RES4LIVE

ENERGY SMART LIVESTOCK FARMING
TOWARDS ZERO FOSSIL FUEL CONSUMPTION

Report on measured current energy demand/consumption and distribution in the pilot farms and comparison with the estimations of D3.1

Deliverable 3.5

WP3. Livestock farm energy flows assessment, smart control and simulation

Project title

RES4LIVE - Energy Smart Livestock Farming towards Zero Fossil Fuel Consumption

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DELIVERABLE FACTSHEET

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ABBREVIATIONS

AMS : Automatic Milking System

MPE : Mean Percentage Error

PVTs : Photovoltaic Thermal (Photovoltaic Thermal Hybrid Solar Collector)

Whs : Watt-hours

PARTNERS SHORT NAMES

AUA - AGRICULTURAL UNIVERSITY OF ATHENS

UNIBO – UNIVERSITY OF BOLOGNA

ATB - LEIBNIZ INSTITUTE FOR AGRICULTURAL ENGINEERING AND BIOECONOMY

EV ILVO - RESEARCH INSTITUTE FOR AGRICULTURE, FISHERIES AND FOOD

UGENT - GHENT UNIVERSITY

CERTH - CENTRE FOR RESEARCH AND TECHNOLOGY-HELLAS

AU - AARHUS UNIVERSITY

LVAT - LEHR- UND VERSUCHSANSTALT FÜR TIERZUCHT UND TIERHALTUNG GROß KREUTZ E.V.

PSYCTOTHERM - G. LIGEROS & SIA OE

PLEGMA LABS- PLEGMA LABS TECHNOLOGIKES LYSEIS ANONYMOS ETAIRIA

CRMT SAS - CENTRE DE RECHERCHES EN MACHINES THERMIQUES

TERRA - TERRA ENERGY

MG SUSTAINABLE - MG SUSTAINABLE ENGINEERING AB

CETRI - CENTER FOR TECHNOLOGY RESEARCH & INNOVATION LTD

GOLINELLI - GOLINELLI GIULIO

EAAP - FEDERAZIONE EUROPEA PER LA ZOOTECNICA

EUREC - EUREC EESV

PUBLISHABLE SUMMARY

The overall objective of this report is to depict the electrical energy demand/consumption and distribution of each pilot farm based on the energy metering devices installed within Task 3.3 ("Precise indoor environmental control of agricultural buildings and energy smart control"); in order to compare it with the estimations of D3.1 ("Report on the analysis of energy demand/consumption and RES availability in typical livestock farms"). Some of the work carried out within Task 3.4 ("Development of a farm-specific numerical platform for energy management and operations optimisation") is also presented, as the numerical platform's results regarding the energy demand are utilized for a more detailed comparison.

In the first section the installed energy meters per pilot farm, building of interest, or specific load are briefly presented. The number of energy meters per farm varies, depending on the complexity of each facility and the number of consumers that were deemed necessary to be recorded. In general, devices that are being operated according to a fixed schedule were not selected to be constantly monitored by a dedicated meter. In most farms, the logging process began in the second half of 2022.

In the second section, the aforementioned comparison is being carried out per pilot farm and is focused on energy consumption, while a smaller part is dedicated to energy production. For each of the pilot farms (EV ILVO, GOLINELLI, LVAT, and AUA) the energy requirements are presented in comprehensive graphs. In the **EV ILVO** pilot farm, the estimations were very similar to the measured values. In the **GOLINELLI** pilot farm the energy demand estimations were not very accurate, something which was expected mostly due to the limited existing data in the first place. In the **LVAT** pilot farm, the estimations of D3.1 were accurate enough, but more time is needed to get a better picture of the whole, yearly demand. In the **AUA** pilot farm, the logged data is insufficient for a meaningful comparison; however, the two-month measurements (May-June 2023) indicate that the estimations of D3.1 are very close to the real values. Unfortunately, in many cases, energy meters' failures occurred, leading to poor or no gathered data. To a significant extent, this was since (i) the objectives of D3.5 were not included in the project's initial plans, and (ii) the data logging troubleshooting took place mostly during the installations in all pilot farms that were due on June 2023. In all cases, now that meters are installed and log their measurements directly to the platform making them easily accessible for any interested member, a better picture for each of the pilot farms is constantly being drawn.

This Deliverable may conclude Task 3.1, but as a future step, the frequent observation of the farms' energy consumption will be intensified in the framework of WP4 ("Implementation and testing of the solutions in pilot farms") and WP5 ("Technical, socio-economic and environmental assessment"), acting as a positive factor for (a) the management of the specific loads in each farm (task scheduling, etc.) by the farms' personnel and (b) research purposes, by assisting in identifying the outcome of the planned within RES4LIVE interventions; by comparing the previous and the future state of each pilot farm.

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1 INTRODUCTION

1.1 Overall and specific objectives

The overall objective of this report is to evaluate the energy estimations of D3.1 ("Report on the analysis of energy demand/consumption and RES availability in typical livestock farms")[1] and make a detailed comparison between those and the data acquired by the energy meters installed in the four pilot farms. To make this report more complete, the estimations of D3.1 have been augmented with the updated information of D3.4 ("Development of livestock farm-specific numerical platform")[2]. In that way, a more comprehensive depiction of the values is feasible. It should be clarified that in the three pilot farms (namely LVAT, GOLINELLI & AUA) the values differ, while in the EV ILVO pilot farm, the estimations of D3.1 and D3.4 are made with the same set of data and therefore, the projected results are similar.

The work presented in this document focuses on the electrical energy demand and consumption of the pilot farms. Therefore, for each of the pilot farms (EV ILVO, GOLINELLI, LVAT, AUA) the energy requirements have been collected and presented in the respective dedicated section. The work is not limited only to the electrical energy demand; information about the energy production from the PVTs is presented and the estimations of D3.4 are compared with real data (measurement from the meters), where available. It should be noted that the exact PVT/PV installation dates along with the respective actual, measured values for each pilot farm will be presented in D4.3 ("Report with the results obtained on energy and production performances of RES and energy efficiency solutions").

More specifically, for each of the pilot farms, it was concluded that the best approach is to make estimations of the maximum level of inspection that can be achieved (e.g. per specific consumer/device). Therefore, in the pilot farms where data about specific machinery/loads are available, they have been collected and compared with the corresponding data of the aforementioned deliverables.

Before that, it was deemed useful to dedicate the next section to briefly presenting the energy meters selected for each pilot farm and building of interest, along with the loads they record.

[1] Delivered on September 2021.
[2] Delivered on March 2023.

2 INSTALLED ENERGY METERS PER FARM

2.1 Pilot farm in Belgium (swine)

In the EV ILVO pilot farm the main electrical energy consumers can be categorized according to their purpose as follows: ventilation, lighting, heating with heat lamps, feeding, and air scrubbing. Since lighting, heat lamps, feeding, and air scrubbing devices work according to a schedule[3], it was deemed necessary to install meters to measure ventilation-related consumptions.

It should be noted that an energy meter for the whole swine farm electricity usage pre-existed but offered no interconnectivity option (manual readings only), so it was upgraded to allow for Modbus communication. Including the latter, a total of 6 energy meters were installed within RES4LIVE Project, along with 2 communication modules.

The meters were installed accordingly to measure the following consumers (Figure 1 farm layout with notes attached below):

- Whole building – Overall consumption
- A single fan in the controlled fattening pig compartment
- High-pressure ventilators at the left fattening side (measuring 2 ventilators)
- High-pressure ventilators at the right fattening side (measuring 2 ventilators)
- High-pressure ventilator at sows
- A ventilator at quarantine and boar compartments

The energy meters in the EV ILVO pilot farm began logging in **late September 2022.**

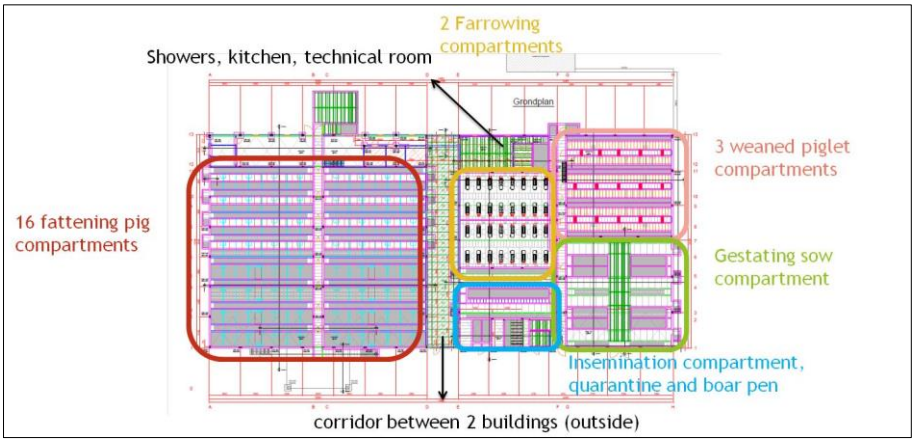


Figure 1. *EV ILVO farm layout.*

[3] Devices' working schedule is available for RES4LIVE Partners and can be shared after consultation with the farm.

2.2 Pilot farm in Italy (swine)

The GOLINELLI pilot farm, a commercial swine farm in Italy, had no energy metering device installed before the Project. After consultations with the farm management and UNIBO, it was deemed suitable to install 3 energy meters in the two buildings/barns of interest, namely the hog barn (B12) and nursery barn (B16), taking into consideration the expected consumptions along with the available fuses (Figure 2). It should be noted that lighting in both buildings is operated according to schedule.

- Overall consumption of Building 12 – hog barn
- Overall consumption of Building 16 – nursery barn
- Thermal lamps of Building 16

The energy meters in the GOLINELLI pilot farm began logging in **July 2022**.

Figure 2. *GOLINELLI farm layout.*

2.3 Pilot farm in Germany (dairy)

In the LVAT pilot farm, the available energy consumption data were quite detailed, however, the installation of specific energy meters was decided in order to accurately depict the allocation of the loads within the farm. It should be noted that LVAT is a dairy farm, and therefore milk production constitutes a large part of the electrical energy demand. Barn lighting is operated through a schedule. A total of 14 meters were installed as follows throughout the farm in specific rooms or devices (Figure 3):

- Compressor of AMS (Automatic Milking System) 2 & 3
- AMS 2 & 3
- Feeding Table (extension)
- Heater Rinse Tank
- Milk Cart
- Milk Cooling
- Milk parlor
- Milk Tank outside
- Pump Slurry
- Rotator Slurry left
- Rotator Slurry right
- Total Consumption Barn 1 + Welfare
- Tunnel Ventilation
- Welfare Barn

The energy meters in the LVAT pilot farm began logging in **late November 2022**.

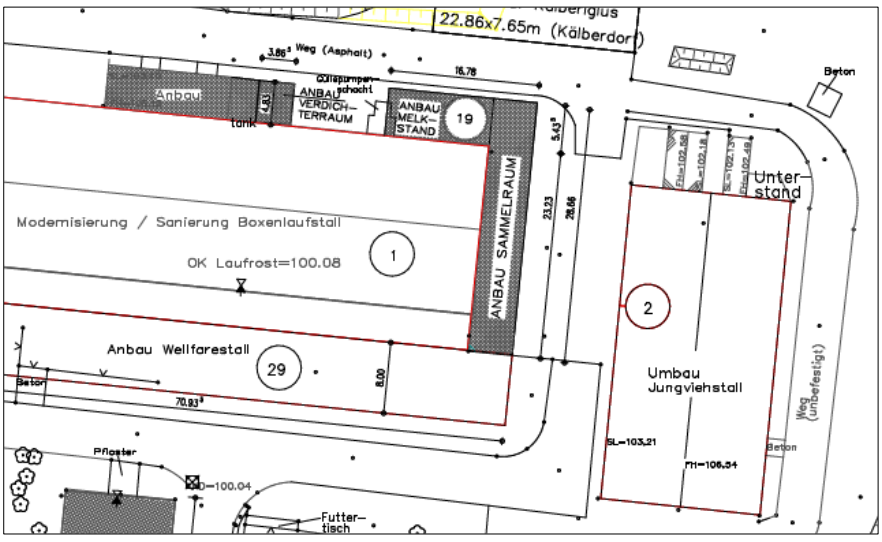


Figure 3. LVAT farm layout.

2.4 Pilot farm in Greece (poultry)

The experimental pilot farm in AUA is smaller than the 3 previous farms and consists of a single building with 2 separate rooms (Figure 4). All D3.1 estimations were done based on the given farm manager operating schedule of the main consumers. The farm utilizes electricity for lighting, heating, ventilation, manure removal, and feeding. It was decided to place a single energy meter to measure the whole building's consumption; the newly installed LED lights demand is measured through a standalone system and the energy production is measured through the power inverter:

- Overall consumption
- LED lights consumption
- PVs' production (power inverter)

The energy meters in the AUA pilot farm began logging in **January 2023** the LED lights consumption, in **May 2023** the overall consumption; and in **January 2023** the PVs' production.

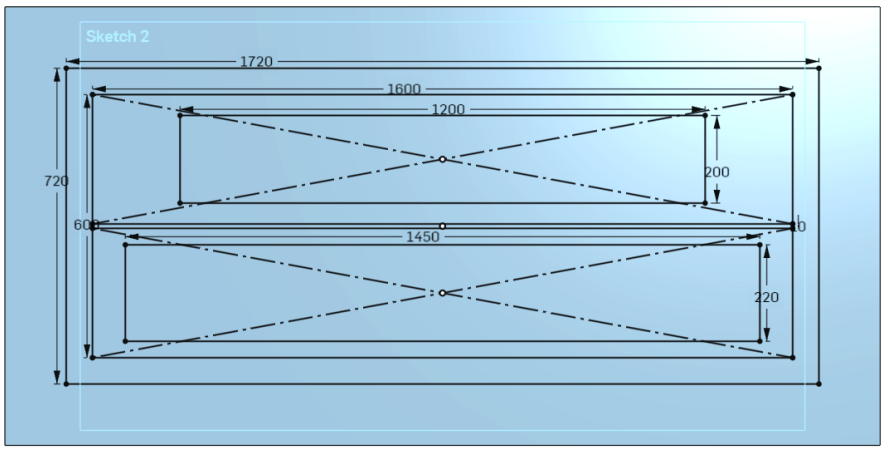


Figure 4. *AUA farm layout.*

3 ESTIMATED AND MEASURED ENERGY CONSUMPTION & ENERGY PRODUCTION DATA PER FARM

This section is dedicated to the comparison between the estimations of D3.1, D3.4, and the real data derived from the sensors installed in the pilot farms. The collection of the sensors' information was performed through the dedicated cloud platform[4] (*https://cloud.gr/*) developed by PLEGMA.

