mo).



- GPS collar
- BLE (Bluetooth low energy) reader collar
- BLE eartag

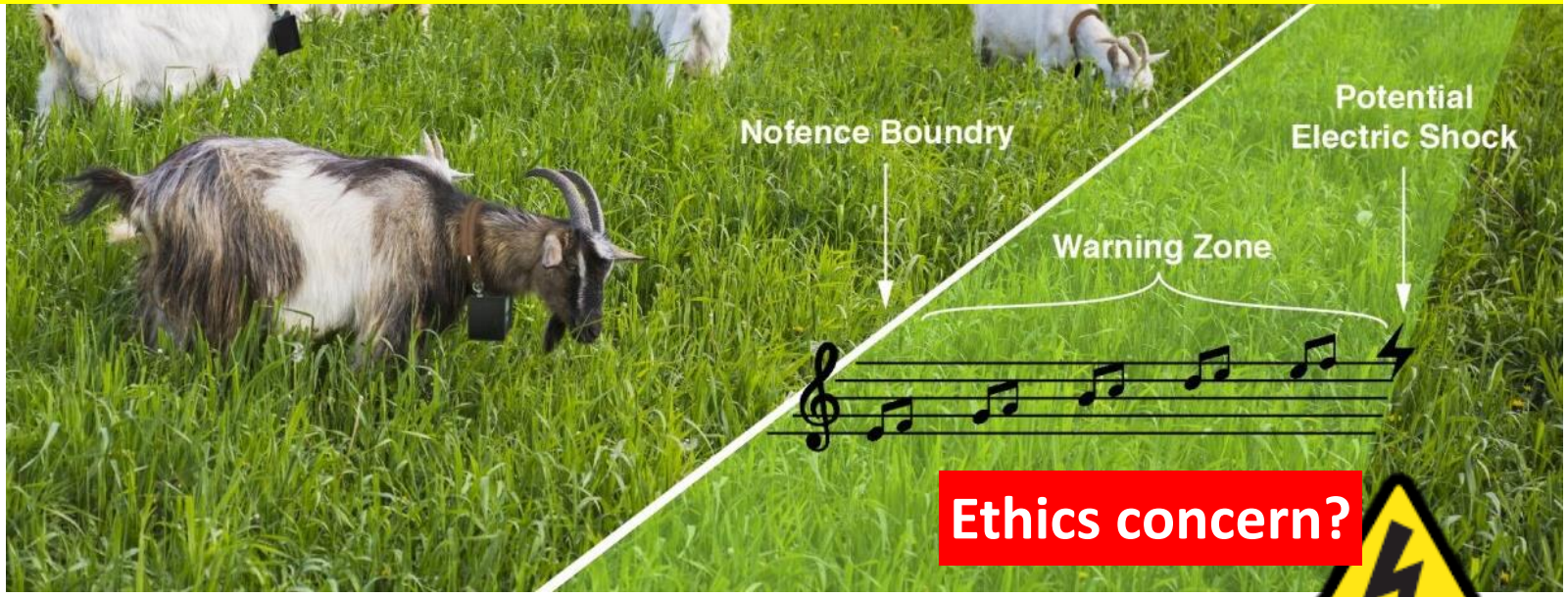


Wearable: Virtual fencing by Global Positioning System (GPS)

Efficient learning in goats (>80%), but the paper was **retracted** (Muminov et al., 2019). Further research is needed!!!.

Inefficient learning in sheep (≈1/3) needing at least 3 interactions (Brunberg et al., 2017; Marini et al., 2018).

- GPS sensor and Bluetooth (beacon).
- Grazing map drawing.
- Total weight = **505 g**.
- Battery operated (8-10 h).



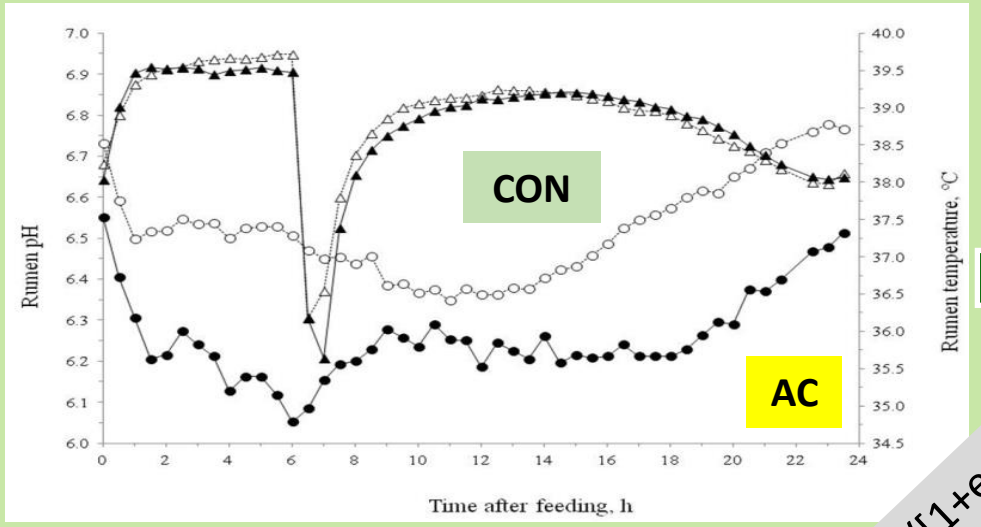
Electric shock (4000 V, 0.2 s) and alarm message

Wearable: Rumen temperature and pH in goats according to diet and ambient (Castro-Costa et al., 2015)

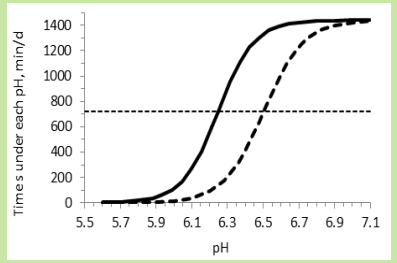
Rumen bolus (n = 8)

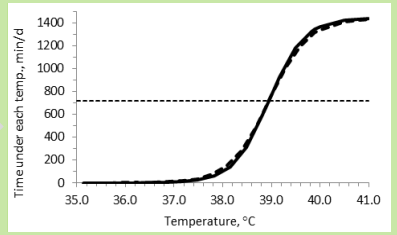
Needing < 70 × 20 mm !

Exp. 1
(8 goats)
Diet effects (F:C ratio):
70:30 (CON, ○)
vs.
30:70 (AC, ●)

