RES4LIVE Best practices handbook

Deliverable 7.5

WP7. Dissemination – Communication – Exploitation

Project title

RES4LIVE - Energy Smart Livestock Farming towards Zero Fossil Fuel Consumption

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ABBREVIATIONS

BTES : Borehole Thermal Energy Storage

CHP : Combined heat and power

DCES : Dissemination, Communication And Exploitation Strategy

GHG : Greenhouse gases

PVT : Photovoltaic thermal

PV : Photovoltaic

RES : Renewable Energy Sources

SCOP : Seasonal coefficient of performance

SMA's : Social media accounts

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

WP7 (Dissemination, Communication, Exploitation) of RES4LIVE is structured into six main tasks, as outlined below:

WP7 – Dissemination – Exploitation – Communication	
Task 7.1	Dissemination and communication plan and activities
Task 7.2	Access to additional funding sources
Task 7.3	Exploitation, plan activities and IPR management
Task 7.4	Innovation management
Task 7.5	Practices abstracts submission
Task 7.6	RES4LIVE collaboration with other projects funded under FNR-06 A&B

This report is associated with Deliverable 7.5, titled "RES4LIVE Best Practices Handbook", which contains valuable insights and lessons learned that can serve as a guide for future projects of a similar nature. The tools examined in this report are categorized as follows:

1. Lessons learnt during the RES4LIVE project
2. Communication of scientific results tailored to different audiences
3. Exploitation strategies and best practices related to key results and achievements

The lessons learned are the outcome of ongoing communication with each project partner, as well as consultation with the WP7 manager, to ensure the integration of best practices in the areas of communication, dissemination, and exploitation of RES4LIVE's primary technological accomplishments. These lessons are comprehensively summarized in the following report.

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1 INTRODUCTION

The RES4LIVE summarises lessons learned across the project's progress to identify issues that occurred, challenges, and strategies to avoid potential similar bottlenecks arising in future projects. It is important to note that achievements, challenges, successes, and improvements, have been included. The key issues described below are:

- Identification of activities or areas needing additional attention,
- Useful information and conclusions regarding the:
  - organization of the work
  - installation and deployment of technological RES solutions
  - licensing of the installations
  - evaluation (environmental, financial, social) of the technologies, and
  - gathering of all results,
- Identification of effective activities or strategies, to face any drawbacks.

The identification and documentation of lessons learned aim at providing the opportunity for future improvement. The main goal of this report is to gather under one roof all the relevant information for better organizing future projects, treating upfront the challenges, minimizing potential risks and improving the assessment of potential difficulties. In brief, the scope of the report and the main goal is to provide:

- Guidelines for projects in the same scientific area based on the learned lesson in RES4LIVE,
- Instructions for the dissemination of communication and exploitation strategies highlighting the importance of the involvement of the general public and targeted stakeholder groups for the success of the project.

2 GENERAL BEST PRACTICES DURING RES4LIVE

Besides technological installations followed by the corresponding best practices, during RES4LIVE there were various general aspects related to the project management and daily difficulties and challenges faced by the project's partners.

It goes without saying that RES4LIVE was progressing it turned out that close collaboration amongst project partners was essential to address bottlenecks and challenges. The designed methodology followed a user-centered approach with the objective of meeting the needs of the end-users (the farms), aiming at achieving an optimal satisfaction level and experience of installation and use of the RES technologies with minimum efforts and disruptions to their daily workload.

Within RES4LIVE, due to the COVID-19 pandemic emergency and the quarantine, the in-person interaction and involvement of the users were limited for the first 1.5 years of the project. To overcome the lack of in-person, lively discussions, online virtual meetings were organised between the different project partners. This undoubtedly helped the consortium tackle many of the challenges faced at the initial stages of the project. More specifically, to tackle the technical challenges that have arisen due to the pandemic, WP-centered online meetings were organized at least once per month, while Task-specific meetings were organized more often to exchange – directly or via the project's online repository (primarily MS TEAMS at that time) – photos and videos from the pilot farms, as well as draft drawings and diagrams for the systems to be developed.

Moreover, an internal evaluation process to ensure the quality and sustainability of deliverables was established. Each lead partner, responsible for the preparation of the deliverable, sent a draft version to the Coordinator, approximately three weeks before submission to the Commission. After review, the Coordinator forwarded it to an assigned partner for internal evaluation, who reviewed it using a defined checklist and returned it within a week. The lead partner then revised the document, which is re-checked by the Coordinator before the final version is proofread and uploaded to the SYGMA tool.