It must be noted that as presented in the previous section, the installation dates of the sensors in each pilot farm vary, therefore the comparison is performed only for the available data, that in some cases are not complete enough for a thorough evaluation. To tackle this issue all available data were collected and sorted over a monthly period to compare the estimated values with the real data for as many months as there are available logged data. The time period that was selected for this study was May 2022 to June 2023. Furthermore, due to the pending installation of the complete metering system, information about the PVTs' energy production is only available for the AUA pilot farm at the time that this report is being written. So, for the rest of the farms, only the estimations of D3.4 are available.

In the following sub-sections, a detailed evaluation of the derived results is presented and the errors between the estimations and real data are explained extensively.

3.1 Pilot farm in Belgium (swine)

3.1.1 Energy Consumption

In the EV ILVO pilot farm, the estimations of D3.1 and D3.4 for the electrical energy demand were performed based on the existing data that was shared by the farm. These estimations are an accumulation of the individual loads' consumption based on real information, representing the complete energy requirements of the farm. On the other hand, the cloud platform hosts the measurements of multiple on-site meters that measure specific loads and their energy consumption, as well as the complete energy demand of the whole building.

To retrieve the data from the 6 energy meters (*ILVO FARM > Energy Meter – {id} > total active power*)[5], the available for each month of interest values were collected using the options Frequency: '*Monthly*' and Function: '*Average*' and were summed up for each month in order to calculate the electrical energy expressed in Whs. These data are presented in Figure 5.

[4] Authentication is required.

[5] Where {id} represents the identification of each energy meter, namely: 1) Fan, 2) Ventilation high pressure left at fattening side, 3) Ventilation high pressure right at fattening side, 4) Ventilation high pressure sows, 5) Ventilation Quarantine, 6) Whole Building.

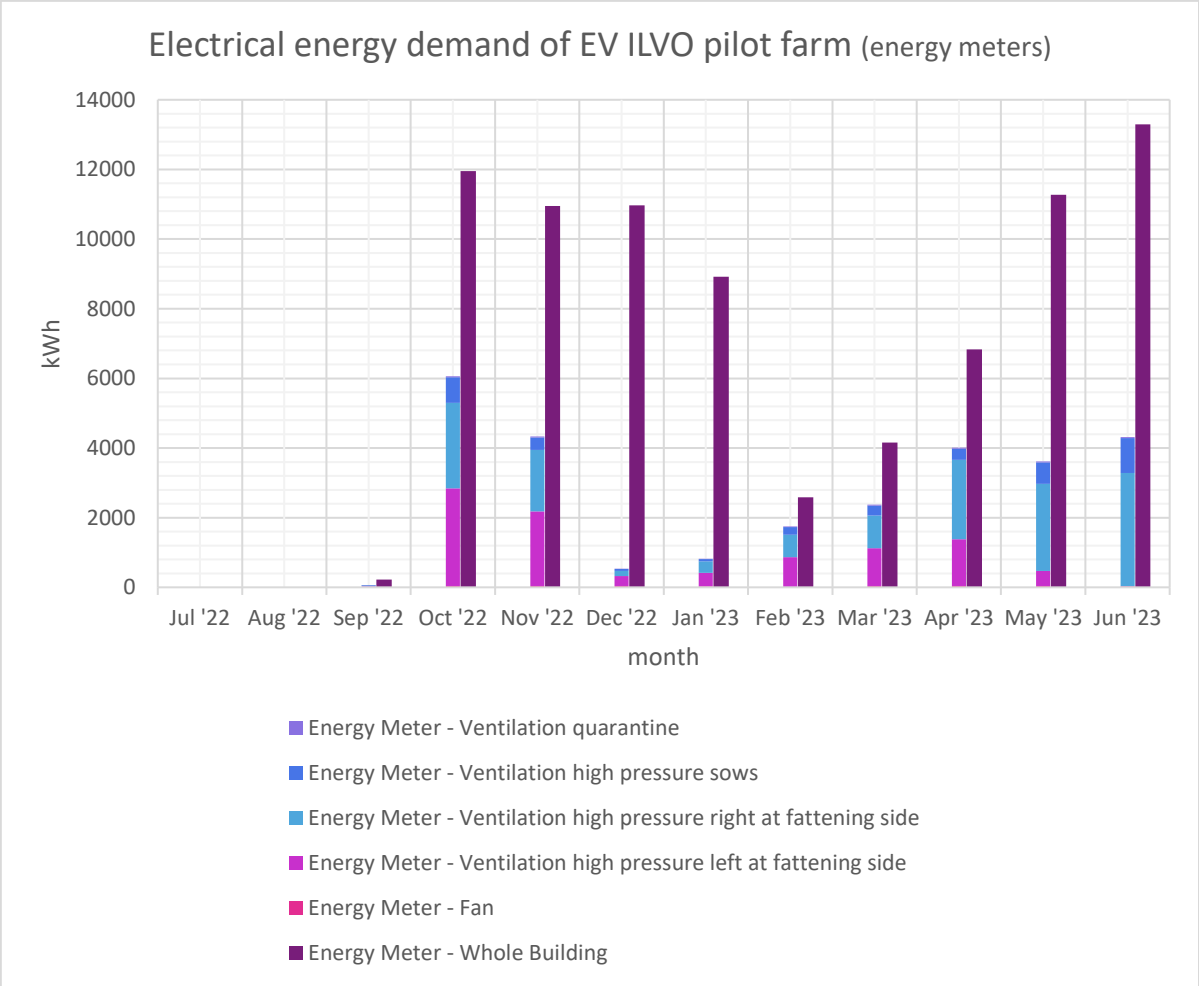


Figure 5. *The electrical energy demand of EV ILVO pilot farm (energy meters).*

In the above graph, it can be observed that the combined consumption of the 5 distinct energy meters does not add up to the value of the one that measures the total consumption of the whole building. This can be explained by the fact that no specific energy meters for all loads present in the EV ILVO pilot farm were installed; thus the 5 distinct energy meters measure the ventilation consumption only, disregarding the other loads as described in Section 2 of this report. Also, it must be highlighted that in the first 2 months of the selected period (July 2022 to August 2022), the energy meters were not receiving any measurements and only a few of those started operating in September 2022. Finally, from the data retrieved it is clear that the energy meter with the id: '*Ventilation high pressure left at fattening side'* malfunctions between 06/12/2022 to 25/01/2023 and has stopped logging measurements. In the above graph that is visible as an abrupt decrease in the respective months' log.

For two of the above energy meters, more specifically the ones with the ids: *'Fan'* and *'Whole Building'*, besides the total active power the total active energy import could be calculated using the options Frequency: '*Monthly'* and Function: '*Delta'*. These measurements were accumulated to verify that the method used, which was described previously, was accurate enough for the needs of this study. Those results are presented in Figure 6 and Figure 7.

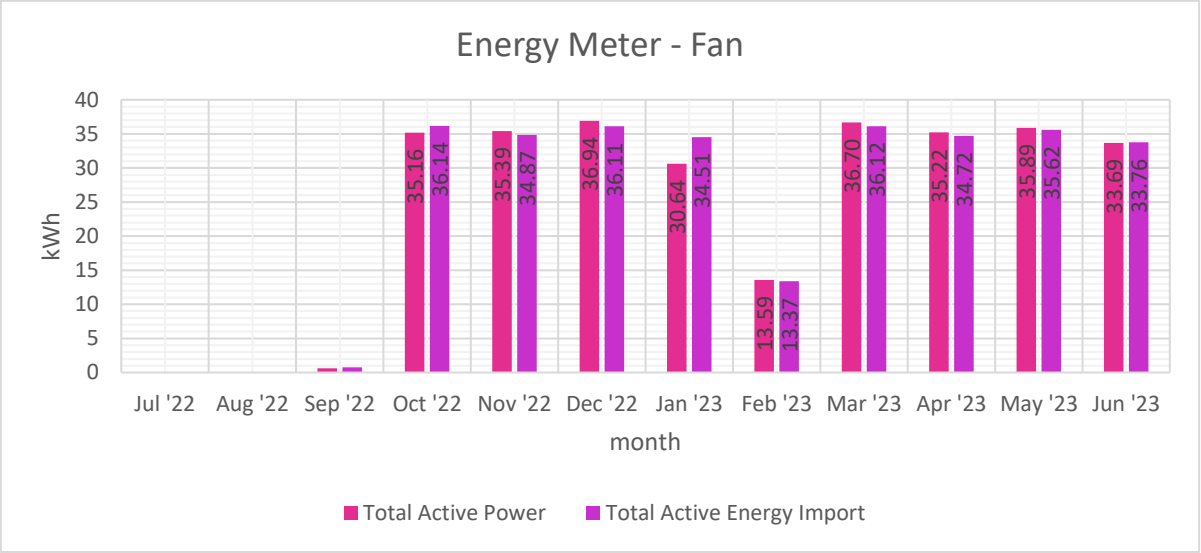


Figure 6. *EV ILVO pilot farm 'Energy Meter – Fan' total active power and total active energy import.*

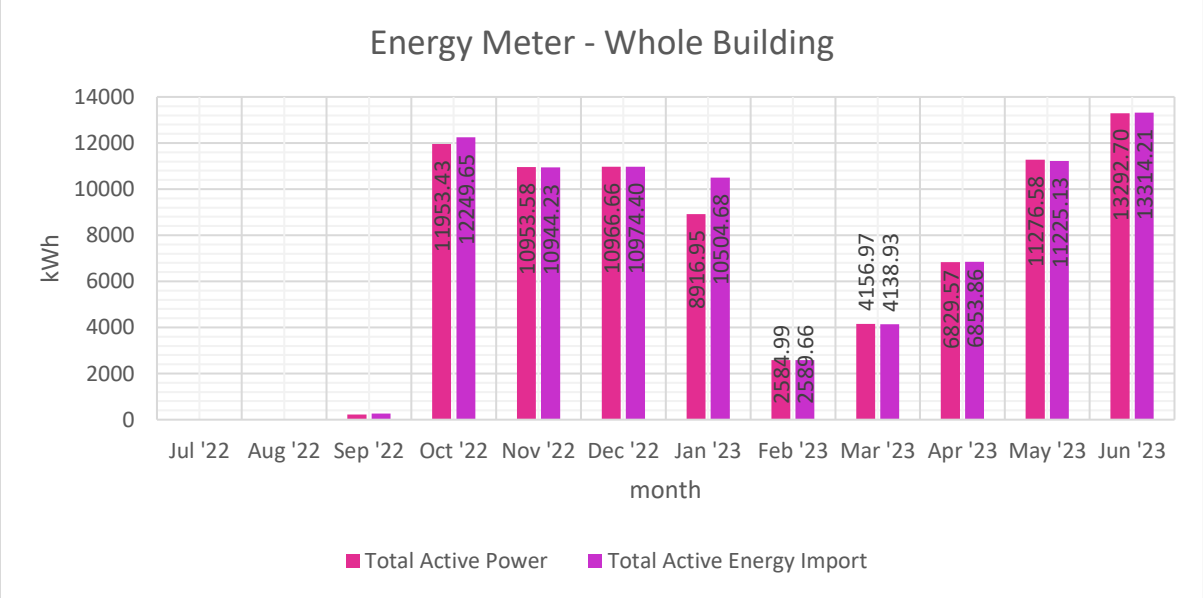


Figure 7. *EV ILVO pilot farm 'Energy Meter – Whole Building' total active power and total active energy import.*

In these graphs it can be observed that the two measurements have minimum to insignificant deviation, verifying the accuracy of the method used and described previously.

In order to carry out the comparison between the estimated values and the actual, real-life data, only the accumulated energy consumption was taken into account. This information is presented in Figure 8, along with the MPE (Mean Percentage Error) score between the estimated and real values in Table 1.