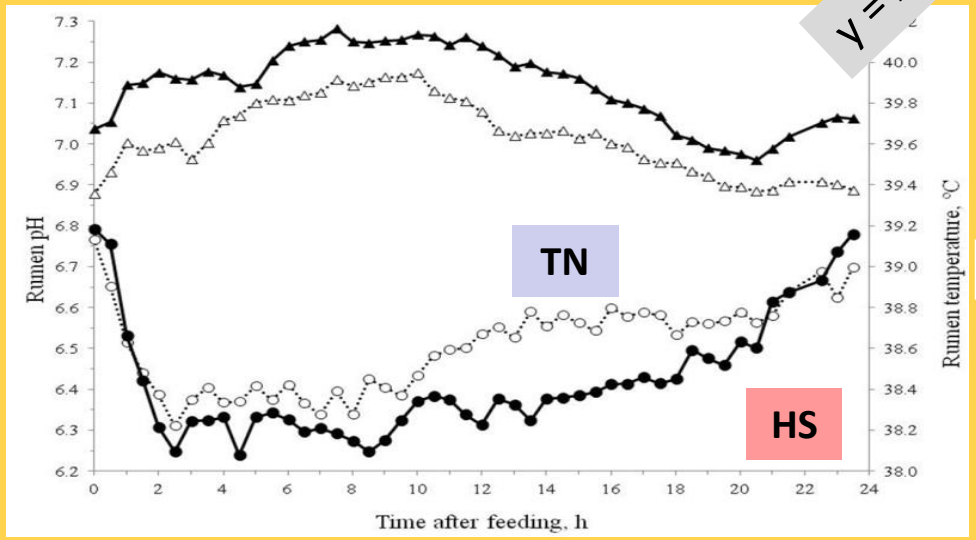


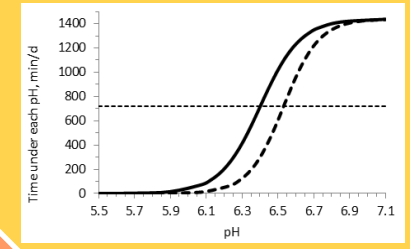
$y = A/[1+e^{-(b+cx)}]$

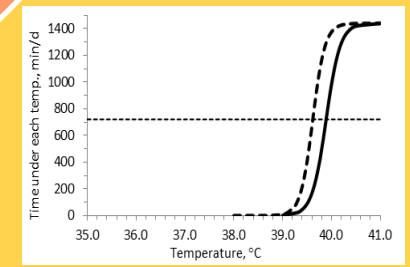




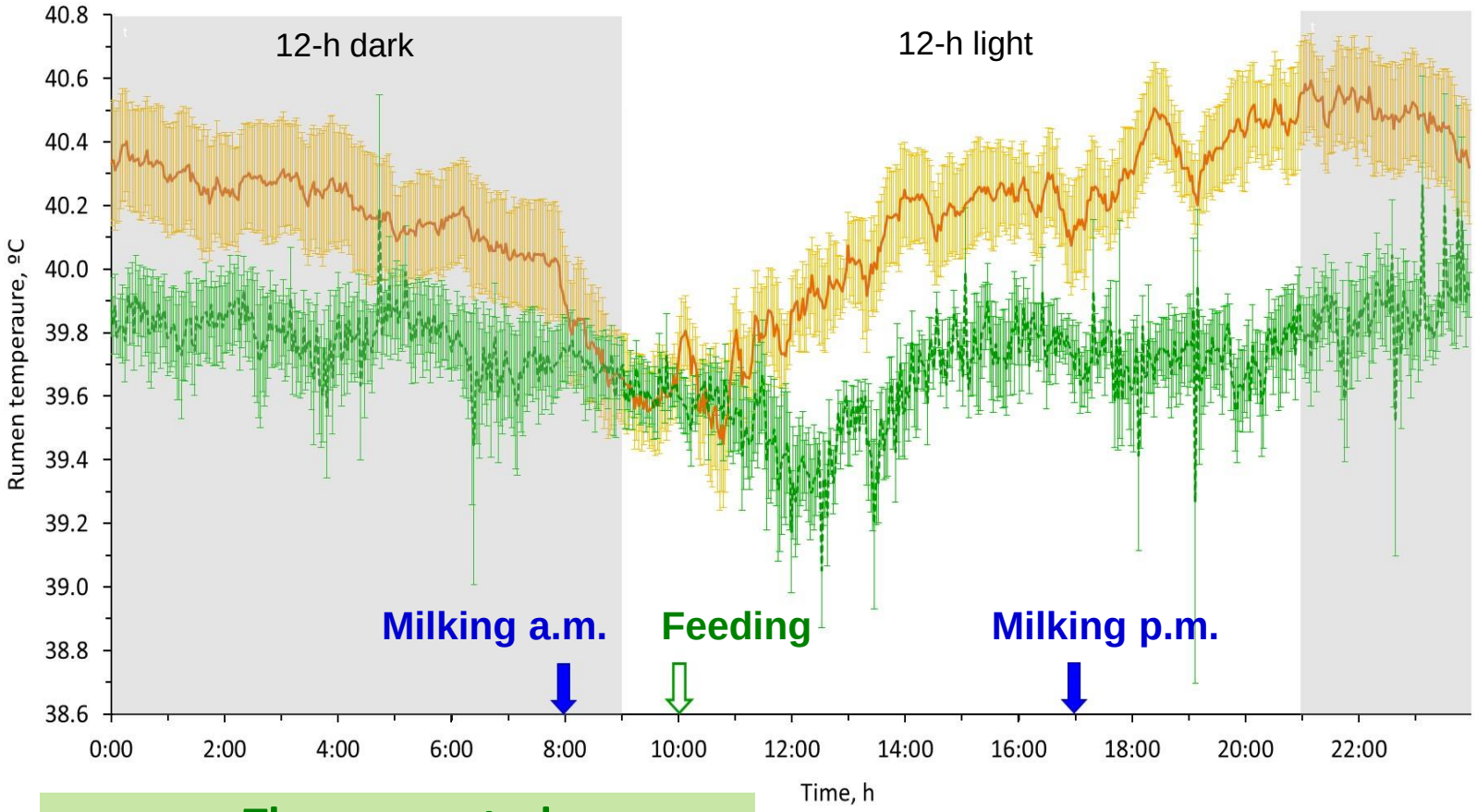
Exp. 2
(9 goats)
Ambient:
Termo neutral (TN, ○)
vs.
Heat stress (HS, ●)







Wearable: Rumen temperature of Manchega dairy ewes (n = 8; BW = 70 kg) according to ambient (Caja et al., 2020)



Thermoneutral (night and day, 20ºC; 50%RH)

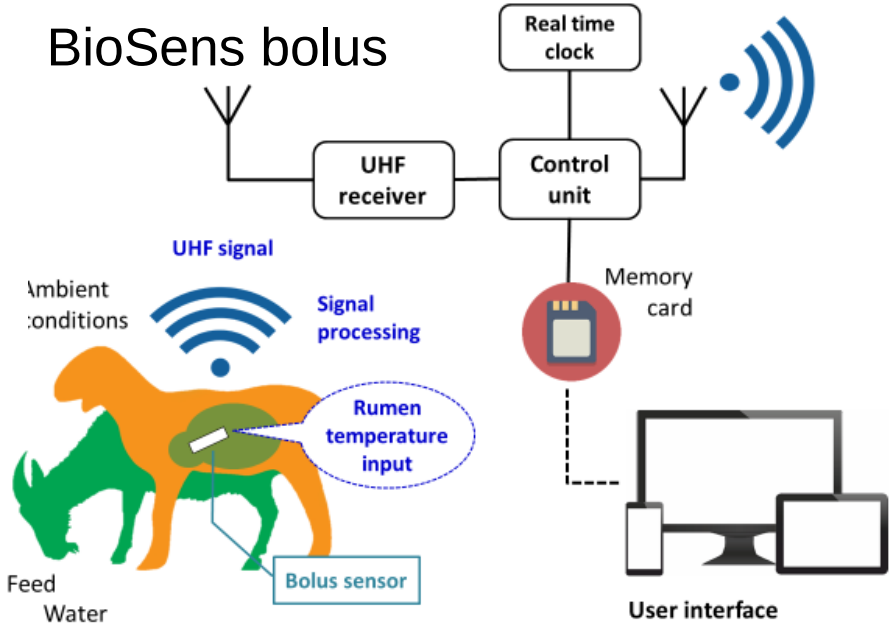
Heat stress (night, 30ºC; day, 37ºC, 50%RH)

Caja et al. (2021)

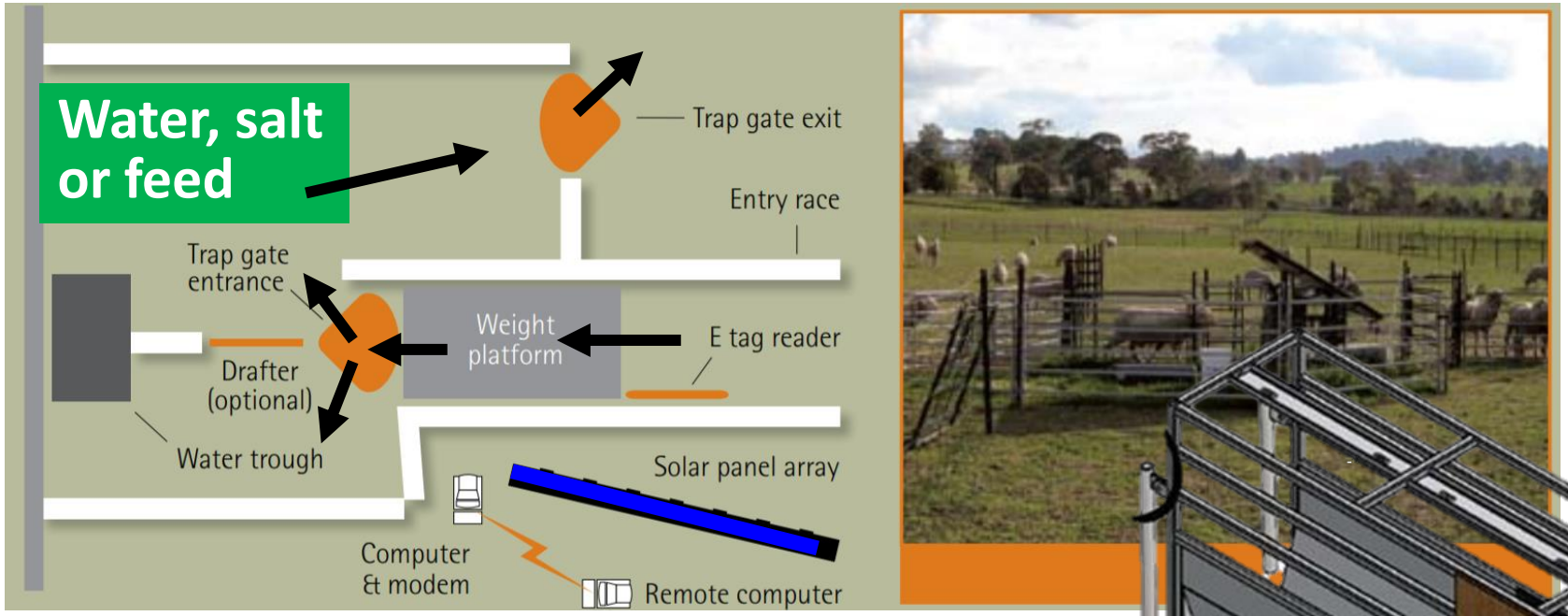
Prototype (2×10 cm)

55 g

BioSens bolus



Non-wearable: Walk-over-weighing (WoW) using e-ID and sensors (González-García et al., 2018, 2021)



New results on farm applications and data management (Leroux et al., 2023)

Updated aprox. cost (EU, 2023):

Autodrafter	=	5,800 €
Indicator	=	1,400 €
e-ID reader	=	1,500 €
Load bars	=	800 €
		9,500 €

Solar panels and batteries = 2,000 €

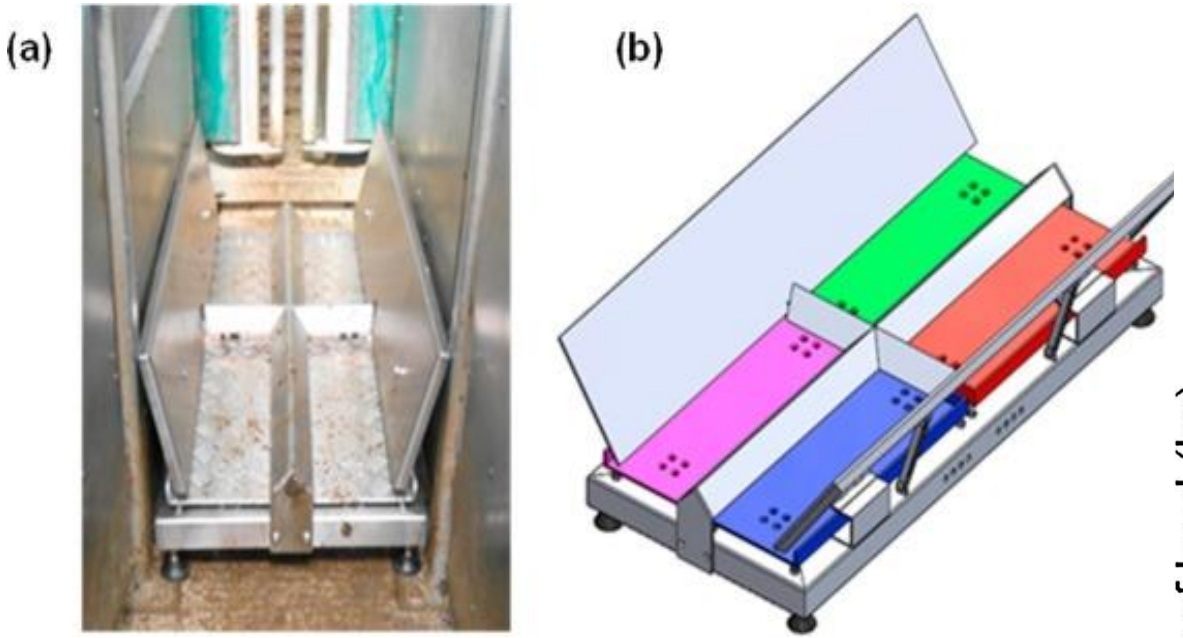
Research in goats is needed!!!