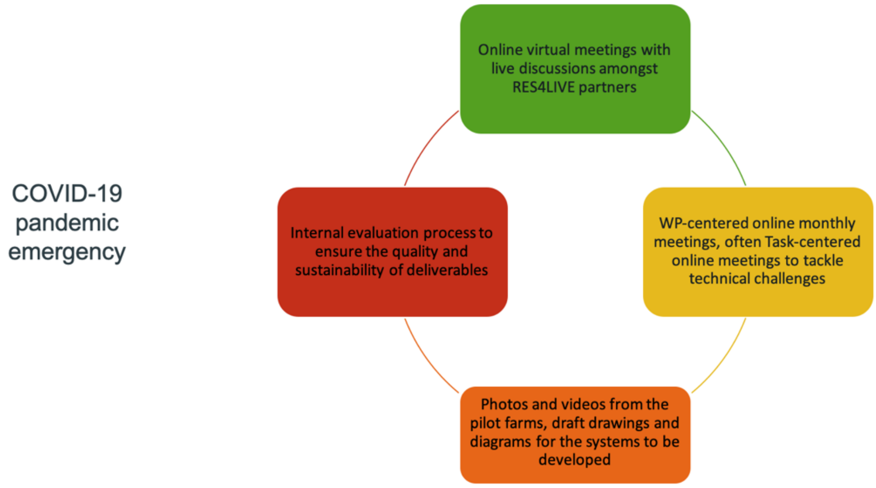

Figure 1. Measures to overcome the COVID-19 pandemic emerged during the first 1.5 years of RES4LIVE.

In a different direction, the consortium derived best practices related to more efficient ways to implement data protection and privacy rules dictated by the GDPR directive. Besides implementing the data protection rules, where the best practices are well-known and documented, integrating GDPR rules into aspects such as the social assessment of the REAS4LIVE technologies, led to the provision of anonymised questionnaires to the related stakeholders to maintain their privacy and to conduct an unbiased assessment.

Another important lesson learnt during RES4LIVE was the significance of clustering with other relevant EU projects. Since almost the beginning of the project, the development of the AreaZero Cluster helped RES4LIVE to gain visibility and also to get important insights such as issues concerning policy-making and strategy through the participation of the project in corresponding events organized by AreaZero cluster members.

Last but not least, it should be mentioned that at the of RES4LIVE, many results gathered together for the successful finalisation of the project as well as for the technological, environmental, financial and social assessments of the installed technology. The overall gathering of the results was possible due to the excellent collaboration between the project partners, the on-time exchange of information between the partners responsible for each of the assessments and the smooth leading by the coordination team.

Overall, the challenges posed during the RES4LIVE project along with the measures taken to overcome those challenges are summarised in Table 1.

Table 1. General challenges during RES4LIVE and measures taken to overcome them.

Challenge	Measures to mitigate challenges
COVID-19 pandemic	1. Online meetings between project partners 2. Monthly WP meetings, often Task meetings 3. Photos and videos exchange from farms, draft drawings and diagrams for systems to be developed 4. Internal evaluation process for the deliverables
Data protection and privacy rules	1. Respect and implement established privacy rules 2. GDPR rules during the social assessment with anonymised questionnaires
Clustering with relevant EU projects	Participation from the beginning of the project in the AreaZero Cluster and participation in all events organised by this cluster
Successful finalisation of RES4LIVE	1. Gather together all the project's result on time 2. Excellent collaboration between project partners with on-time exchange of valuable information

2.1 Conclusions on general best practices

Overall, RES4LIVE did not face major problems and disruptions during its progress, the most important was due to the COVID-19 pandemic which did not allow the live meetings between project partners and most importantly, the realization of technical works at the initial stages of the project. However, the excellent leadership and solutions by the coordination team in this – and all aspects - rendered possible the smooth progress of RES4LIVE with the development, installation, evaluation and assessment of all the RES technologies.

3 BEST PRACTICES OF RES4LIVE TECHNOLOGIES

The best practices of RES4LIVE technologies are presented in detail in deliverable D6.5 "Inventory of RES4LIVE best practices". In the present report, a brief overview is presented which summarises the best practices of the RES4LIVE technological achievements. Furthermore, the challenges faced during the implementation of the technological solutions are presented as well as the ways that project partners used to overcome those challenges. The presentation of best practices is based on the test results and their processing (Tasks 4.3, 5.1), the case studies (Task 6.3), the co-design (Task 6.2), and economic, environmental and social evaluations (Tasks 5.2, 5.3, 5.4).