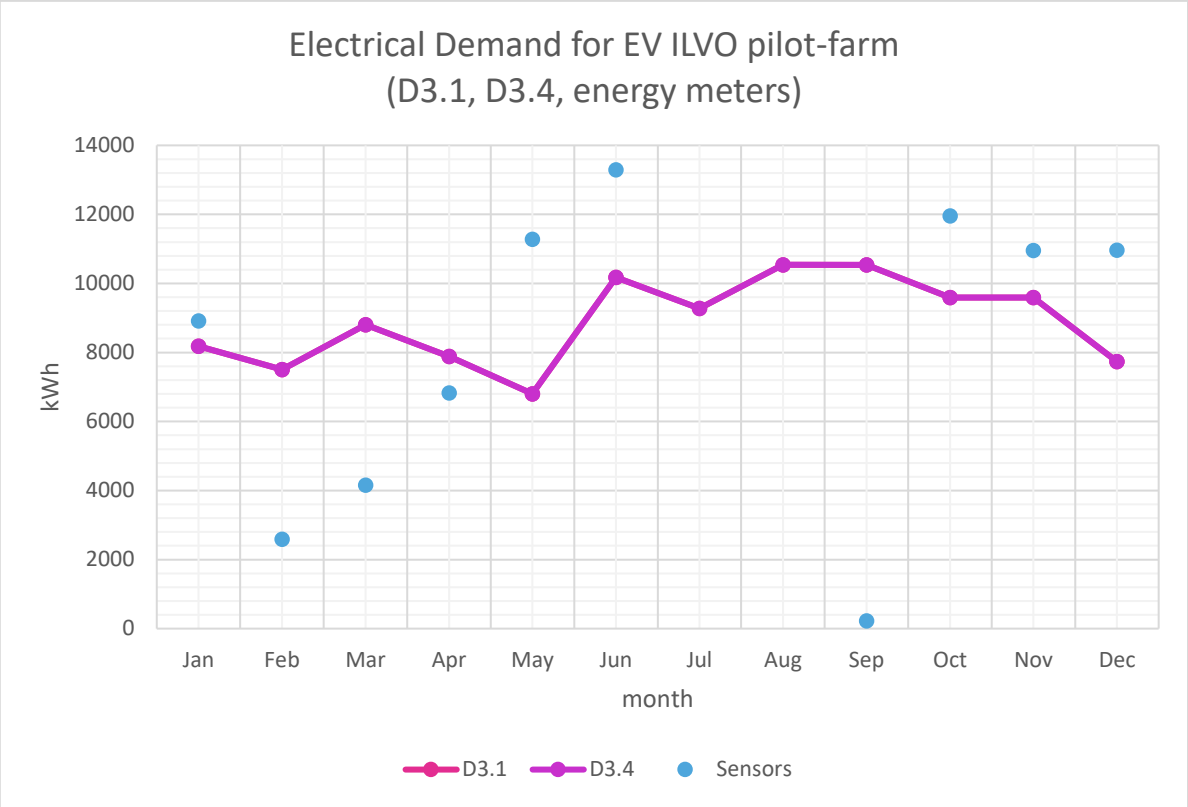


Figure 8. *The electrical energy demand of EV ILVO pilot farm (D3.1, D3.4, energy meters).*

Table 1. *MPE scores of the electrical energy demand of EV ILVO pilot farm (D3.1, D3.4, energy meters).*

Month	D3.1 [kWh]	D3.4 [kWh]	Sensors [kWh]	MPE Score $\left(\frac{x_{D3.1}-x_{D3.4}}{x_{D3.1}}\cdot 100\right)$ [%]	MPE Score $\left(\frac{x_{Sensors}-x_{D3.1}}{x_{Sensors}}\cdot 100\right)$ [%]	MPE Score $\left(\frac{x_{Sensors}-x_{D3.4}}{x_{Sensors}}\cdot 100\right)$ [%]
Jan	8181.60	8181.60	8916.95	0.00	8.25	8.25
Feb	7500.20	7500.20	2584.99	0.00	-190.14	-190.14
Mar	8804.60	8804.60	4156.97	0.00	-111.80	-111.80
Apr	7880.40	7880.40	6829.57	0.00	-15.39	-15.39
May	6803.40	6803.40	11276.58	0.00	39.67	39.67
Jun	10172.50	10172.50	13292.70	0.00	23.47	23.47
Jul	9272.60	9272.60	#N/A	0.00	#N/A	#N/A
Aug	10541.10	10541.10	#N/A	0.00	#N/A	#N/A
Sep	10541.00	10541.00	222.69	0.00	-4633.58	-4633.58

Oct	9587.50	9587.50	11953.43	0.00	19.79	19.79
Nov	9587.60	9587.60	10953.58	0.00	12.47	12.47
Dec	7735.40	7735.40	10966.66	0.00	29.46	29.46

The above values indicate that the estimations of D3.1 and D3.4 are the same since the MPE score is zero for each month. As clarified in the Introduction, this is due to the same set of data being utilized for the EV ILVO pilot farm for the estimations of D3.4. Furthermore, the MPE score between the real and estimated values showcases the accuracy of the methodology of the previous deliverables. For the majority of the available samples, the MPE score is below the 20% mark, and only for two months is slightly above that. The high MPE score spotted in September can be explained by the fact that it depicts the first month of the energy meters' operation and the measurements only include the last few days. Also, the high MPE scores in February and March were due to malfunctions of the energy meters during that period.

3.1.2 Energy Production

Even though the PVT system in the EV ILVO farm was partially installed when this report was being written, the installation of the energy meters to monitor the energy produced had not been completed, thus the only data available are the estimations of D3.4 which are illustrated in Figure 9[6].

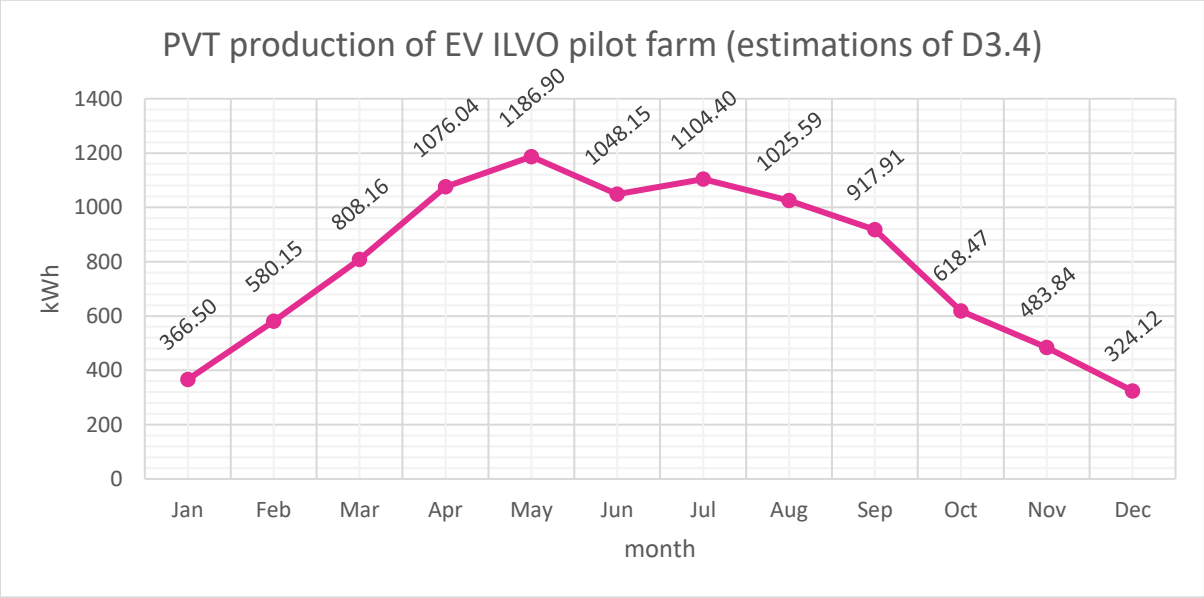


Figure 9. *PVT Production of EV ILVO pilot farm (estimations of D3.4).*

Here it can be noted that as expected, the PVTs' production is higher during the spring and summer periods, reaching a peak value in May, while the rest of the year the produced energy is slightly lower.

3.2 Pilot farm in Italy (swine)

[6] The exact PVT/PV installation dates along with the respective actual, measured values for each pilot farm will be presented in D4.3.

3.2.1 Energy Consumption

In the GOLINELLI pilot farm, the available data were very limited, therefore in D3.1 a numerical-study simulation was performed utilizing the computational analysis software ANSYS Steady-State Thermal Solver to estimate the energy required for maintaining the desired conditions in the two buildings/barns of interest. Data derived from the CFD simulation are presented in Figure 10. A detailed graph including the data labels is attached in Appendix .

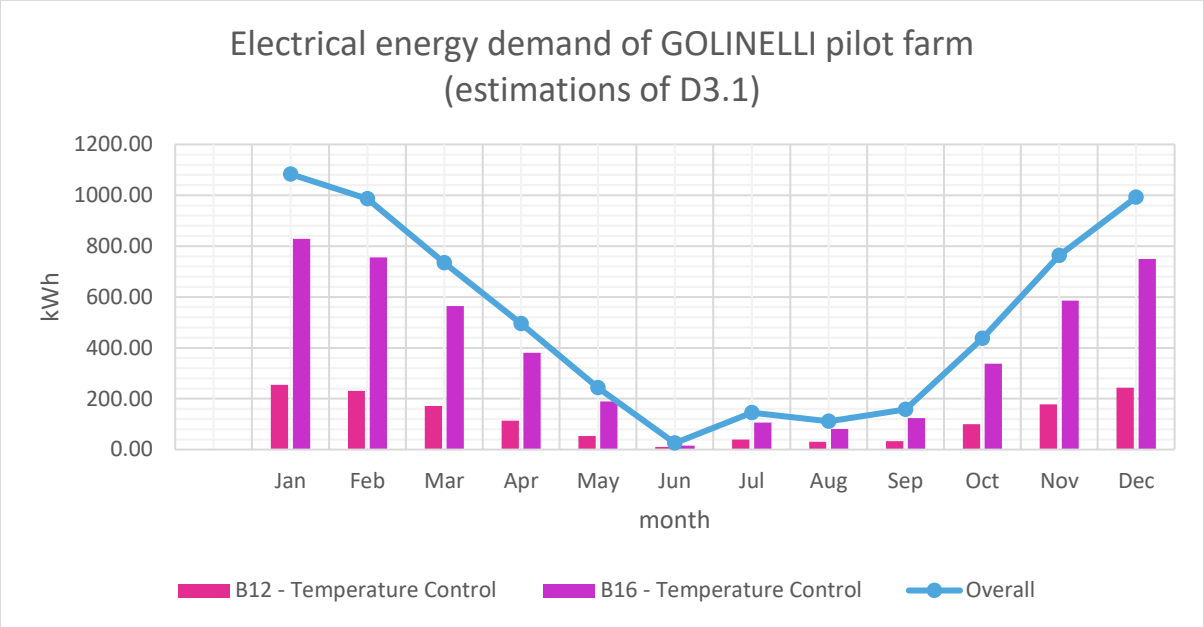


Figure 10. *The electrical energy demand of the GOLINELLI pilot farm (estimations of D3.1).*

However, the estimations of D3.4 are complete and can be used for a detailed comparison with the data acquired by the meters, which were in this case categorized as: 1) B12[7] – Ventilation & Lights, 2) B16[8] – Ventilation and 3) B16 – Thermal lamps and lights. Figure 11 are presented the estimated values of D3.4. A detailed graph including the data labels can be found in Appendix .

[7] Building 12 – Hog barn
[8] Building 16 – Nursery barn

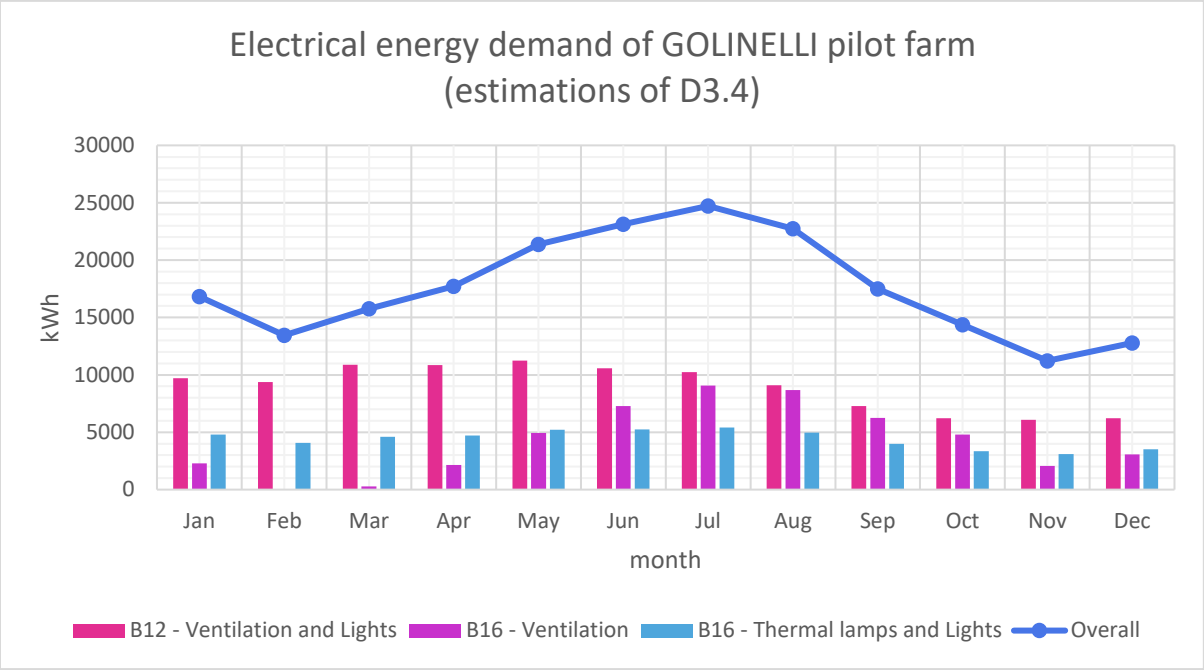


Figure 11. *The electrical energy demand of the GOLINELLI pilot farm (estimations of D3.4).*

To retrieve the data from the energy meters, the following 3 nodes were taken into account:

- *GOLINELLI farm > Energy meter - Hog barn, Building 12 > positive_active_energy*
- *GOLINELLI farm > Energy meter - Nursery barn, Building 16 > positive_active_energy*
- *GOLINELLI farm > Energy meter - Thermal lamps, Building 16 > positive_active_energy*

The measurements were accumulated using the options Frequency: *'Hourly'* and Function: *'Delta'* for each of the 13 months between May 2022 and June 2023. Afterward, the hourly consumptions were summed up and multiplied by a factor of 100 to calculate the consumed Whs for each month. These data are presented in Figure 12.