Non-wearable: Watering-weighing systems using e-ID and sensors (TechCare Prototypes)

- **EWS system based on smart water trough** (Bar-Shamai et al., 2023), **UHF eartags**

- **2W system (Digitanimal-UAB), LF bolus**

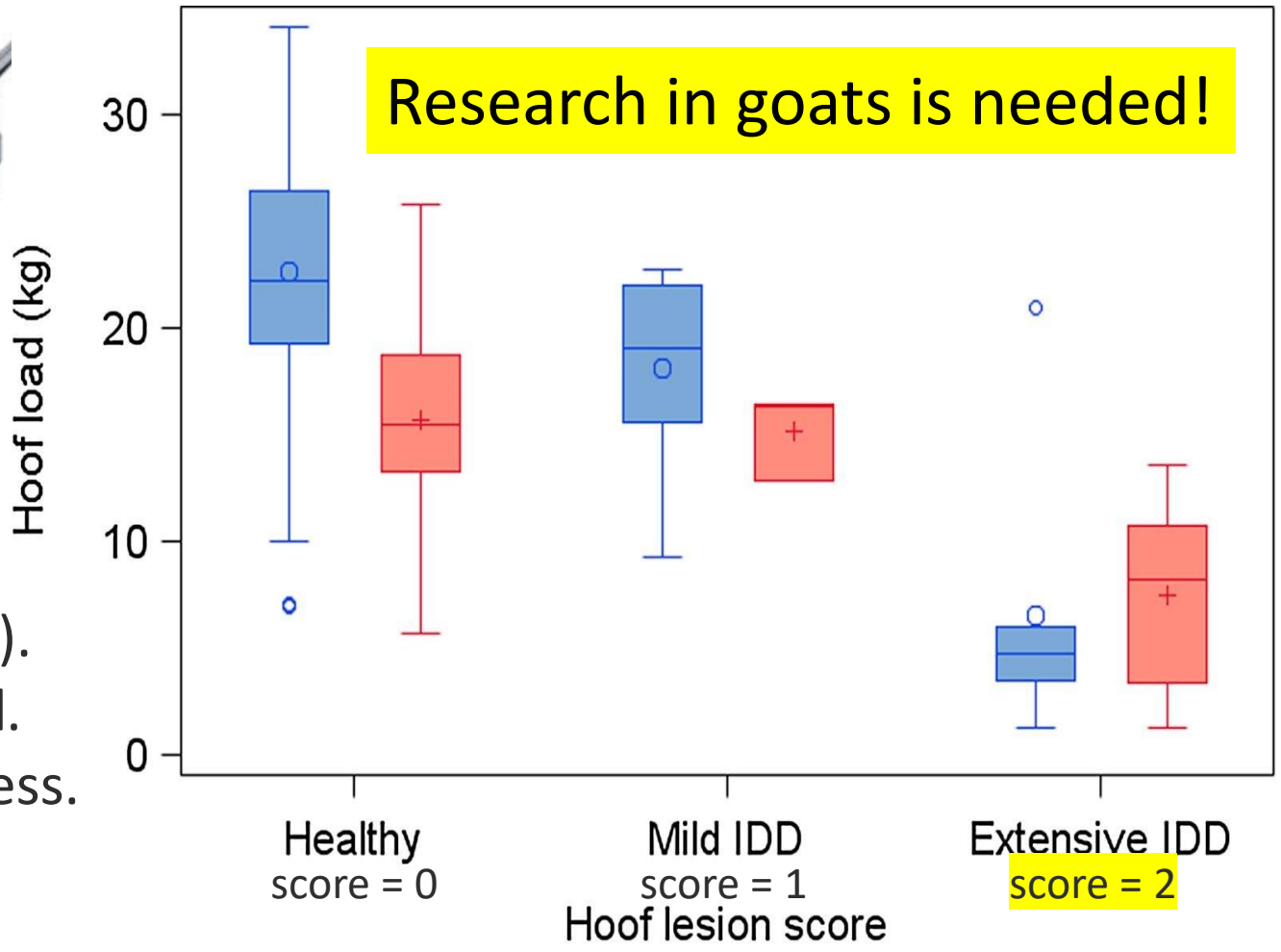
Non-wearable: Lameness detector in sheep using hoof weigh sensors (Byrne et al., 2019)



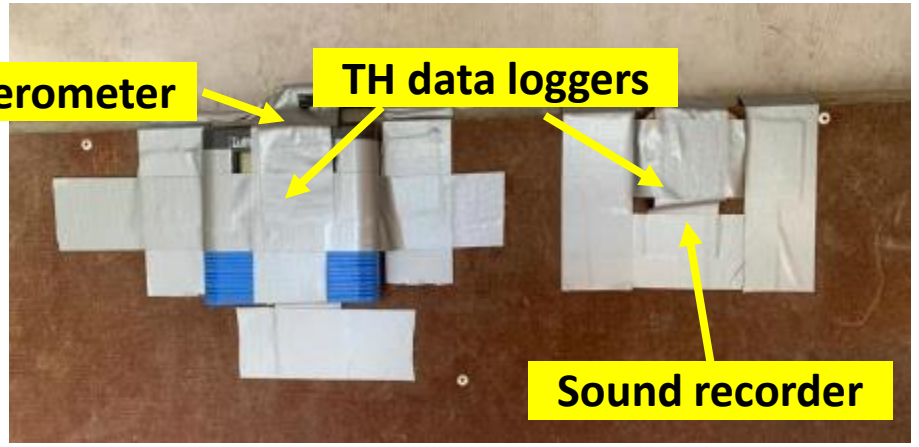
Lameness prevalence: 10 to 33%

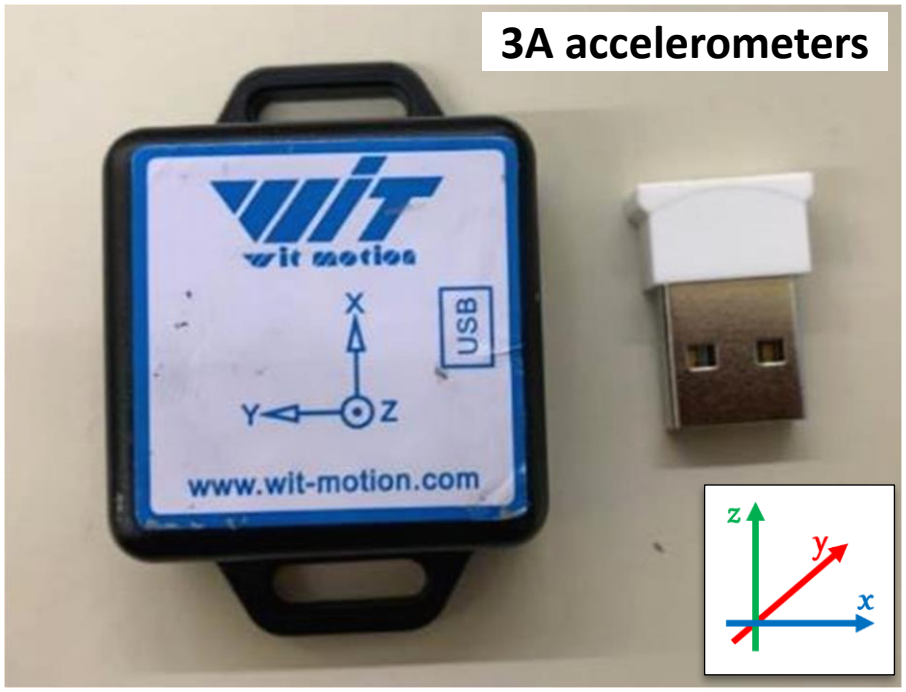
- Healthy hooves: front > back load (60:40%).
- **Extensive infected hooves: same low load**.
- Mild infected hooves: were difficult to assess.
- Sensitivity 66-100% (**Score 2 = 85-100%**)
- Specificity: 51-100% (**Score 2 = 95-100%**)

Inter-digital dermatitis (IDD) assessment



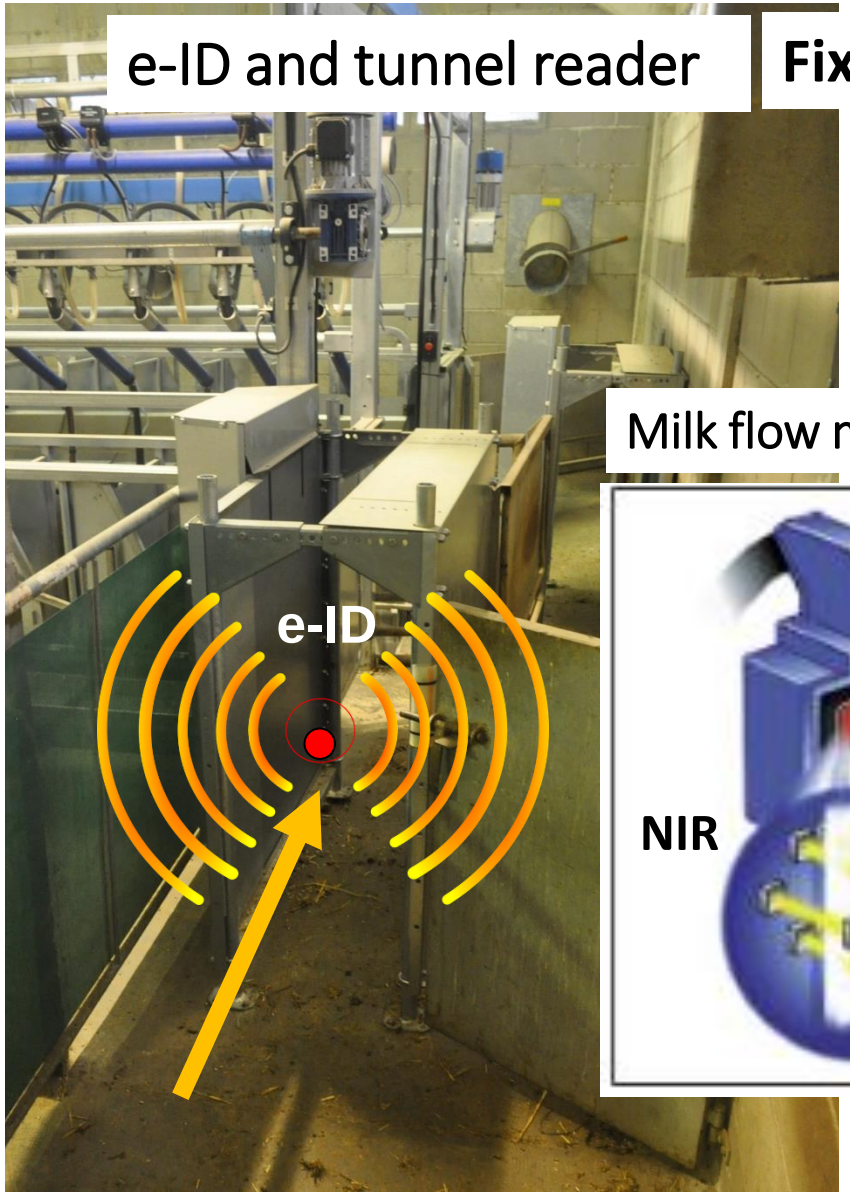
Non-wearable: Trailer monitoring during lamb and kid transportation (Elhadi et al., 2023; Sort et al., 2023)