3.1 Best practices of solar plants

Intensive livestock farming consumes a considerable amount of thermal and electrical energy. Therefore, photovoltaic thermal (PVT) collectors, that convert solar radiation into usable thermal and electrical energy are an ideal source of renewable and carbon-free energy source for agriculture and livestock farming specifically. Moreover, photovoltaic (PV) systems are becoming increasingly popular on livestock farms due to their potential to reduce energy costs and environmental impact. When implementing a PV system on a farm, several best practices should be followed to ensure optimal performance and return on investment.

In particular, in swine farms, heating is required during the whole year to keep the piglets around 34-38°C (newborn piglets), 24-35°C (piglets in the farrowing compartments) and 17-29°C (in nursery rooms). Therefore, a considerable amount of heat is needed, even in summer. A heat storage tank can be used to store excess heat during the day for use at night, which can then provide space heating during the night for the piglets. This energy can be provided by PVT collectors. Using PVT technology has shown that payback time can be around 3-8 years depending on the availability of subsidies and the amount of solar installed. For a lifetime of 25 years with less maintenance requirements than a gas boiler, this is also a very economical solution.

Furthermore, in dairy farms, heat is only used for cleaning the barn, the milk tanks, and the automatic milking systems. Therefore, the heat required is usually at a high temperature, around 60-70°C or even more. It is advisable to use higher-temperature solar thermal collectors to preheat the heat before an e-boiler takes the heat to the desired temperature. Farms with automatic milking systems must ensure that preheated water can be inputted into the system as these systems mostly have their way of heating the water. Even if it is not possible to integrate solar thermal with the automatic milking system, solar thermal can be used for domestic hot water and cleaning of the barn and tanks. In this case, not as many panels are needed. Some cattle farms are equipped with milk storage, where heat can be recovered from the milk chillers to pre-heat water for domestic hot water use. If this system is available on the cattle farm, then it must be made sure that the collectors are performant enough to be able to further increase this heat without any risk of overheating the solar system. The implementation of PVT technology in dairy farms has shown that payback time can be around 2-6 years depending on the availability of subsidies and the amount of solar installed. The payback can be estimated as lower than swine farms as the heat demand is not that high. However, the higher temperature may contribute to higher costs for the solar system overall. For a lifetime of 25 years with less maintenance requirements than a gas boiler, this is also a very economical solution.

Finally, in a poultry farm, the first consideration before the installation of a PV system is the design and sizing of the system by taking into consideration and analysing historical energy consumption data.

Proper placement of the panels to maximize sunlight exposure, typically on rooftops or open fields with minimal shading, is also vital. The orientation and tilt angle of the panels should be optimized to capture the maximum amount of solar energy. Another key factor is the cost and payback period of the system. While the initial investment can be significant, the long-term savings can be substantial. The payback period, or the time it takes for energy savings to cover the initial investment, depends on factors such as local electricity rates, available incentives, and the specific energy consumption patterns of the farm. Net-metering and storage are also important considerations. The first option allows the farm to sell excess electricity generated by the PV system back to the grid, effectively reducing electricity bills. This is particularly beneficial during peak sunlight hours when the system may produce more energy than the farm consumes.

During the installation of PVT panels at the EV ILVO pilot farm, the project partners realised that there was significant bending on the vertical support rails connecting the PVT panels to the roof. The PVT panels were quite heavy, and couldn't be supported by the original aluminium beams from the manufacturer, as initially planned. Thus, the EV ILVO partners with the agreement of the RES4LIVE Consortium decided to use new, stronger steel supports, as well as a different installation scheme, which came out after calculating a new configuration. The new system was successfully implemented and it became evident that the bending on the PVT panel support beams not only was improved but it was totally removed.

Concerning the electrical and heat circuit connections of the PVT system installed at the LVAT farm there were still some tasks pending after the installation of the panels. The challenge was the significantly limited availability of external workers during the period of the project when the PVT panels were installed at the German pilot farm. Nevertheless, to overcome this bottleneck LVAT, ATB and MG Sustainable cooperated closely in order to find and assign the required tasks to plumbers and electricians, and eventually, all the required works were realised, thus, rendering the installed system fully operational.