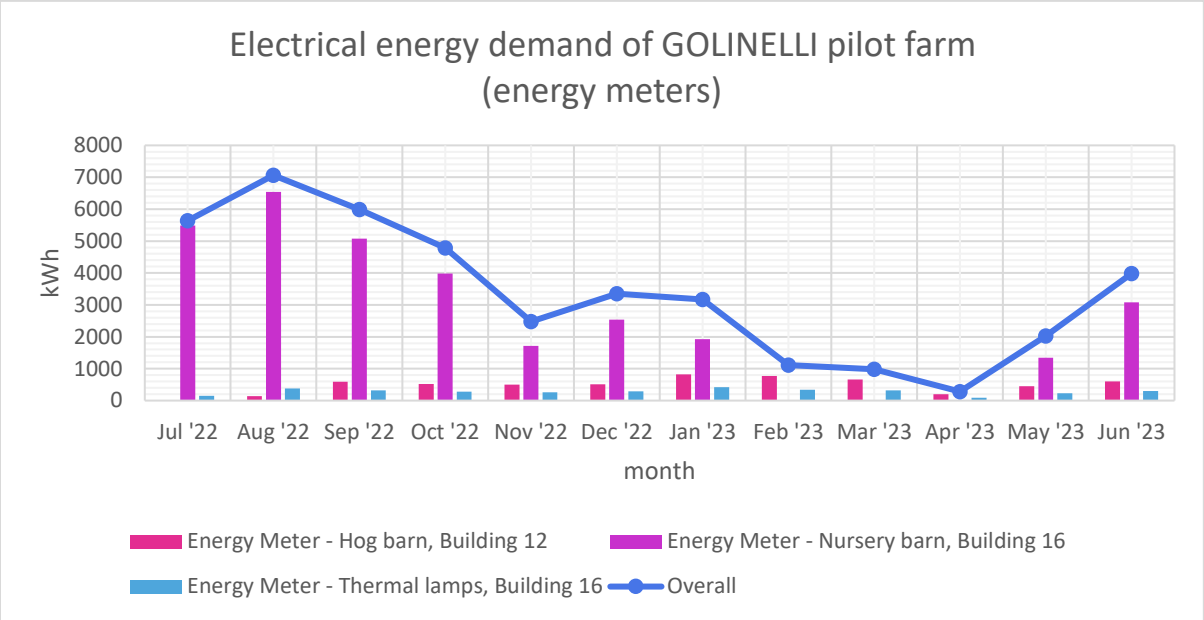


Figure 12. *The electrical energy demand of the GOLINELLI pilot farm (energy meters).*

As observed, the actual energy demand has been monitored for the period July 2022 to June 2023. Due to malfunctions, however, the first node *(Energy Meter – Hog barn, Building 12)* did not calculate the consumption during July 2022 and the second node *(Energy Meter – Nursery barn, Building 16)* monitored a non-realistic, zero demand for 3 consecutive months, February 2023 to April 2023.

A comparison between the estimations of D3.1, D3.4, and the actual data derived from the sensors was performed and the results are presented in Figure 13, accompanied by the MPE score in Table 2.

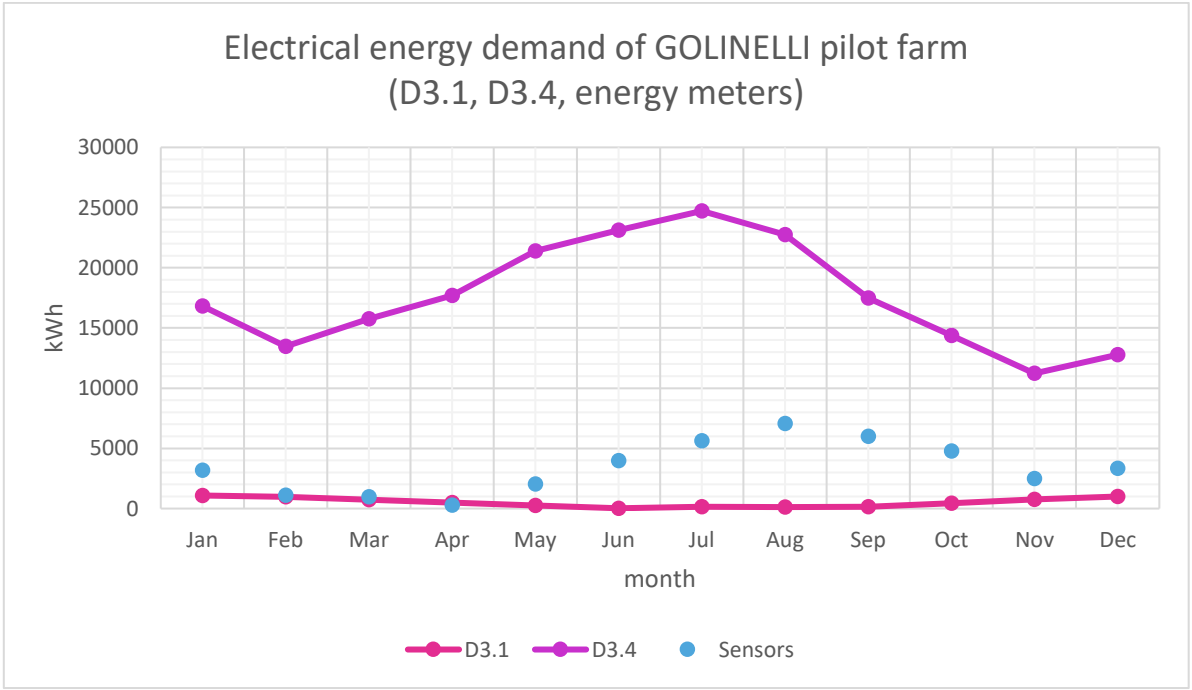


Figure 13. *The electrical energy demand of the GOLINELLI pilot farm (D3.1, D3.4, energy meters).*

Table 2. *MPE scores of* ***the*** *electrical energy demand of the GOLINELLI pilot farm (D3.1, D3.4, energy meters).*

Month	D3.1 [kWh]	D3.4 [kWh]	Sensors [kWh]	MPE Score ($\frac{x_{D3.1}-x_{D3.4}}{x_{D3.1}}$. 100) [%]	MPE Score ($\frac{x_{Sensors}-x_{D3.1}}{x_{Sensors}}$. 100) [%]	MPE Score ($\frac{x_{Sensors}-x_{D3.4}}{x_{Sensors}}$. 100) [%]
Jan	1083.29	16822.26	3170.30	-2396.03	65.83	-430.62
Feb	986.14	13458.53	1112.00	-1894.64	11.32	-1110.30
Mar	734.70	15765.60	984.10	-1598.27	25.34	-1502.03
Apr	494.69	17708.55	283.50	-1712.89	-74.49	-6146.40
May	243.25	21381.51	2029.40	-2146.01	88.01	-953.59
Jun	25.35	23124.11	3986.60	-2149.28	99.36	-480.05
Jul	145.35	24720.34	5635.60	-2209.10	97.42	-338.65
Aug	111.07	22739.10	7063.70	-2065.75	98.43	-221.91
Sep	157.53	17497.79	5992.10	-1781.49	97.37	-192.01
Oct	437.54	14368.69	4783.00	-1856.25	90.85	-200.41
Nov	763.27	11223.78	2478.80	-2290.77	69.21	-352.79
Dec	992.58	12788.62	3348.80	-2587.97	70.36	-281.89

The results above demonstrate that the estimations of D3.1 and D3.4 were not accurate, resulting in a high MPE score when compared to the measured data. This can be explained in two ways. A) Due to a complete lack of energy data for the GOLINELLI farm, the estimations of D3.1 were performed only for the temperature control requirements, which are only a fraction of the overall consumption and are thus significantly lower than both the real consumption and the estimations of D3.4, and B) The estimations of D3.4 were performed using interpolation based on the given, from the farm, data to complete a full-year cycle. By observing the high deviations it can be assumed that the given data were not representative of the actual consumption. That, in addition to the malfunction of the energy meters, had as a result the estimations of D3.4 to be higher than the actual, measured consumption.

3.2.2 Energy Production

Regarding the energy production for the GOLINELLI farm, the PVT's system energy metering had not been completed when this report was being written[9]. So, the only data available that can be

[9] The exact PVT/PV installation dates along with the respective actual, measured values for each pilot farm will be presented in D4.3.

presented are the estimations of D3.4 which are illustrated in Figure 14. There it can be observed that, as expected, the production of the PVT system is higher during the spring and summer periods when compared to winter and autumn.

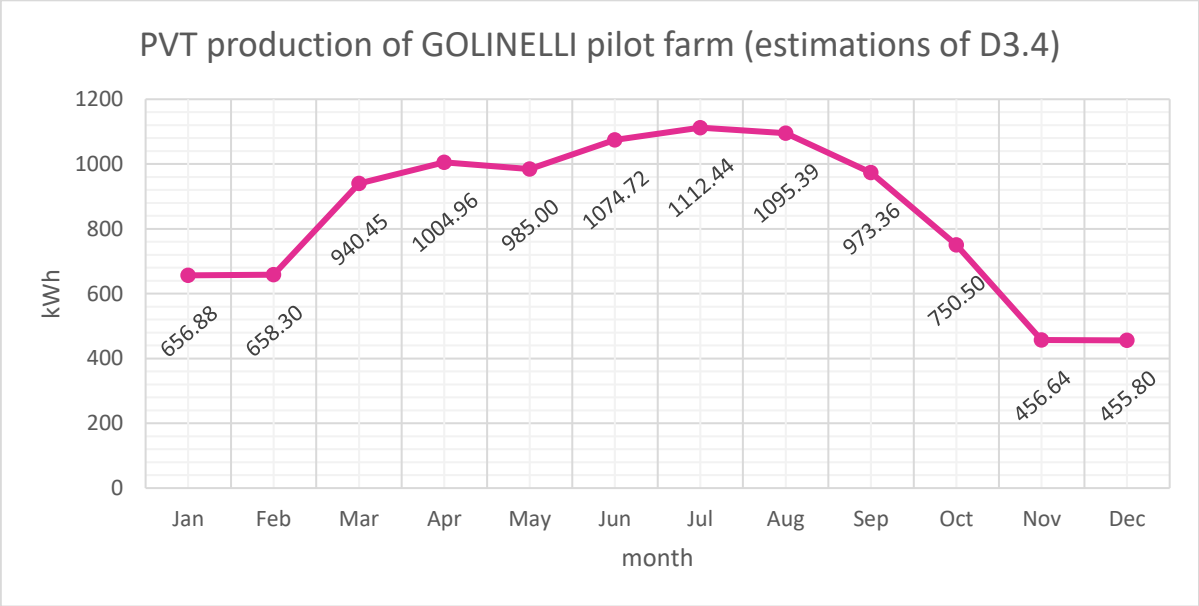


Figure 14. *PVT production of GOLINELLI pilot farm (estimations of D3.4).*

3.3 Pilot farm in Germany (dairy)

3.3.1 Energy Consumption

The estimations of D3.1 regarding the LVAT pilot farm were made utilizing data given by the farm and were calculated on a barn/building basis. Figure 15 presents the load distribution of the electrical energy for the whole farm, while in Figure 16 the demand on a barn/building basis is presented. A similar method was followed for the estimations of D3.4 (Figure 17). The datasets which produced the aforementioned graphs vary slightly, due to D3.4 being most recently updated. Detailed graphs of the abovementioned estimations including the data labels can be found in Appendix .

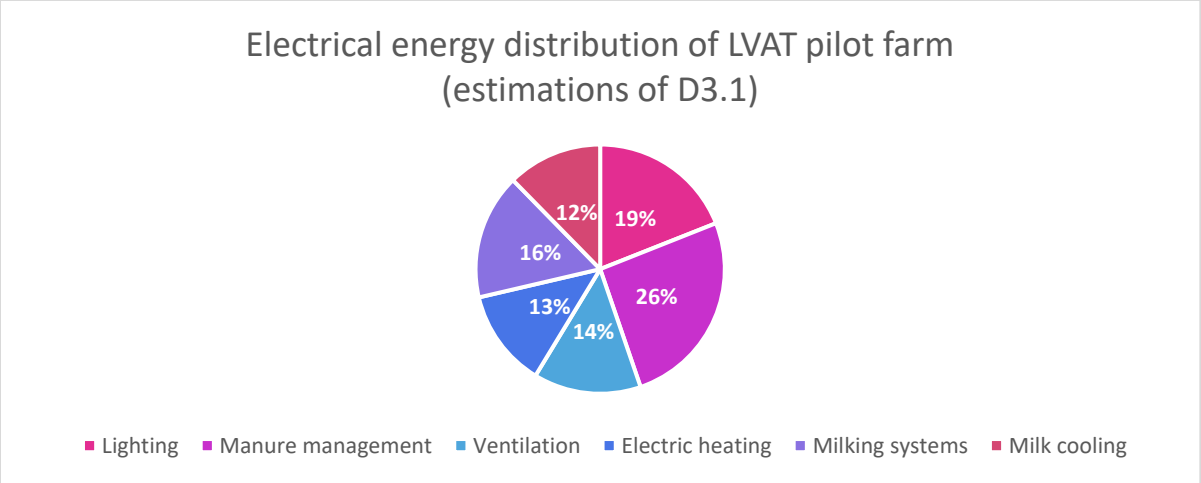


Figure 15. *Electrical energy distribution of LVAT pilot farm (estimations of D3.1).*