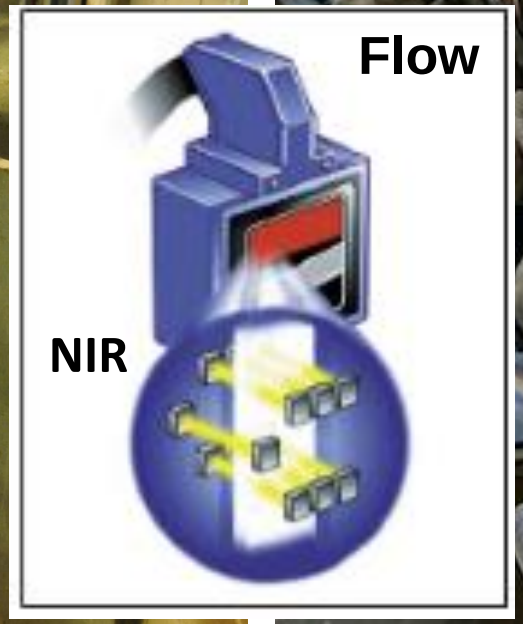
Non-wearable: Milk recording using (e-ID) and sensors (NIR)

e-ID and tunnel reader



Fixed order by stall number

Milk flow meter (NIR)



Key point:
Reading efficiency 96-99%
(Nieddu & Caja, 2017) line errors?

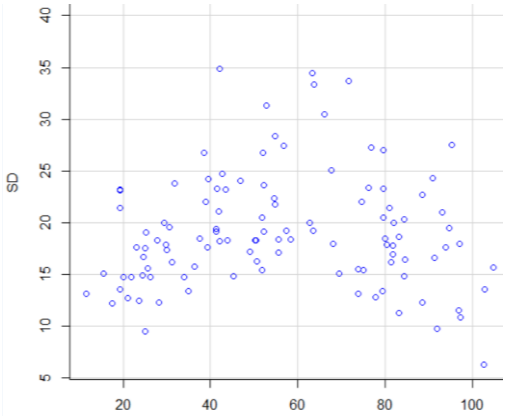
Non-wearable: Milking order controversy as a warning system

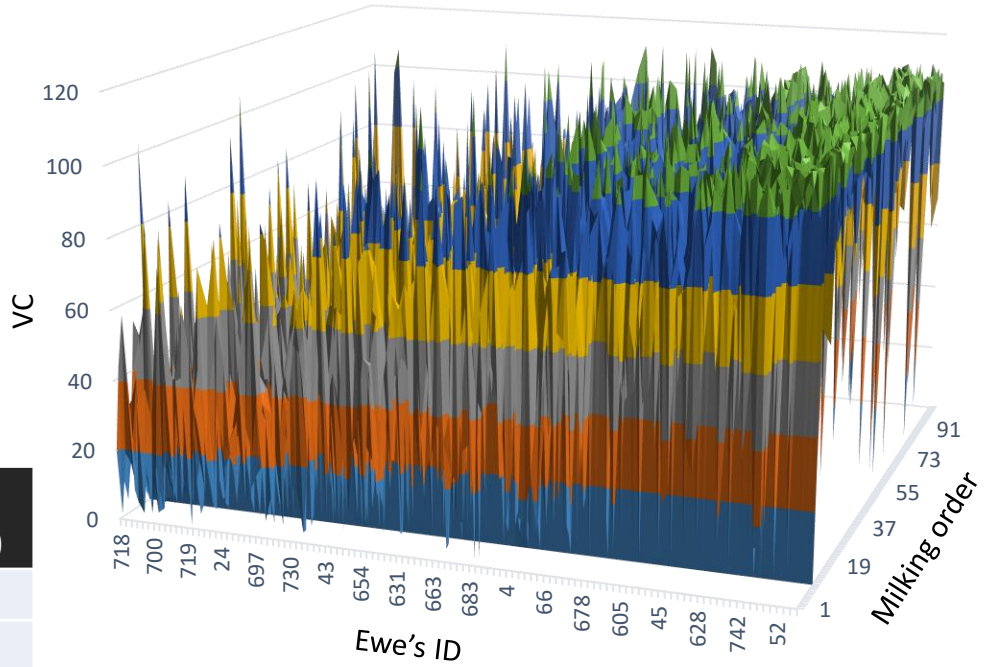
Recio et al. (2023, unpublished data from M.Sci. Thesis)

Milking order in goats:
Influenced by social range, milk yield, age, BW (Sambraus & Keil, 1997; Gorecki & Wojtowski, 2004).

Milking order in sheep:
Influenced by their milkability (Villagrá et al., 2007), toxoinfection (Gorecki et al., 2008) and milk yield (Macuhová et al., 2017).

SD and VC coefficients (%) of dairy ewes' milking order (n = 112) and correlations during mid lactation (d 110 to 140)



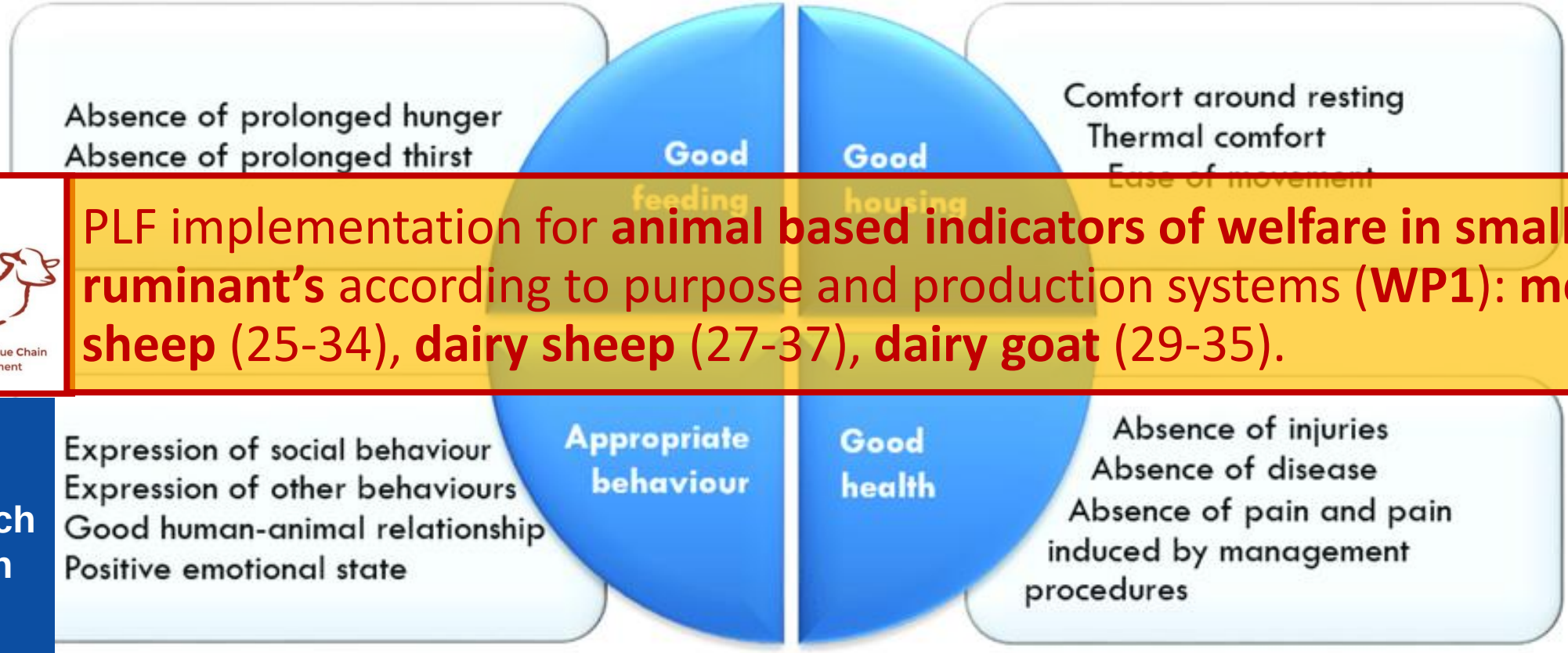


Correlation tests (*P* values)	d 110	d 140
Spearman:		
Milk yield, kg	0.44	0.07
SCC, Log10	0.91	0.10
Fat, %	0.007	0.005
Protein, %	0.027	0.012
Lactose, %	0.006	0.001
BW, kg	0.001	0.001
Wilcoxon:		
Bact culture	0.49	0.021

Milking order in dairy sheep was more affected by **age and BW** than by milk yield, composition or udder health traits (SCC, lactose, bacterial culture), **but last ewes had lower udder health** in late lactation.

AWIN (2015): Animal welfare indicators assessment protocol for livestock species/systems

4-Welfare Principles



PLF implementation for **animal based indicators of welfare in small ruminant's** according to purpose and production systems (**WP1**): **meat sheep** (25-34), **dairy sheep** (27-37), **dairy goat** (29-35).