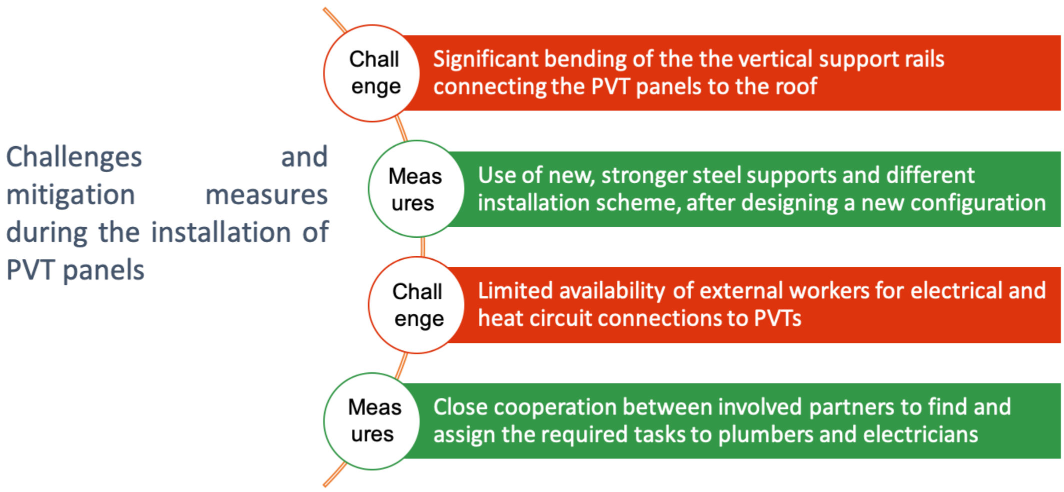

Figure 2. Challenges during the RES4LIVE installation of PVTs and measures to mitigate them.

3.2 Best practices of heat pumps

When installing heat pumps, especially multi-source systems, it's crucial to ensure that the design and placement are correct from the beginning. A thorough assessment of the farm's heating and cooling needs is a prerequisite, considering factors like building insulation, climate, and the specific requirements of the animals. Proper sizing is essential; an undersized heat pump will struggle to maintain the desired temperature, while an oversized system will cycle on and off frequently, reducing efficiency and lifespan. Location matters too, so the heat pump should be placed in an area where it can easily access the energy sources it needs, like the ground, air, or water. Ensure the system is installed by a qualified professional who follows local codes and manufacturer guidelines. Proper installation and maintenance not only maximize efficiency but also prevent issues like noise, vibrations, and unnecessary wear and tear.

In particular, in swine and poultry farms, where efficient heating and environmental control multi-source heat pumps are essential for maintaining animal welfare and optimizing production. When designing and sizing heat pumps for swine and poultry farms, it is essential to consider the unique thermal demands of these environments. Swine farms, for example, require consistent and reliable heating, particularly during the colder months, to ensure that piglets are kept warm. In contrast, poultry houses demand a more dynamic approach, with heating, cooling, and ventilation all playing crucial roles in maintaining an optimal environment for bird health and productivity. To accurately size a multi-source heat pump system, one must conduct a detailed analysis of the farm's heating and cooling load requirements, considering factors such as building insulation, local climate, and the thermal mass of the structures. The preferred managerial practices have also to be taken into consideration for their proper integration. A well-designed system should be capable of meeting peak demand without oversizing, which would lead to higher upfront costs and reduced efficiency.

Another crucial parameter is the seasonal coefficient of performance (SCOP) which is a key metric for evaluating the efficiency of heat pumps across different seasons. For multi-source heat pumps, SCOP values are typically higher than those of single-source systems because they can optimize their performance by switching to the most efficient energy source available at the time. A high SCOP not only translates to lower energy bills but also contributes to the sustainability of the farming operation by reducing its carbon footprint.

The challenges faced during the installation of HVAC systems were observed at the AUA pilot farm. Due to the lack of available space in the AUA pilot farm as well as due to the age of the poultry house building repositioning the HVAC channels was necessary since it was significantly hard to penetrate the external walls. However, most of the challenges were resolved through efficient design during the corresponding phase, not causing actual issues during the installations.

The main challenge posed at the AUA farm was the dust accumulation inside the hens' room. Even though the air quality in terms of CO_2 and NH_3 concentration was improved, the dust particles generated primarily by the feed were not carried outside the building by the exhaust fan. For the heat pump's performance to be efficient it would not make sense to supply a heating or cooling load to the indoor air that would be immediately exhausted to the environment. For this reason, a minimum ventilation approach was followed, limiting the air changes per hour (ACH) to approximately 5. Since this led to non-optimal conditions, the system was modified, initially through the installation of an additional fan, and at a second step by adapting the control approach. The adaptation of the control approach was expected to minimize high ventilation rates when extreme outdoor conditions occur (very high/ low temperature, and/ or relative humidity), and increase ACH to enhance indoor air quality when the weather conditions are more favourable. Based on the long-term system's performance, additional adaptations will be also conducted.