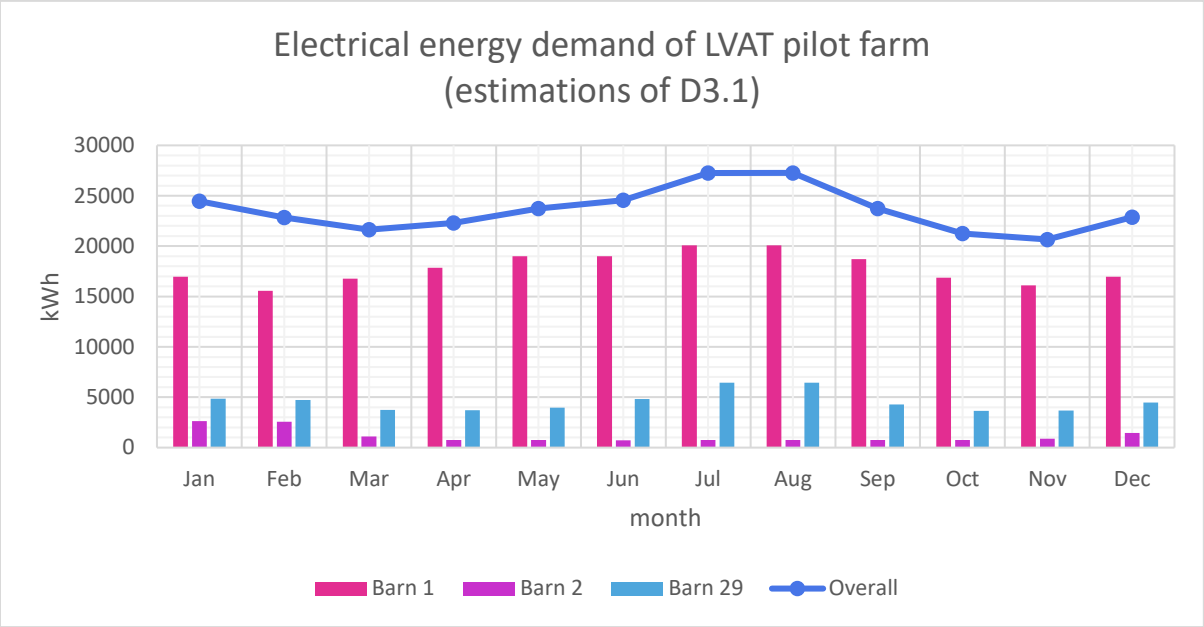


Figure 16. *The electrical energy demand of LVAT pilot farm (estimations of D3.1).*

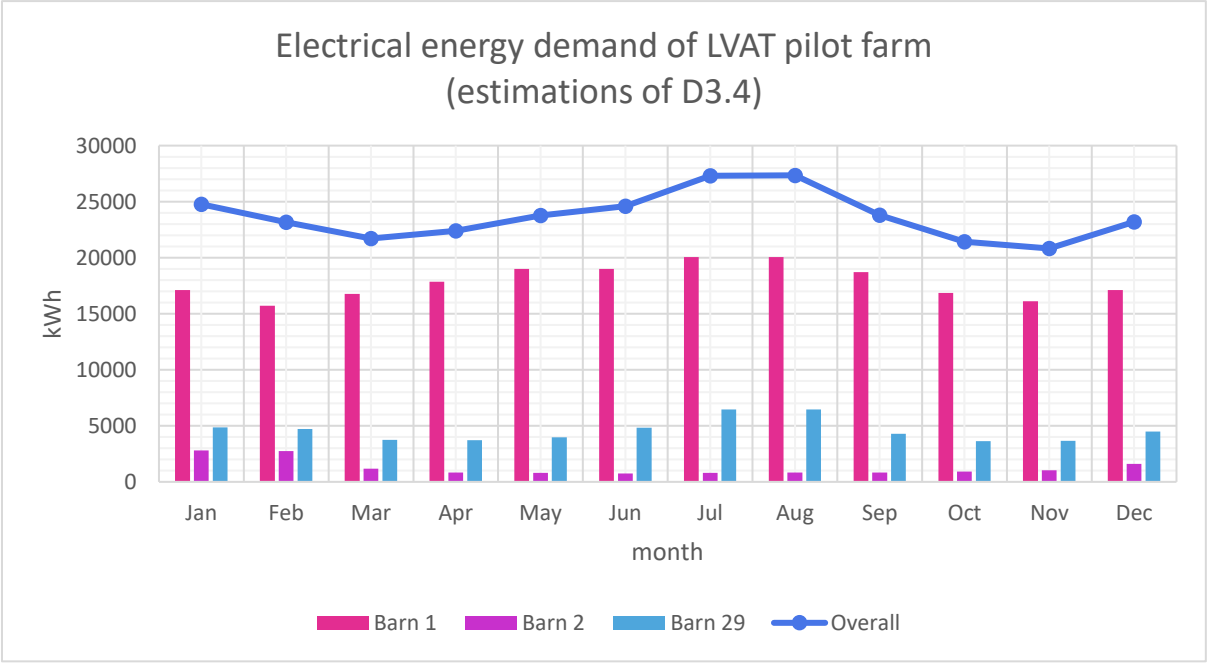


Figure 17. *The electrical energy demand of LVAT pilot farm (estimations of D3.4).*

Regarding the measurements retrieved in the cloud platform, the data processing methodology was similar to the other farms. Data from the 14 installed energy meters *(Germany Farm > Energy Meter: {id} > Kwhimport)*[10] were retrieved using the options Frequency: '*Monthly*' and Function: '*Delta*'. These data are presented in Figure 18.

[10] Where {id} represents the identification of each energy meter, namely: 1) AMS 2+3 Compressor, 2) Automatic Milking System (AMS) 2+3, 3) Feeding Table (extension), 4) Heater Rinse Tank, 5) Milk Cart, 6) Milk Cooling, 7) Milk parlor, 8) Milk Tank outside, 9) Pump Slurry, 10) Rotator Slurry left, 11) Rotator Slurry right, 12) Total Consumption Big Barn + Welfare, 13) Tunnel Ventilation, 14) Welfare Barn.

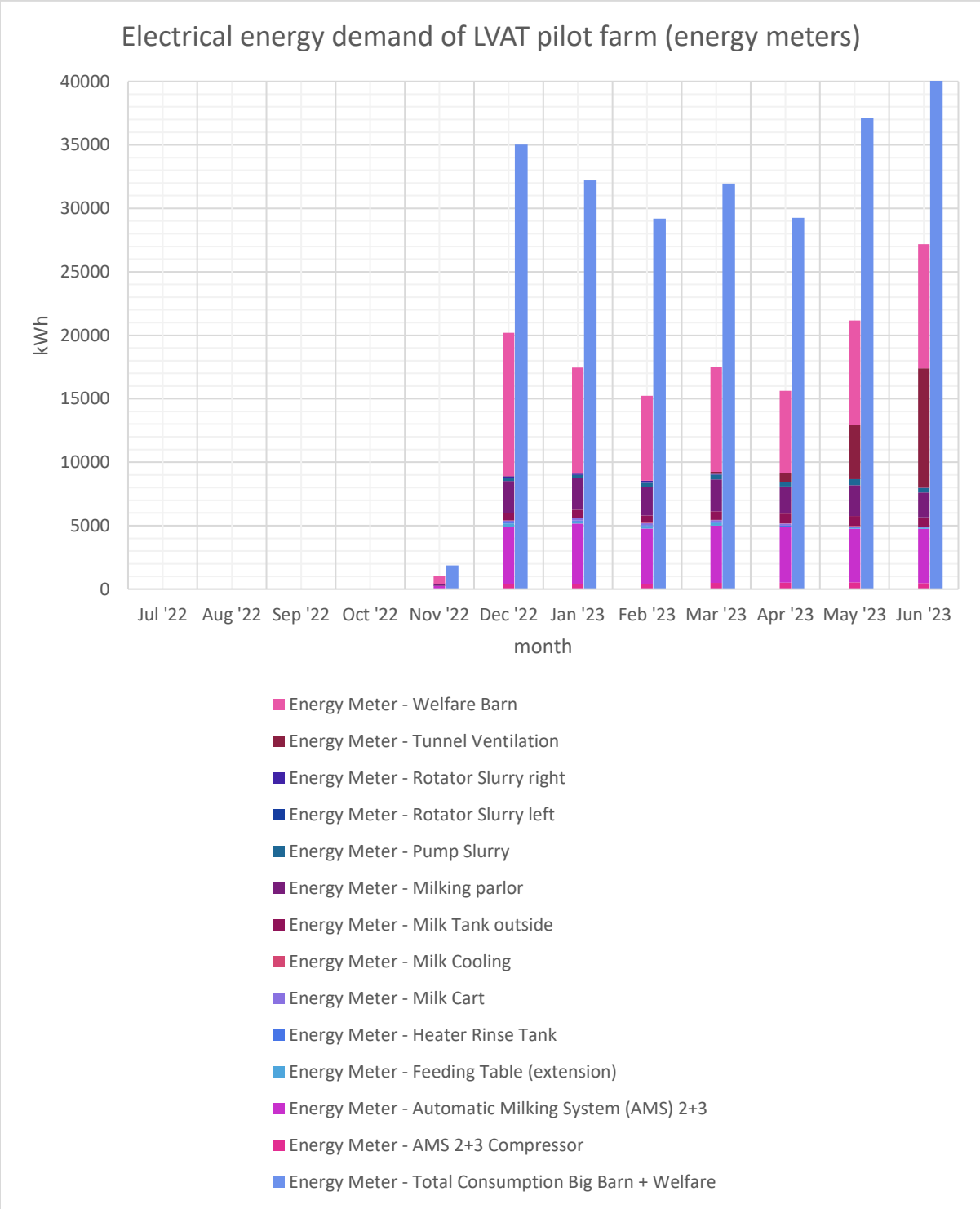


Figure 18. *The electrical energy demand of LVAT pilot farm (energy meters).*

It can be observed that the energy meters receive no data in the first 4 months (July 2022 to October 2022), with their first readings being present on month November 2022. Also, the overall consumption is higher than the accumulated consumption of the 13 other energy meters as those do not include all loads present in the pilot farm, as described also in the case of the EV ILVO pilot farm. Finally, from the data retrieved, it is clear that the node *(Energy Meter – Rotator Slurry left)*

malfunctions as it delivers zero values over the complete duration of the study, while the *(Energy Meter – Tunnel Ventilation)* shows zero values for the months January 2023 and February 2023.

In order to make the necessary comparisons between the estimated and actual, measured values, the total electrical demand was accumulated for each of the datasets for every month and the corresponding results are presented in Figure 19, alongside the MPE score in Table 3.

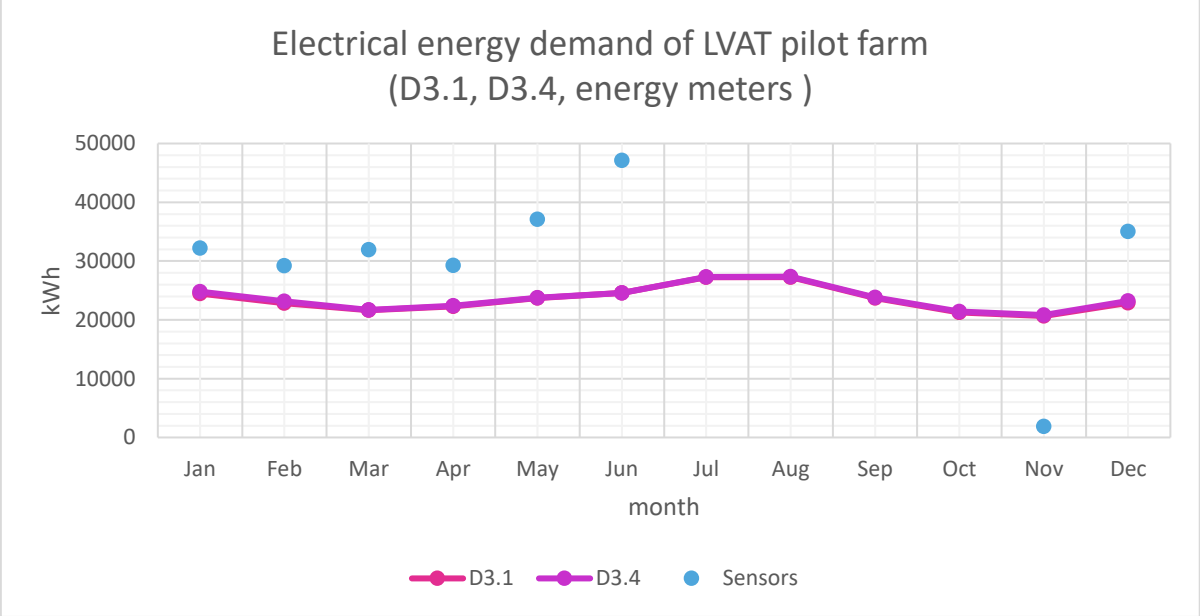


Figure 19. *The electrical energy demand of LVAT pilot farm (D3.1, D3.4, energy meters).*

Table 3. *MPE scores of the electrical energy demand of LVAT pilot farm (D3.1, D3.4, energy meters).*

Month	D3.1 [kWh]	D3.4 [kWh]	Sensors [kWh]	MPE Score ($\frac{x_{D3.1}-x_{D3.4}}{x_{D3.1}}$. 100) [%]	MPE Score ($\frac{x_{Sensors}-x_{D3.1}}{x_{Sensors}}$. 100) [%]	MPE Score ($\frac{x_{Sensors}-x_{D3.4}}{x_{Sensors}}$. 100) [%]
Jan	24448.28	24770.68	32198.00	-125.39	24.07	23.07
Feb	22845.05	23167.45	29188.40	-78.20	21.73	20.63
Mar	21628.53	21709.73	31950.80	-14.39	32.31	32.05
Apr	22303.71	22384.91	29259.10	-9.57	23.77	23.49
May	23720.18	23760.78	37119.30	-4.72	36.10	35.99
Jun	24566.87	24583.11	47149.60	-1.97	47.90	47.86
Jul	27266.08	27306.68	#N/A	-4.96	#N/A	#N/A
Aug	27269.88	27351.08	#N/A	-10.10	#N/A	#N/A
Sep	23729.11	23810.31	#N/A	-11.73	#N/A	#N/A

Oct	21261.78	21424.18	#N/A	-40.54	#N/A	#N/A
Nov	20660.66	20823.06	1866.30	-58.64	-1007.04	-1015.74
Dec	22884.98	23207.38	35024.40	-155.97	34.66	33.74

Here it appears that the estimations of D3.1 and D3.4 have a few differences since the respective datasets were processed with slightly different inputs. Nevertheless, the comparison between those and the measured data retrieved from the cloud platform indicates that the estimations were accurate enough as for the majority of the available data the MPE score is around or well below the 35% mark. The only unfavourably high MPE score that can be spotted is for November when the energy meters initialized their measurements and thus do not depict a complete month's inputs.