European Commission H2020 Research and Innovation Program:
TechCare project
Grant #862050
(2019-2024)

12-Welfare Criteria

×2 = 24 Welfare Indicators

Prioritization of welfare issues in the TechCare project and in Spain: Sheep (Caja & Elhadi, 2021)

TECH CARE

Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

www.techcare-project.eu

Welfare problems by species and purpose	Priority	Votes
All sheep in TechCare (meat & dairy)		
Nutrition (subnutrition, malnutrition)	1	n/d
Mastitis (udder health)	2	
Internal parasites (GIT)	3	
Lameness	4	
External parasites	5	
Meat sheep (Spain)		
Nutrition (subnutrition, malnutrition)	**1**	**76%**
Shelter and facilities conditions	2	52%
Density (intensive) and stocking-rate (extensive)	3	48%

Prioritization of welfare issues in the TechCare project and in Spain: Sheep (Caja & Elhadi, 2021)

TECH CARE

Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

www.techcare-project.eu

Welfare problems by species and purpose	Priority	Votes
All sheep (meat & dairy)		
Nutrition (subnutrition, malnutrition)	1	n/d
Mastitis (udder health)	2	
Internal parasites (GIT)	3	
Lameness	4	
External parasites	5	
Meat sheep (Spain)		
Nutrition (subnutrition, malnutrition)	**1**	**76%**
Shelter and facilities conditions	2	52%
Density (intensive) and stocking-rate (extensive)	3	48%
Dairy sheep (Spain)		
Mastitis and milking management	**1**	**79%**
Nutrition (subnutrition, malnutrition)	2	69%
Shelter conditions (air, gasses, temp…)	3	69%

Prioritization of welfare issues in the TechCare project and in Spain: Goats (Caja & Elhadi, 2021)

TECH CARE

Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

www.techcare-project.eu

Welfare problems by species and purpose	Priority	Votes
All dairy goats in TechCare (n = 150)		
Mastitis (udder health)	**1**	n/d
Nutrition (subnutrition, malnutrition, water)	**2**	
Agonist behavior (dominance, feed)	**3**	
Shelter conditions (air, gasses, temp…)	4	
Internal parasites (GIT)	5	
Dairy goats (Spain; n = 47)		
Mastitis and milking management	**1**	**83%**
Nutrition (low, high, bad) and offer (excess)	2	79%
Shelter conditions	3	66%

Prioritization of welfare issues in the TechCare project and in Spain: Lambs and kids (Caja & Elhadi, 2021)

TECH CARE

Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

www.techcare-project.eu

Welfare problems by species and purpose	Priority	Votes
Adult sheep in TechCare (meat & dairy)		
Nutrition (subnutrition, malnutrition)	1	n/d
Mastitis (udder health)	2	
Internal parasites (GIT)	3	
Lameness	4	
External parasites	5	
Milk fed lambs/kids (Spain)		
Colostrum and peri-parturition	**1**	**69%**
Hygiene and disinfection of shelter and facilities	2	59%
Shelter and facilities conditions	3	41%
Fattening lambs 3 mo (Spain)		
Shelter and facilities conditions	**1**	**83%**
Animal density and bedding conditions	2	66%
Respiratory problems	3	34%

Correspondence between prioritized technologies and welfare issues for early warning systems (EWS) in SR

TECH CARE

Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

www.techcare-project.eu

Technology	Welfare issue
Weather stations (internal-external)	Shelter and facilities conditions
Automatic milk meters (or bulk tank weight)	Mastitis and milking management, nutrition
Automatic weighing scales (WoW, 2W)	Nutrition, health
GPS and accelerometers UHF-ID readers and accelerometers	Grazing, agonistic and nutritive behavior

Prioritized technologies for early warning systems (EWS) in dairy sheep: Project consortium & Spain

TECH CARE

Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

www.techcare-project.eu

Technology	TC project (n = 150)	Spain NW2 (n = 42)	Spain dairy sheep (n = 40)
Weather stations (int-ext)	1	1 (83%)	1 (60%)
Milk meters (or bulk tank weight)	2	2 (68%)	2 (53%)
Automatic weighing scales (WoW, 2W)	3	2 (56%)	5 (43%)
GPS/UHF-ID readers and accelerometers	4	4 (51%)	3 (43%)

Low cost weather station with outdoor and indoor ambient sensors for sheep farms in TechCare commercial farms

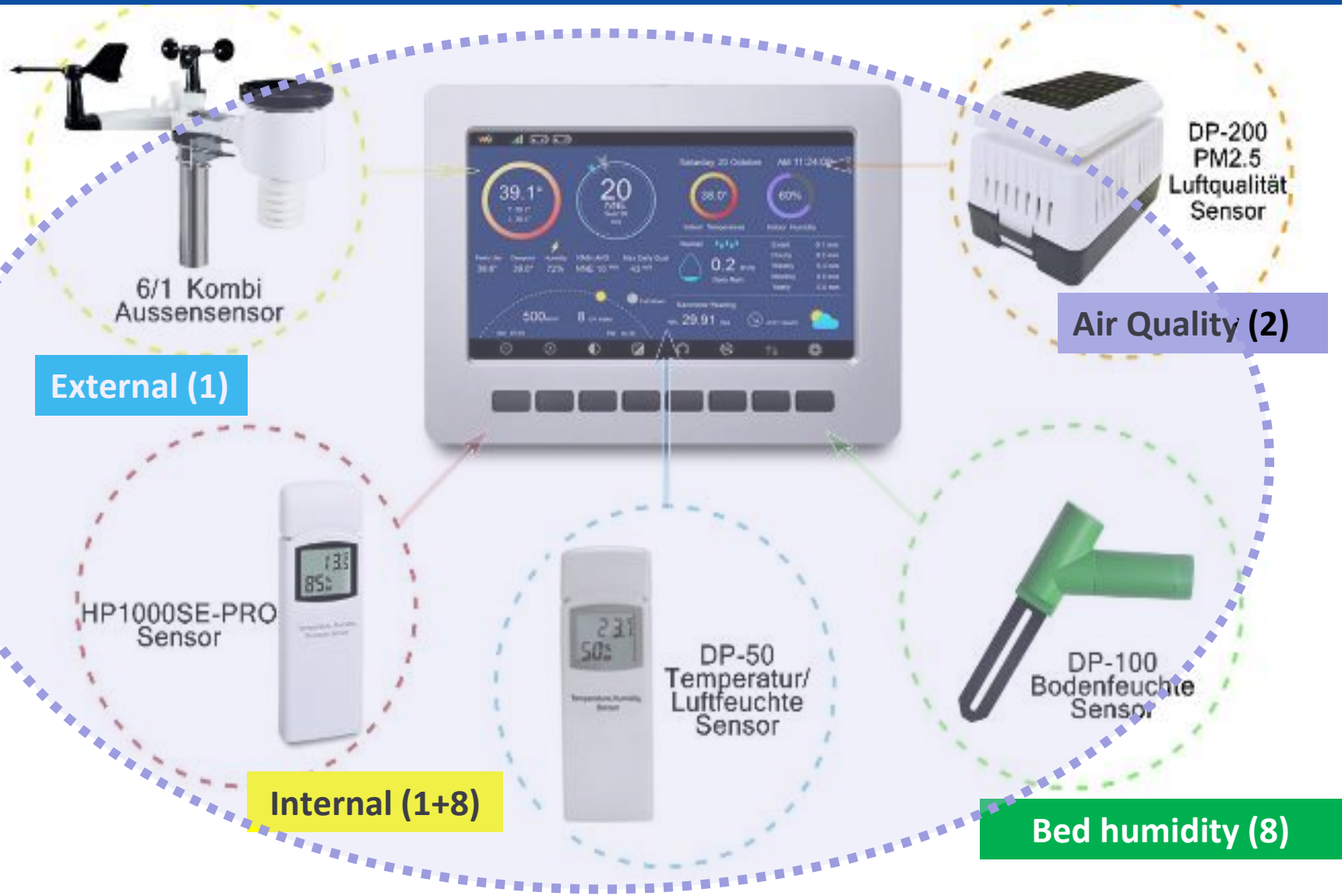
Froggit system (DE):