3.3.2 Energy Production

Regarding the energy production for the LVAT farm, the PVT system had not been installed at the time of writing this report; therefore the only data available that can be presented are the estimations of D3.4 which are illustrated in Figure 20[11].

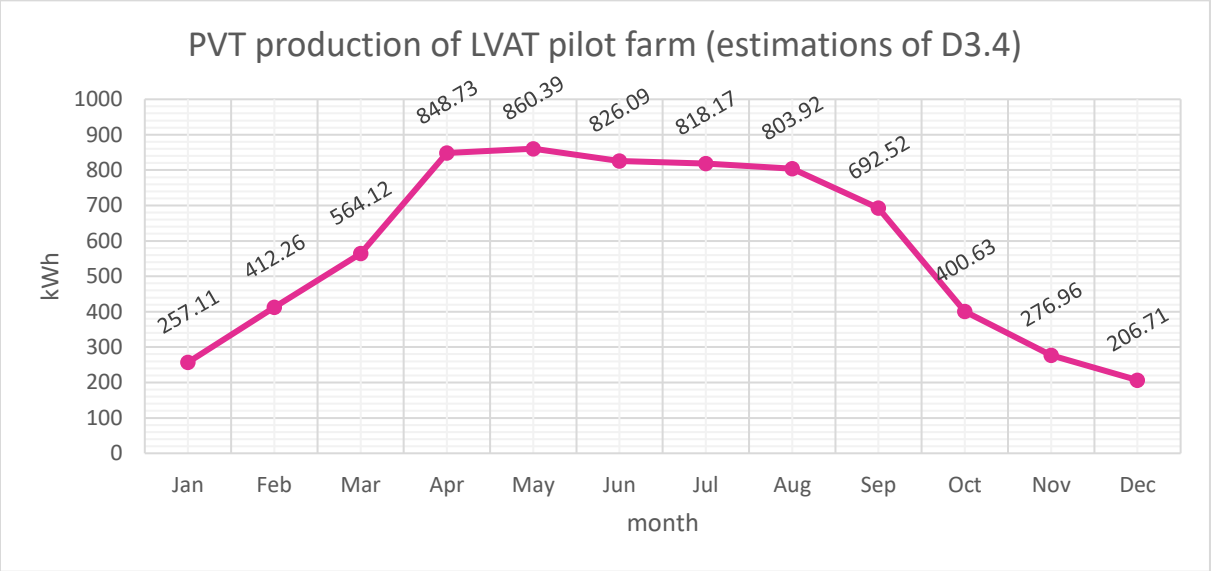


Figure 20. *PVT production of LVAT pilot farm (estimations of D3.4).*

From the results above, it can be spotted that the PVTs' production is higher during the spring and summer months, peaking in May. For the rest of the year cycle, the energy production is slightly below that point, which is expected due to weather conditions.

3.4 Pilot farm in Greece (poultry)

3.4.1 Energy Consumption

[11] The exact PVT/PV installation dates along with the respective actual, measured values for each pilot farm will be presented in D4.3.

The estimations for D3.1 regarding the AUA farm are specific on a component-level basis, accompanied by a numerical-study simulation performed with the computational analysis software ANSYS Steady-State Thermal Solver to estimate the energy required for maintaining the desired conditions in the building. Data derived from the CFD simulation are presented in Figure 21. A detailed graph including the data labels is attached in Appendix .

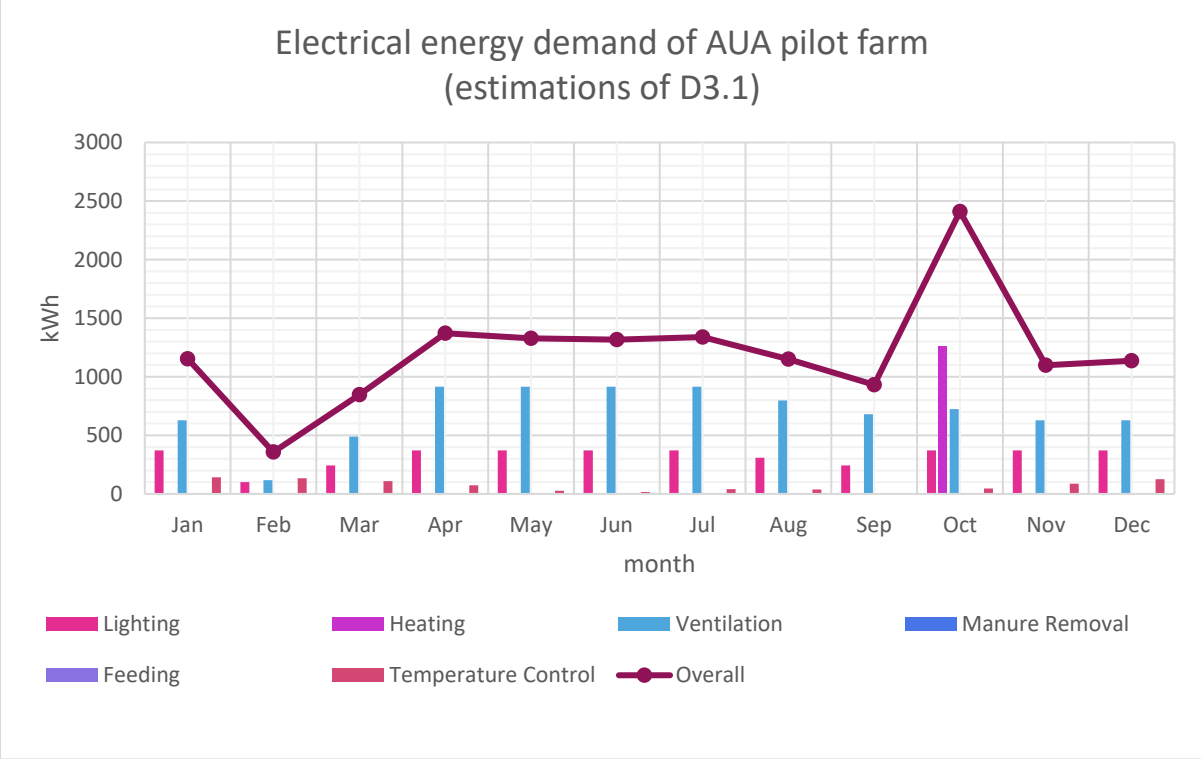


Figure 21. *The electrical energy demand of AUA pilot farm (estimations of D3.1).*

To retrieve the monthly electrical energy demand from the installed energy meter, data from the respective node in the cloud platform *(Athens Farm > Energy Meter – Ptina > EnergyReal_WAC_Sum_Consumed)* were retrieved using the options Frequency: *'Monthly'* and Function: *'Delta'*. However, the values retrieved represent the overall energy consumption over a specified period of time. For this reason, the aforementioned estimations were combined resulting in a total farm demand in order to carry out the comparison between the monthly consumption. In Figure 22 these data are included together with the estimations of D3.4.

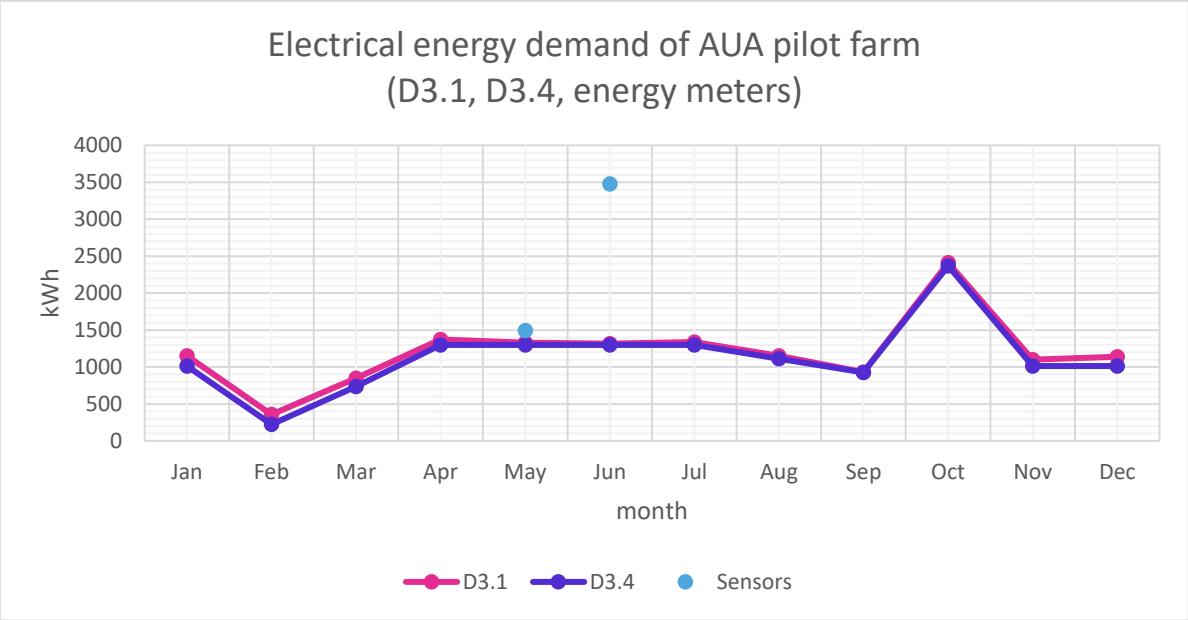


Figure 22. *The electrical energy demand of AUA pilot farm (D3.1, D3.4, energy meters).*

As illustrated in the figure above the estimations of D3.1 and D3.4 are very similar. That is because their only difference is the estimation of the energy required for maintaining the desired temperature in the building, as it was redundant for the needs of the development of the numerical platform of Task 3.4. Regarding the installed meter, only two values (May-June 2023) are available due to prior inefficient operation of the meter, which has now been fixed.

To evaluate the quality of the estimations based on the measured data, the MPE score was calculated between every two sets of values, and the results are presented in Table 4, alongside the electrical demand of each set of values.

Table 4. *MPE scores of the electrical energy demand of AUA pilot farm (D3.1, D3.4, energy meters).*

Month	D3.1 [kWh]	D3.4 [kWh]	Sensors [kWh]	MPE Score $\left(\frac{x_{D3.1}-x_{D3.4}}{x_{D3.1}}\cdot 100\right)$ [%]	MPE Score $\left(\frac{x_{Sensors}-x_{D3.1}}{x_{Sensors}}\cdot 100\right)$ [%]	MPE Score $\left(\frac{x_{Sensors}-x_{D3.4}}{x_{Sensors}}\cdot 100\right)$ [%]
Jan	1153.18	1012.34	#N/A	13.69	#N/A	#N/A
Feb	357.35	223.93	#N/A	12.26	#N/A	#N/A
Mar	847.79	736.61	#N/A	8.18	#N/A	#N/A
Apr	1372.53	1300.34	#N/A	5.14	#N/A	#N/A
May	1328.96	1300.34	1496.40	2.11	11.19	13.10
Jun	1316.23	1300.34	3479.10	1.18	62.17	62.62
Jul	1340.34	1300.34	#N/A	2.79	#N/A	#N/A

Aug	1151.04	1112.41	#N/A	2.56	#N/A	#N/A
Sep	930.81	928.61	#N/A	0.16	#N/A	#N/A
Oct	2410.85	2368.34	#N/A	3.39	#N/A	#N/A
Nov	1099.39	1012.34	#N/A	8.77	#N/A	#N/A
Dec	1137.41	1012.34	#N/A	13.26	#N/A	#N/A

As expected, the results show a small deviation between D3.1 and D3.4 as the only difference is the temperature control consumption, as explained previously, supporting the fact that the estimations of D3.1 are slightly higher in values than those of D3.4. Finally, the two measured values available from the energy meter indicate that the estimated electrical energy demand is rather similar, with some deviation. However, due to a lack of information, it is infeasible to have a detailed analysis and accurately make a more thorough evaluation of the estimations.

3.4.2 Energy Production

Regarding the energy production of the PVTs for the AUA farm, the meter dedicated to these measurements had been installed by January 2023. Given that, the acquired data are compared with the estimations of D3.4, and the results are depicted in Figure 23 and the MPE score is calculated in Table 5. To retrieve the data for the meter, values from the node *(AUA > Power Inverter > TOTAL_ENERGY)*, using the options Frequency: '*Monthly*' and Function: *'Delta'* were accumulated in order to set a baseline. However, only the produced electrical energy for January-June 2023 was measured, due to the energy meter's date of installation.

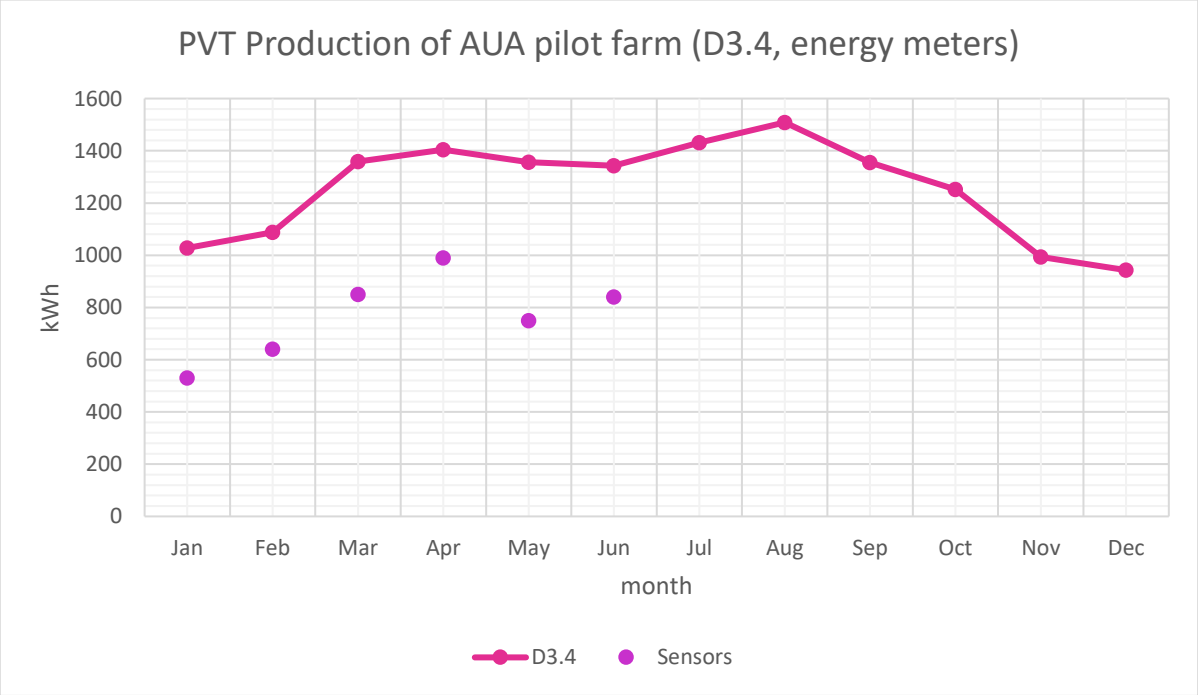


Figure 23. *PVT production of AUA pilot farm (D3.4, energy meter).*

Table 5. *MPE scores of electrical energy production of AUA pilot farm (D3.4, energy meters).*

Month	D3.4 [kWh]	Sensors [kWh]	MPE Score $\left(\frac{x_{Sensors}-x_{D3.4}}{x_{Sensors}} \cdot 100\right)$ [%]
Jan	1028.48	530	-94.05
Feb	1087.96	640	-69.99
Mar	1359.21	850	-59.91
Apr	1404.58	990	-41.88
May	1356.68	750	-80.89
Jun	1343.15	840	-59.90
Jul	1431.47	#N/A	#N/A
Aug	1508.70	#N/A	#N/A
Sep	1354.82	#N/A	#N/A
Oct	1252.40	#N/A	#N/A
Nov	993.10	#N/A	#N/A
Dec	943.04	#N/A	#N/A

The values indicating the produced energy seem to be less than the estimated values. This could easily be explained given the fact that the estimations occurred over a 5-year period and the average values were calculated. Therefore these estimations are only indicative and not fully representative.

4 CONCLUSIONS

In this deliverable, the estimated from D3.1, D3.4, and the measured electrical energy demand and distribution acquired by the installed energy meters are presented in detail. The estimations are compared to the accumulative energy demand per month by the meters. The energy production from PVTs is also presented, but it is mostly based on the estimations of D3.4, except for 6 months' measurements in the AUA pilot farm.

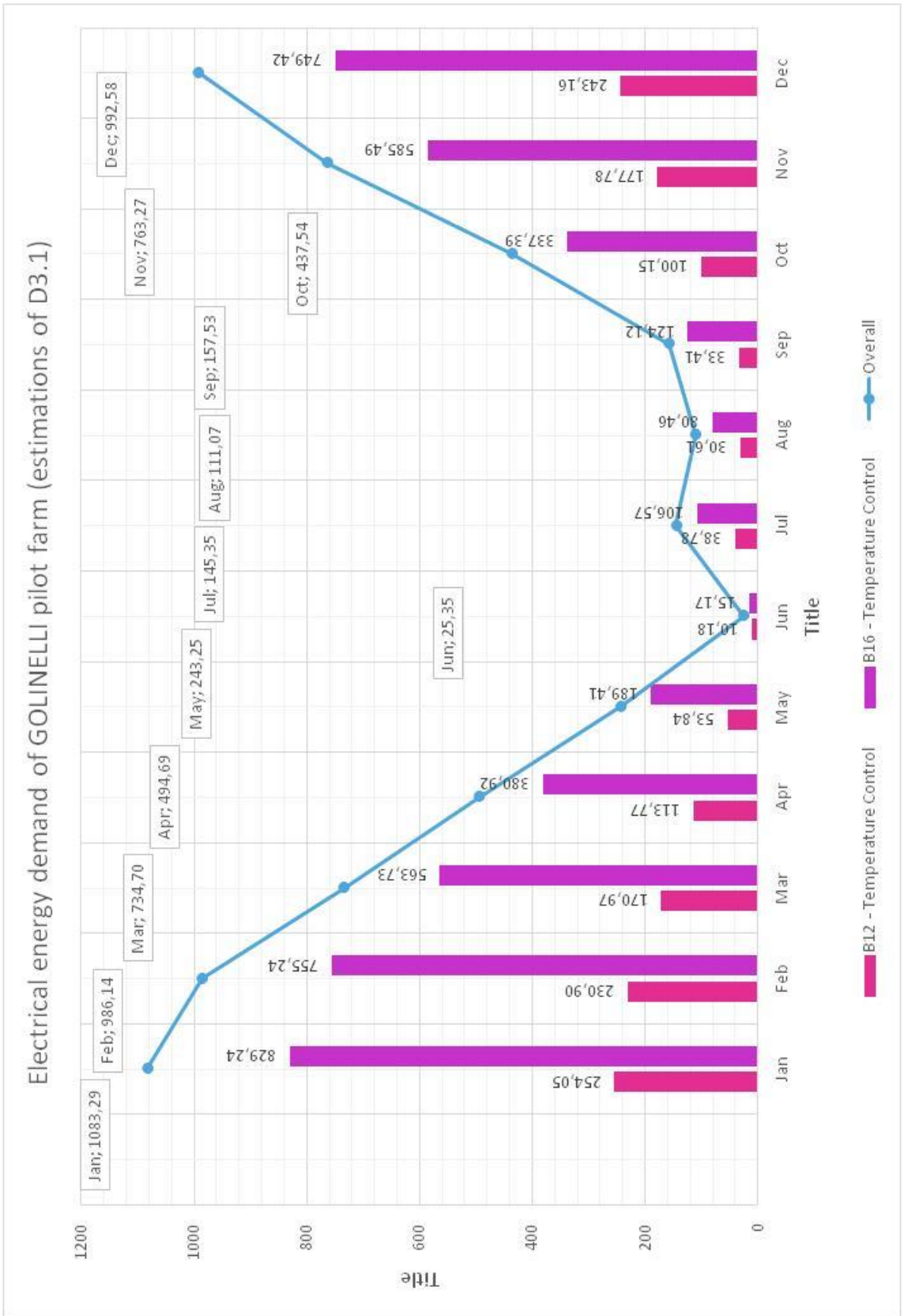
As presented in the first section of this report, in the EV ILVO pilot farm 6 energy meters have been installed, in the GOLINELLI farm 3, whereas in the LVAT farm 14. Finally, in the AUA pilot farm, 3 energy meters have been installed, one of which refers to the power inverter which logs the PVTs' production since January 2023.

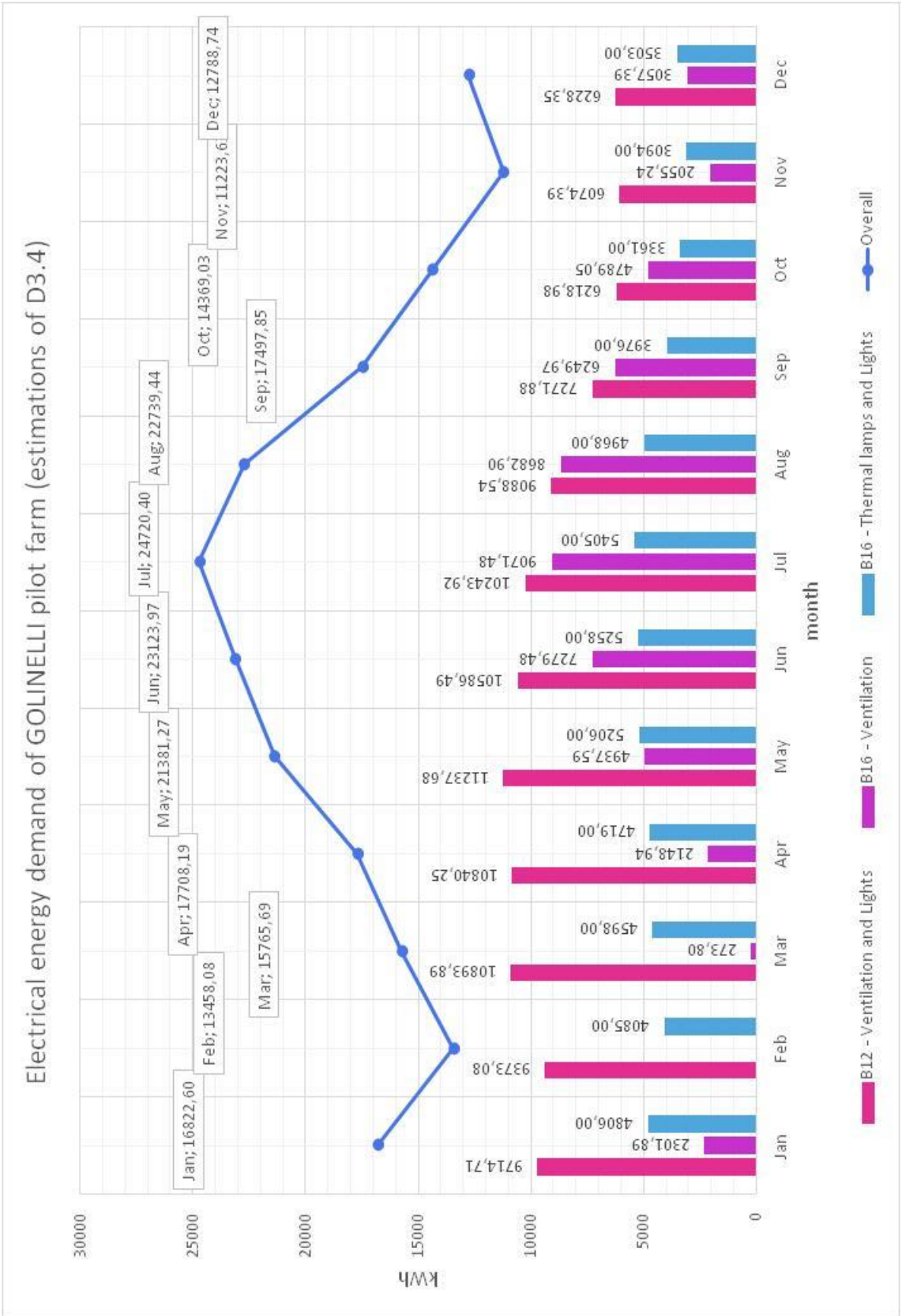
In the EV ILVO farm, the estimated D3.1 values are the same as the ones of Task 3.4. The estimations are close to the measured values, except for February and March 2023, when there was a malfunction in the sensors. In the GOLINELLI farm, D3.1 underestimates the real values of energy demand, which was partly expected as only the temperature control requirements that constitute only a fraction of the overall consumption had been taken into account. On the other hand, the estimations of D3.4 overestimate the energy demand, due to the unavailability of data for the whole year and the malfunction of some energy meters. In the LVAT farm, the estimated values from D3.1 and D3.4 are similar, whereas they describe satisfactorily the actual energy consumption as acquired by the energy meters. Regarding the AUA farm only a two-month period has been logged (May-June 2023) and subsequently a single value for energy consumption is available, due to previous insufficient operation. The values are, however, similar to the corresponding estimated ones, leading to the conclusion that the estimations were accurate enough. The data which will be logged in the next months should confirm this assumption.