1 wi-fi

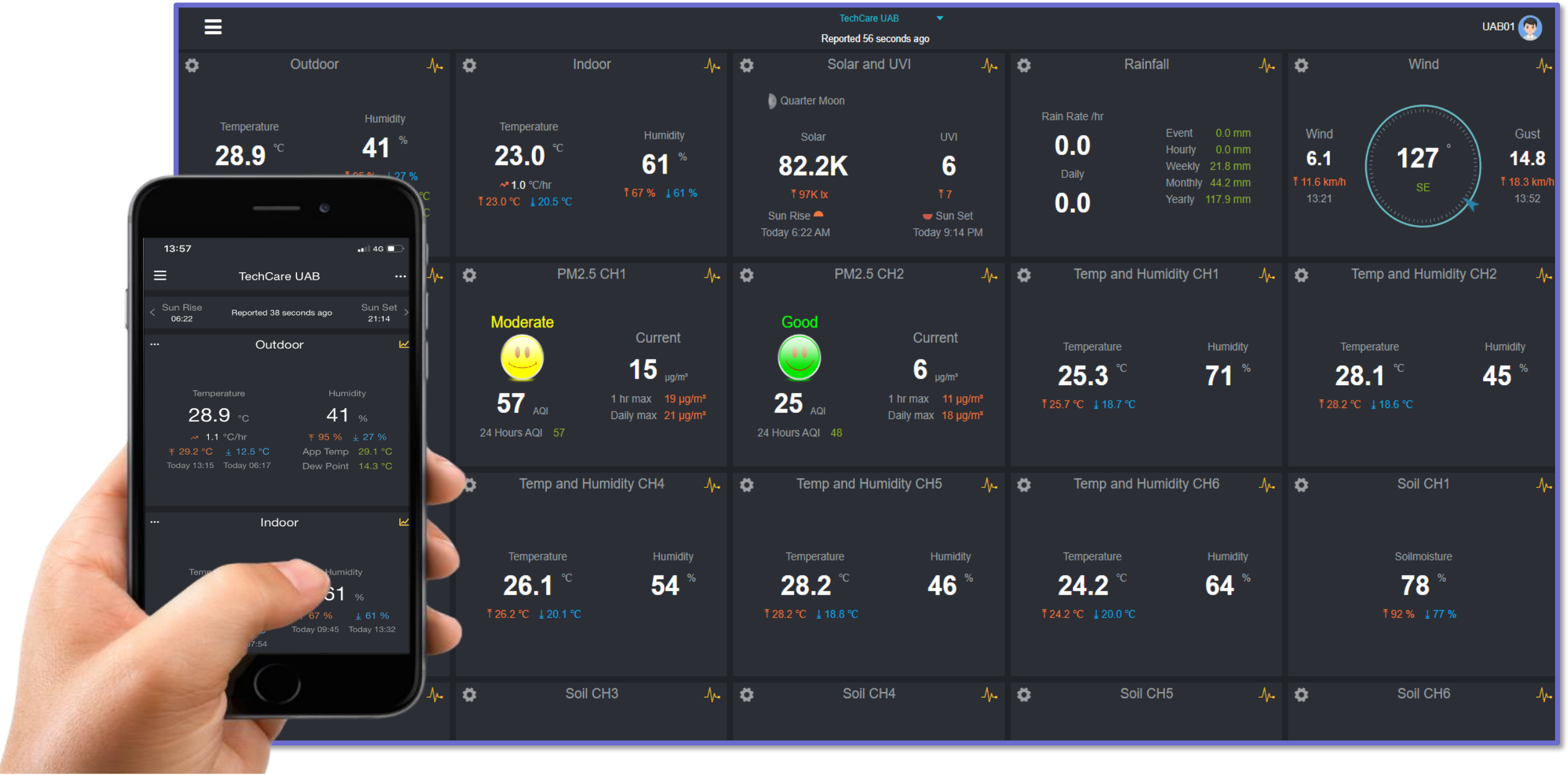
20 sensors
1 tablet
Bluetooth

Web platform & App

ecowitt



Ecowit dashboard in a TechCare commercial farm



Implementation of sensors in the UAB sheep farm

Sensor location for the TechCare project

Wi-fi =

Outdoor weather station =

Internal central console (tablet) = ⌂

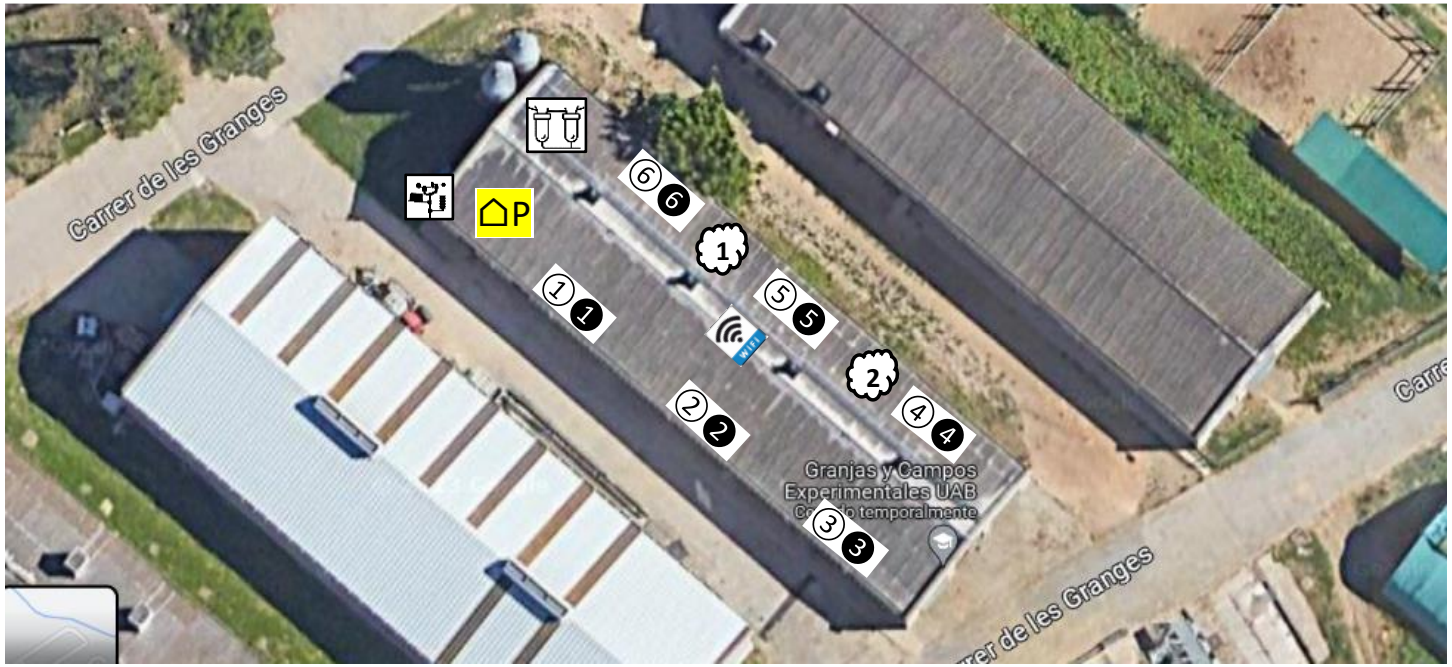
Indoor temperature-humidity-pressure sensor = P

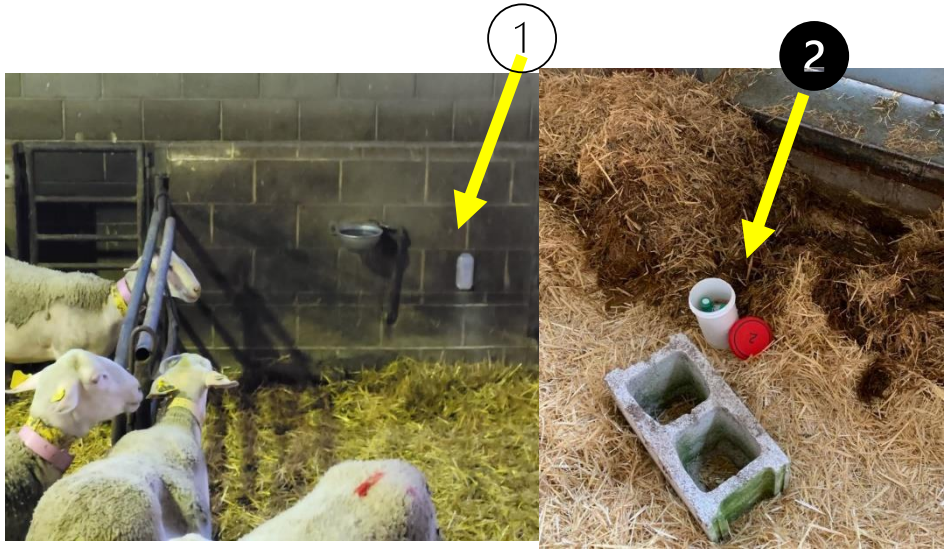
Indoor temperature-humidity sensors = ①-⑧