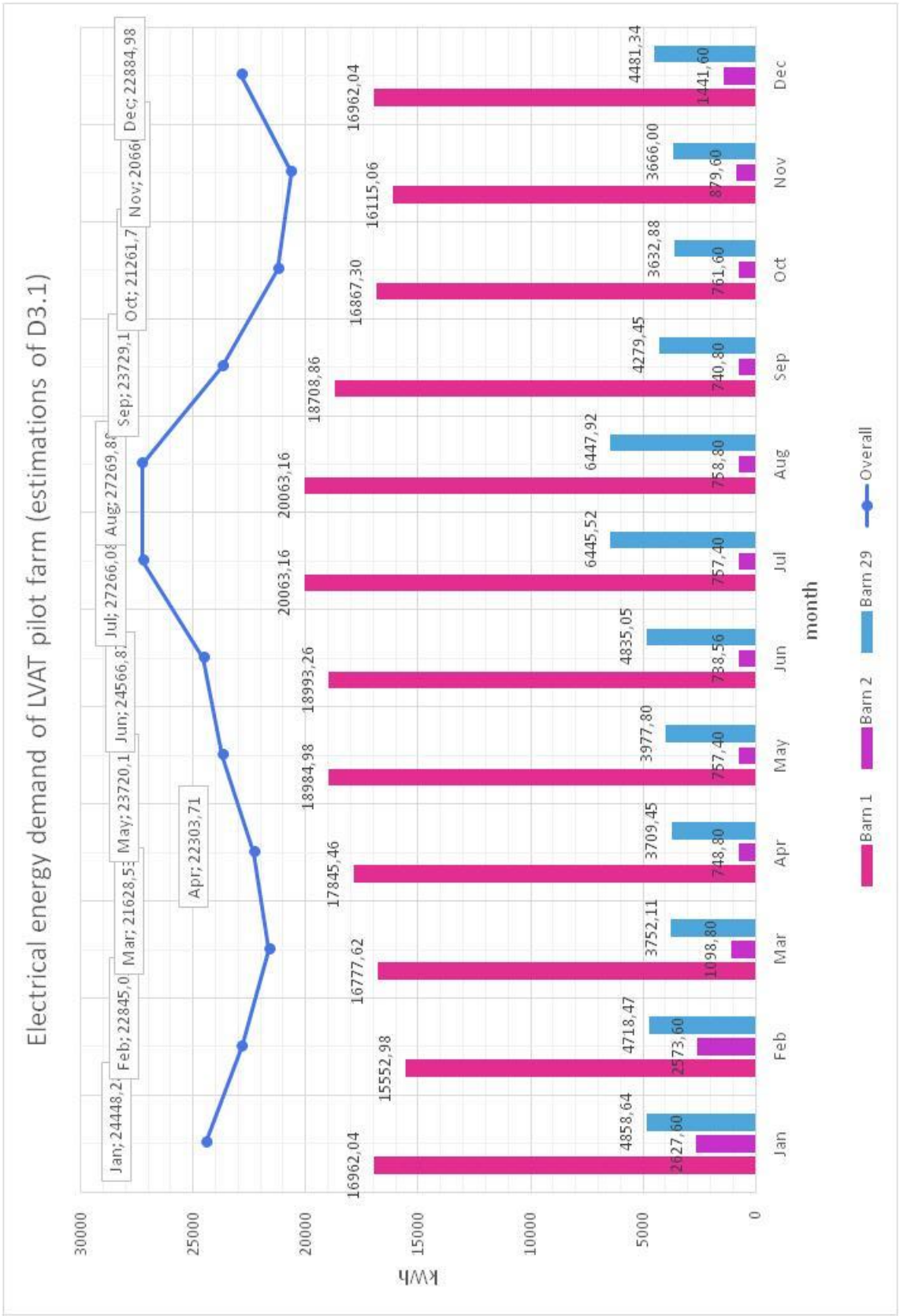
Due to the status of the installations, the energy production from the PVT panels is available only through the estimations of D3.4. In the case of the AUA pilot farm, there are measured values for January to June 2023, which indicate the overestimation of D3.4. However, the differences may be due to some missing measurements of the power inverter.

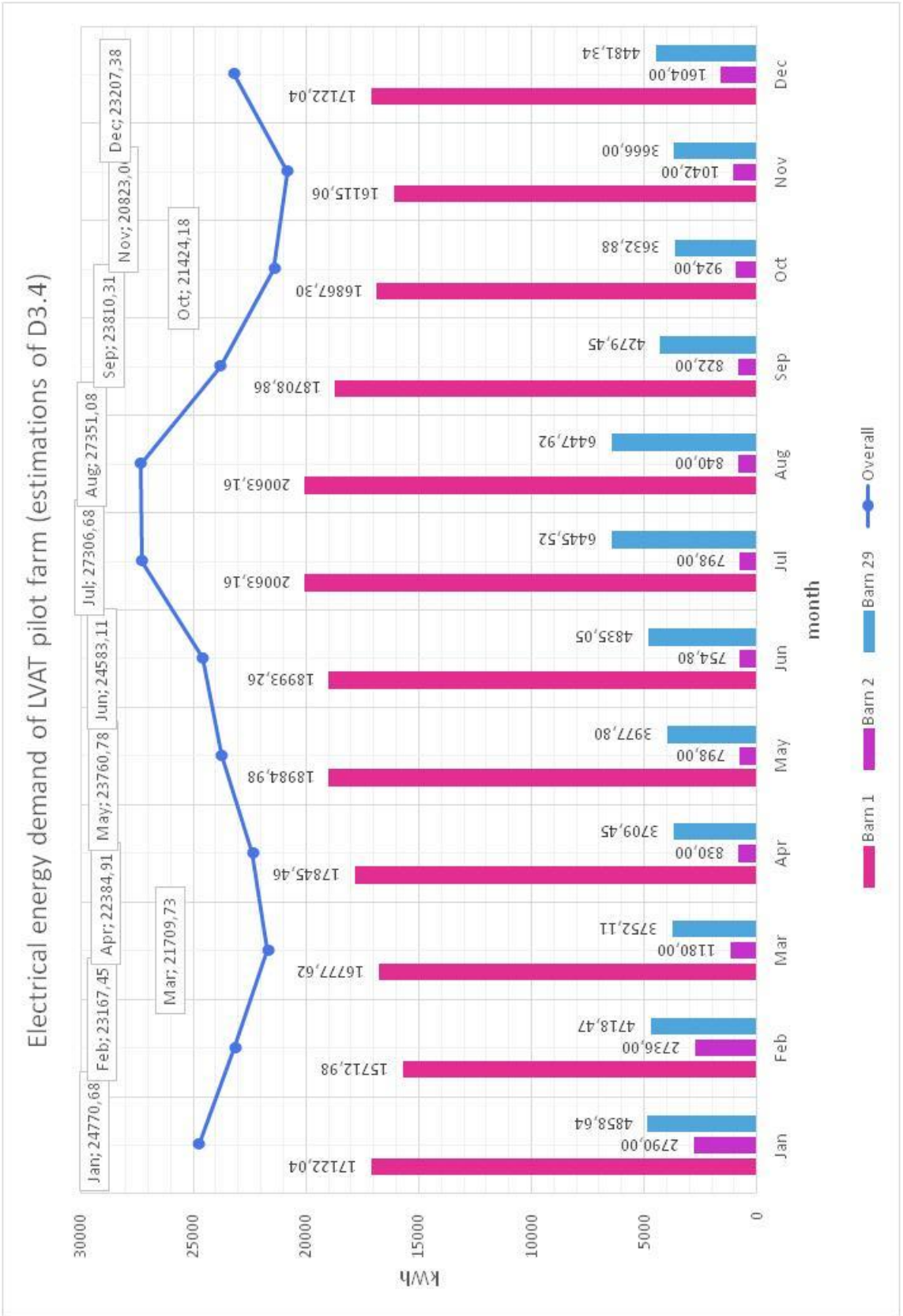
In conclusion, in most cases, the estimated values are quite similar to the measured ones. This proves that a well-structured and executed energy audit can adequately serve as an initial step in the planning of interventions in livestock farms. However, a complete monitoring system logging production and consumption values provides a continuous data flow, as a matter of fact, more accurate, as long as the robustness of the system is ensured; but also constitutes a more costly investment. In the case of an installed monitoring system, numerical tools can assist the system's operation by retrieving/calculating data that are lost due to sensors' faults, which seem to be rather frequent in a livestock farm working environment. Finally, the comprehensive and clear display of the logged data is of utmost importance for further usage of them; either if they are utilized for research purposes or especially at a commercial level.

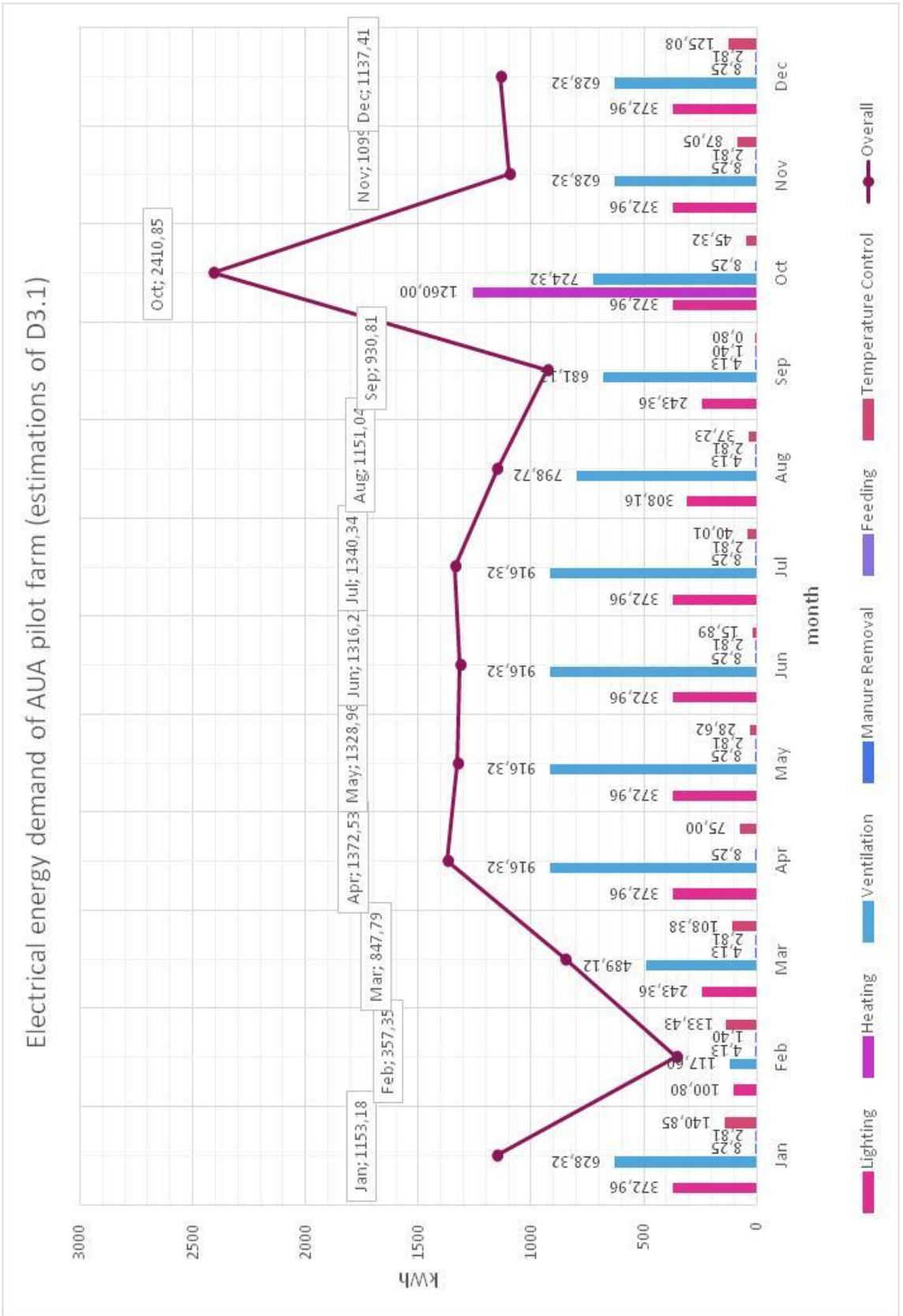
Appendix A


Electrical energy demand of GOLINELLI pilot farm (estimations of D3.1)
Jan; 1083,29
Feb; 986,14
Mar; 734,70
Apr; 494,69
May; 243,25
Jun; 25,35
Jul; 145,35
Aug; 111,07
Sep; 157,53
Oct; 437,54
Nov; 763,27
Dec; 992,58
829,24
254,05
755,24
230,90
563,73
170,97
380,92
113,77
189,41
53,84
10,18
15,17
106,57
38,78
80,46
30,61
124,12
33,41
337,39
100,15
585,49
177,78
749,42
243,16
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Title
0
200
400
600
800
1000
1200
Title
Overall
B16 - Temperature Control
B12 - Temperature Control


Electrical energy demand of GOLINELLI pilot farm (estimations of D3.4)
kWh
30000
25000
20000
15000
10000
5000
0
month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Overall
B16 - Thermal lamps and Lights
B16 - Ventilation
B12 - Ventilation and Lights
Jan; 16822,60
Feb; 13458,08
Mar; 15765,69
Apr; 17708,19
May; 21381,27
Jun; 23123,97
Jul; 24720,40
Aug; 22739,44
Sep; 17497,85
Oct; 14369,03
Nov; 11223,6
Dec; 12788,74
9714,71
2301,89
4806,00
9373,08
4085,00
10893,89
273,80
4598,00
10840,25
2148,94
4719,00
11237,68
4937,59
5206,00
10586,49
7279,48
5258,00
10243,92
9071,48
5405,00
9088,54
8682,90
4968,00
7271,88
6249,97
3976,00
6218,98
4789,05
3361,00
6074,39
2055,24
3094,00
6228,35
3057,39
3503,00


Electrical energy demand of LVAT pilot farm (estimations of D3.1)
kWh
month
Barn 1
Barn 2
Barn 29
Overall
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan; 24448,2
Feb; 22845,0
Mar; 21628,5
Apr; 22303,71
May; 23720,1
Jun; 24566,8
Jul; 27266,08
Aug; 27269,8
Sep; 23729,1
Oct; 21261,7
Nov; 2066
Dec; 22884,98
16962,04
4858,64
2627,60
15552,98
4718,47
2573,60
16777,62
3752,11
1198,80
17845,46
3709,45
748,80
18984,98
3977,80
757,40
18993,26
4835,05
738,56
20063,16
6445,52
757,40
20063,16
6447,92
758,80
18708,86
4279,45
740,80
16867,30
3632,88
761,60
16115,06
3666,00
879,60
16962,04
4481,34
1441,60
0
5000
10000
15000
20000
25000
30000


Electrical energy demand of LVAT pilot farm (estimations of D3.4)
Jan; 24770,68
Feb; 23167,45
Mar; 21709,73
Apr; 22384,91
May; 23760,78
Jun; 24583,11
Jul; 27306,68
Aug; 27351,08
Sep; 23810,31
Oct; 21424,18
Nov; 20823,0
Dec; 23207,38
kWh
30000
25000
20000
15000
10000
5000
0
month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Barn 1
Barn 2
Barn 29
Overall


Electrical energy demand of AUA pilot farm (estimations of D3.1)
kWh
3000
2500
2000
1500
1000
500
0
month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan; 1153,18
Feb; 357,35
Mar; 847,79
Apr; 1372,53
May; 1328,96
Jun; 1316,2
Jul; 1340,34
Aug; 1151,04
Sep; 930,81
Oct; 2410,85
Nov; 109
Dec; 1137,41
Overall
Temperature Control
Feeding
Manure Removal
Ventilation
Heating
Lighting