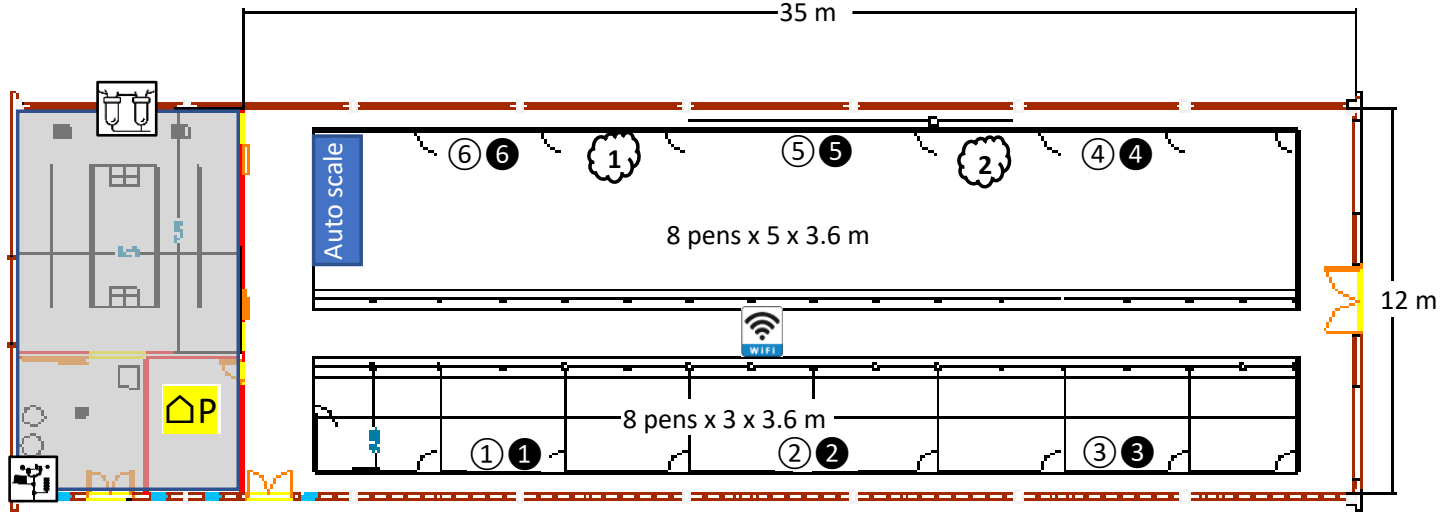
Soil humidity sensors = ❶-❽

Dust particle sensors = ①-②

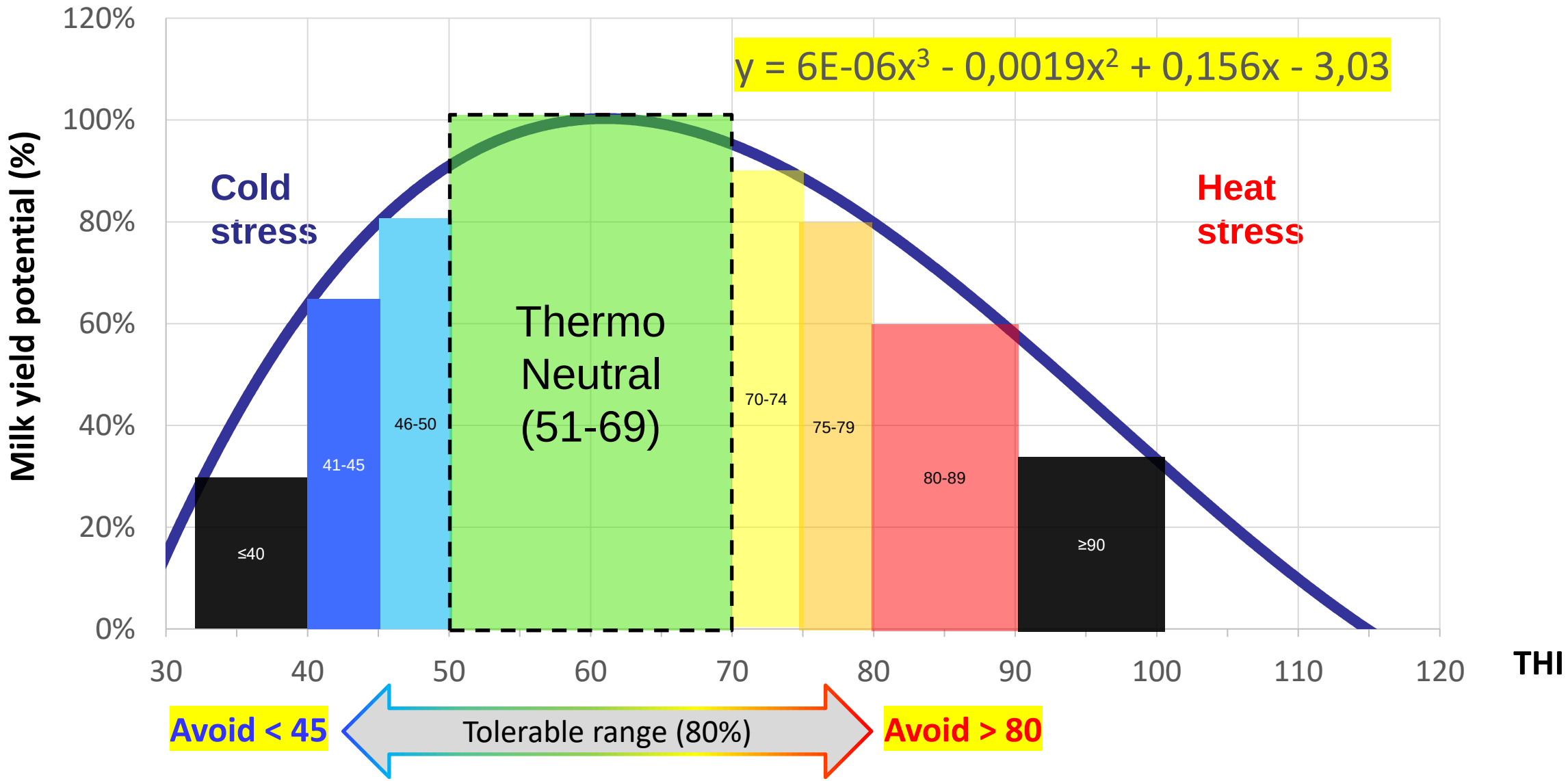
Milking parlor =







Termohigrometic index (THI) and milk yield potential in dairy ewes: Updated data (Caja, 2023)



Specific THI risks chart for dairy ewes: Updated data (Caja, 2023)

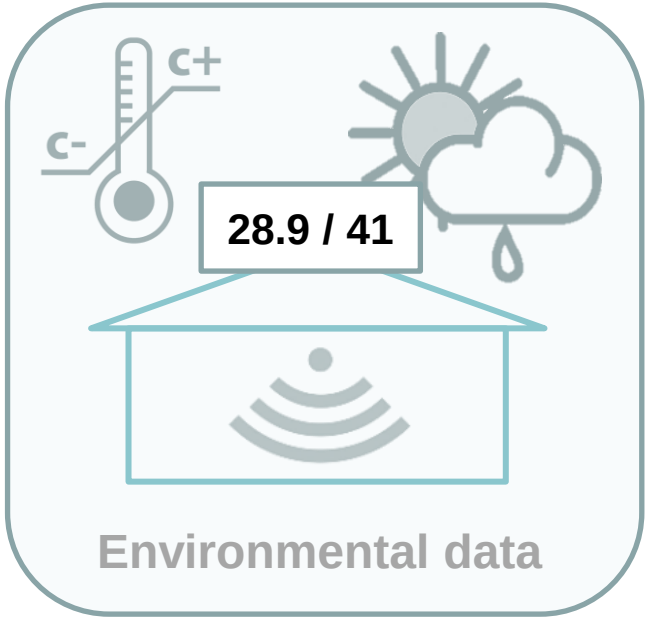
$$THI_{NRC\ (1971)} = 0.8 \cdot T + (RH/100) \cdot (T - 14.41) + 46.4$$

Relative humidity, % \ Temperature, ºC	-10	-8	-6	-4	-2	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
10	36	38	40	41	43	47	49	50	52	54	56	58	59	61	63	65	67	68	70	72	74	76	77	79	81	83	85
20	34	36	38	40	42	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88
30	31	33	35	38	40	44	46	49	51	53	55	57	60	62	64	66	68	71	73	75	77	79	82	84	86	88	90
40	29	31	33	36	38	43	45	48	50	53	55	57	60	62	65	67	69	72	74	77	79	81	84	86	89	91	93
50	26	29	31	34	37	42	44	47	50	52	55	57	60	63	65	68	70	73	76	78	81	83	86	89	91	94	96
60	24	27	29	32	35	41	43	46	49	52	55	57	60	63	66	69	71	74	77	80	83	85	88	91	94	97	99
70	21	24	27	30	33	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102
80	19	22	25	28	32	38	41	44	48	51	54	57	60	64	67	70	73	76	80	83	86	89	92	96	99	102	105
90	16	20	23	27	30	37	40	44	47	50	54	57	61	64	67	71	74	78	81	84	88	91	95	98	101	105	108
100	14	18	21	25	28	36	39	43	46	50	54	57	61	64	68	72	75	79	82	86	90	93	97	100	104	108	111

Fatal	Severe cold	Low cold	Termoneutral	Low heat	Moderate heat	Severe heat	Fatal
<40	41-45	46-50	51-69	70-74	75-79	80-89	>90

Avoid < 45 ← Low cold (>45) to Moderate heat (<79) → **Avoid > 80**

From Ecowitt to THIcare App: 1/3



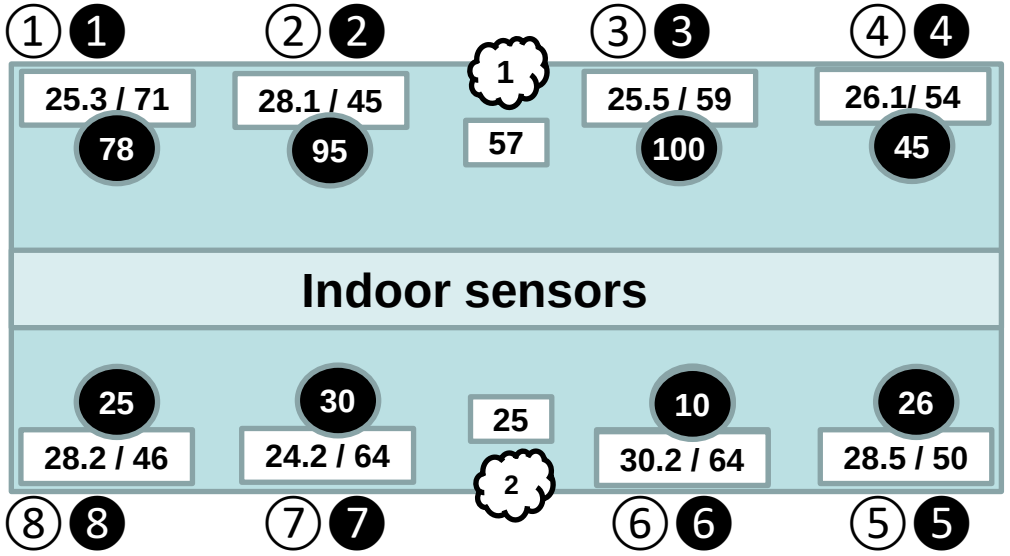
OutdoorTHI:

74

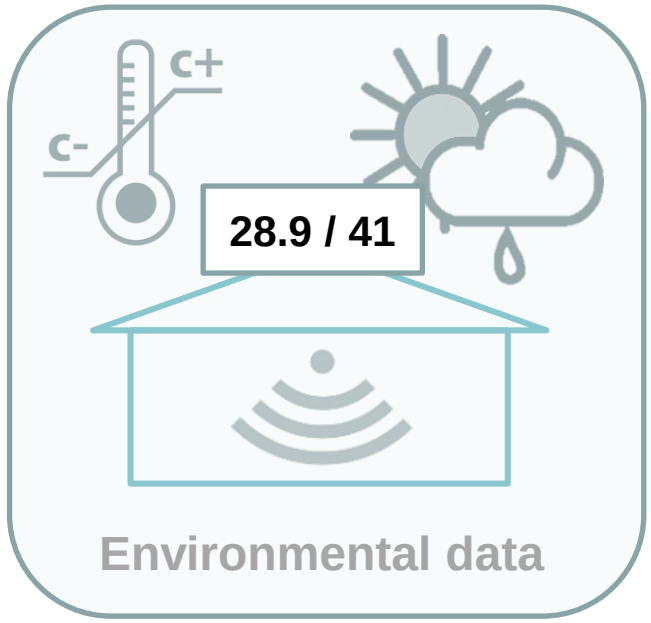
EWS

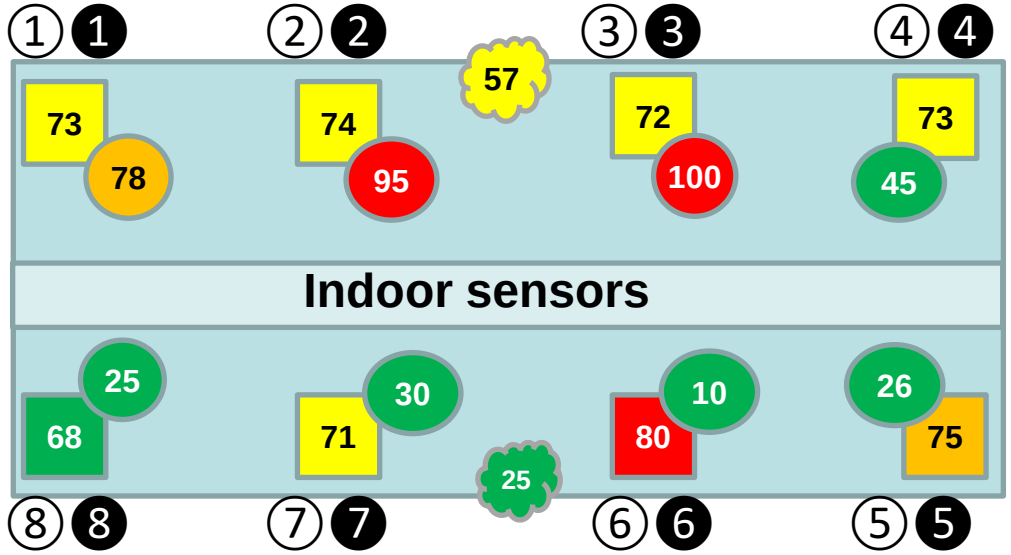
Relative humidity, % \ Temperature, °C	-10	-8	-6	-4	-2	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
10	36	38	40	41	43	47	49	50	52	54	56	58	59	61	63	65	67	68	70	72	74	76	77	79	81	83	85
20	34	36	38	40	42	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88
30	31	33	35	38	40	44	46	49	51	53	55	57	60	62	64	66	68	71	73	75	77	79	82	84	86	88	90
40	29	31	33	36	38	43	45	48	50	53	55	57	60	62	65	67	69	72	74	77	79	81	84	86	89	91	93
50	26	29	31	34	37	42	44	47	50	52	55	57	60	63	65	68	70	73	76	78	81	83	86	89	91	94	96
60	24	27	29	32	35	41	43	46	49	52	55	57	60	63	66	69	71	74	77	80	83	85	88	91	94	97	99
70	21	24	27	30	33	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102
80	19	22	25	28	32	38	41	44	48	51	54	57	60	64	67	70	73	76	80	83	86	89	92	96	99	102	105
90	16	20	23	27	30	37	40	44	47	50	54	57	61	64	67	71	74	78	81	84	88	91	95	98	101	105	108
100	14	18	21	25	28	36	39	43	46	50	54	57	61	64	68	72	75	79	82	86	90	93	97	100	104	108	111

Fatal | Severe cold | Low cold | Termoneutral | Low heat | Moderate heat | Severe heat | Fatal

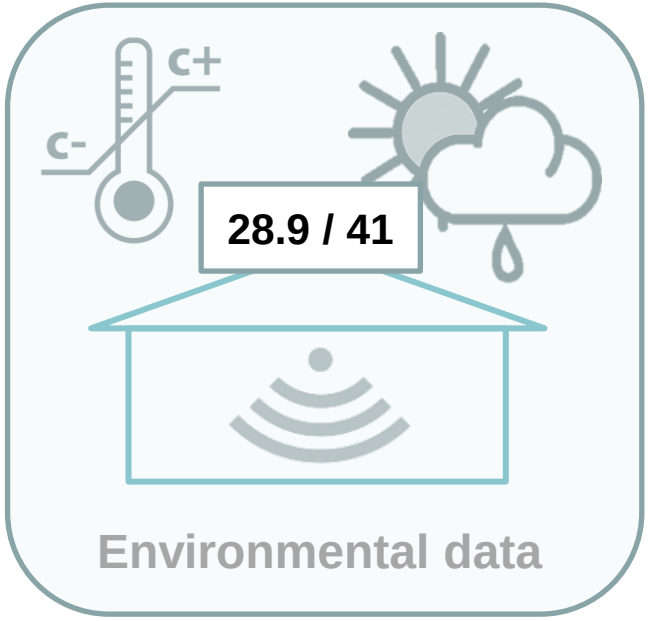


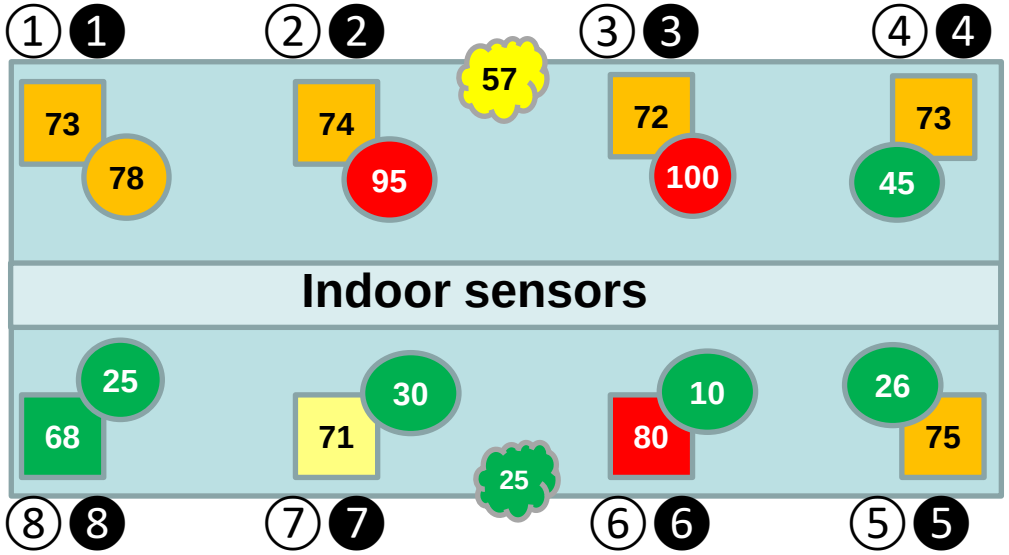
From Ecowitt to THIcare App: 2/3

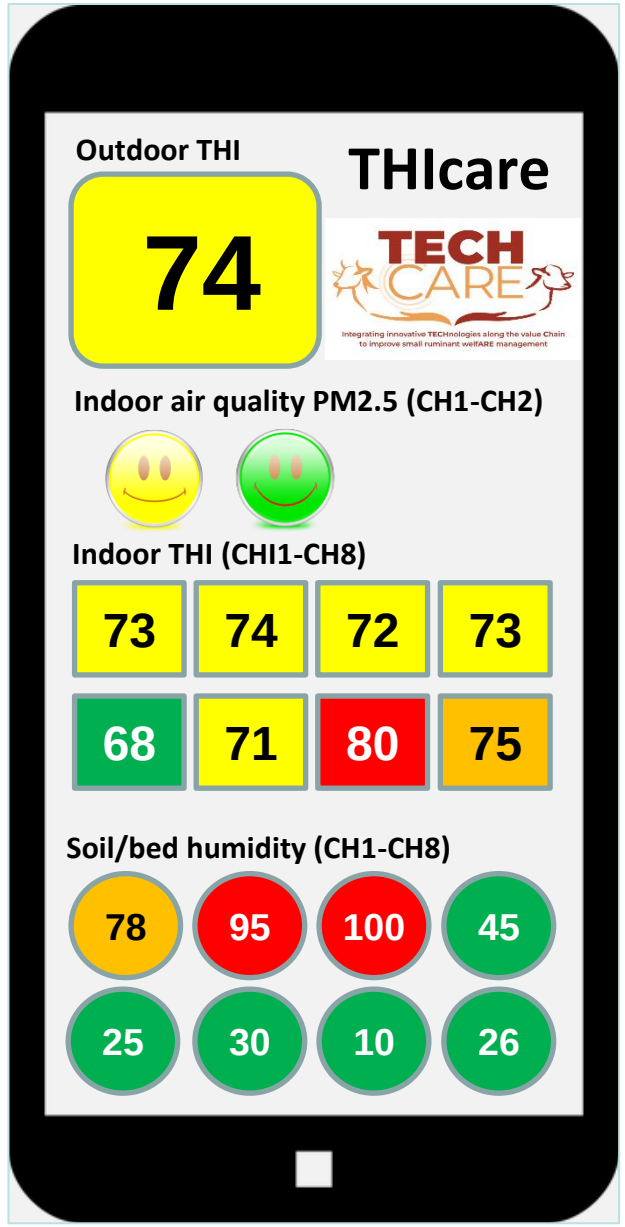




From Ecowitt to THIcare App: 3/3







Conclusions: 1/2

- **SR are a huge market** for sensor development but, currently, PLF implementation is poorly developed.
- Generalization of **e-ID** is a key for individual welfare assessment (e.g. EU).
- **Sensors** are input devices producing variable outputs (signals) according to the input quantity: Expected new developments for SR.
- Currently **prioritization of welfare problems and sensors** depends on **species** (sheep, goat), **age** (adult, young) and **system** (meat, dairy, intensive/extensive).
- Very **few research** has been done **in dairy sheep and goats**.

Conclusions: 2/2

- **Wearable** sensors seems to be the ideal option for animal-based welfare indicators and for early alert/warning systems (EWS), but...
- **Non-wearable** may be the currently cost-efficient option for welfare assessment and EWS.
- **User friendly devices** and software (i.e. Apps) are urgently needed.
- **Not all sensor device expectances are today warranted** and further applied research and **participation of innovation companies** are highly needed.

Thanks for attention.

Acknowledgements:

- **European Commission H2020 Research and Innovation Program**:
  TechCare project Grant #862050.
- **International TechCare Consortium**:

A. Elhadi[1], E. González-García[2], J.B. Menassol[2], G. Tesnière[3], V. Giovanetti[4], M. Decandia[4], M. Acciaro[4], E. Sossidou[5], S.I. Patsios[5], Cziszter L.T.[6], L. Grøva[7], G.H.M. Jørgensen[7], I. Halachmi[8], A.B. Shamai[8], T.W.J. Keady[9], C.M. Dwyer[10], T. Waterhouse[10], A. McLaren[10], C. Morgan-Davies[10]

[1]G2R-UAB (Bellaterra, Spain); [2]SELMET-INRAE (Montpellier, France); [3]IDELE (Toulouse, France); [4]AGRIS-Sardegna (Sassari, Italy); [5]ELGO-DIMITRA (Thessalonica, Greece); [6]BUAS (Timisoara, Romania), [7]NIBIO (Tingvoll/Tjøtta, Norway); [8]ARO (Beit Dagan, Israel); [9]Teagasc (Athenry, Co. Galway, Ireland); [10]SRUC (Edinburgh, UK).

TECH CARE

Integrating innovative TECHnologies along the value Chain to improve small ruminant welfARE management

European Commission

Horizon 2020
European Union funding
for Research & Innovation

Follow us in: www.techcare-project.eu