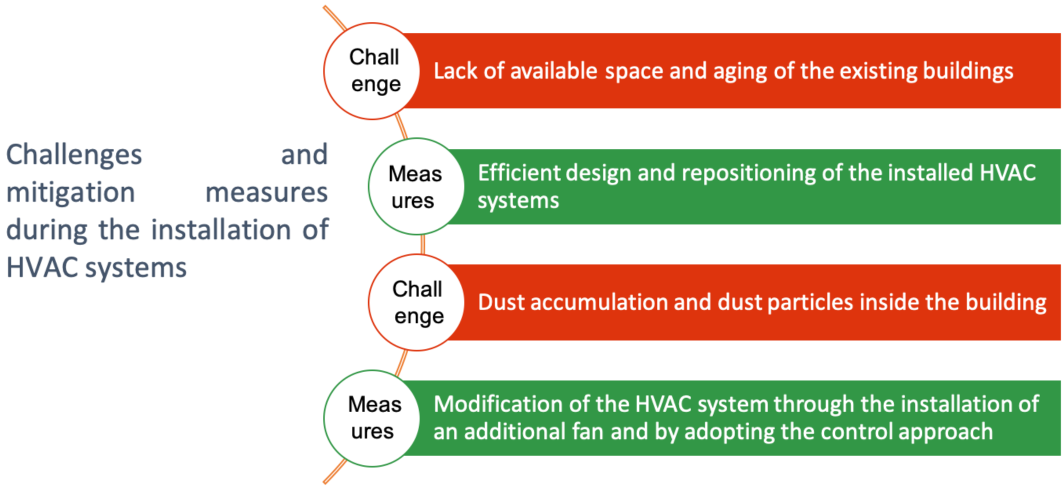

Figure 3. Challenges during the RES4LIVE installation of HVAC systems and measures to mitigate them.

3.3 Best practices of geothermal energy storage

Borehole Thermal Energy Storage (BTES) for livestock structures allows to exploitation of available but not immediately usable heat sources, commonly present in farms, as an alternative to the use of fossil fuels. It consists of a field of geothermal probes of variable depth and number, to be defined based on the characteristics of the ground. The hot fluid from the heat source to be stored, which can be, for example, a solar panel system or a biogas cogeneration system, is circulated in the BTES field and the thermal conduction between the fluid and the ground, through the pipes, leads to an increase in the subsoil temperature, especially in the centre of the BTES field, its thermal core. The main areas of direct application are livestock farms, characterized by the need for considerable heat and the availability of large areas for installing the BTES (drilling and excavation). Seasonal heat storage is environmentally beneficial because it can enable carbon neutrality; it is also economically and logistically advantageous since it contributes to the energy independence of farms.

A challenge faced in the GOLINELLI farm, where the geothermal energy storage system was installed, was that the integration of different RES plants should have been taken into account to create an innovative sustainable system based on RES specifically suited to meet the energy needs of the swine farm. This was a major challenge since it included great complexity in the design of the systems. Additional complexity stemmed in terms of executive details because the integrated plant has represented an unusual kind of work for the companies involved, which have had to define and realize specific solutions. To overcome this challenge, a constant presence of personnel of the RES4LIVE consortium was necessary, to guide the design and works, providing instructions and clarifications. Personnel from UNIBO and GOLINELLI have been dedicated to the coordination and management of the works during the entire installation process. Moreover, qualified personnel from PSYCTO and MG reached the farm in specific periods related to the installation of the heat pump and the PVT panels, respectively. The constant presence of the RES4LIVE consortium in the GOLINELLI farm along with qualified personnel during the works and the installations assisted in overcoming the challenge initially posed and eventually, the installation of the technologies was smoothly developed.

A second, also important, challenge was the management of the costs of the installations because the price of construction works and materials for technical plants skyrocketed after the start of the RES4LIVE project, due to incentive policies promoted by the Italian government and due to the inflation caused by the war. The combination of inflation and the abovementioned complexity of the specific works carried out by specialized companies led to incurring high costs, which it was possible to cope with thanks to the precise organization of the tasks assigned to the various partners and the definition of the expenses of their respective competence.

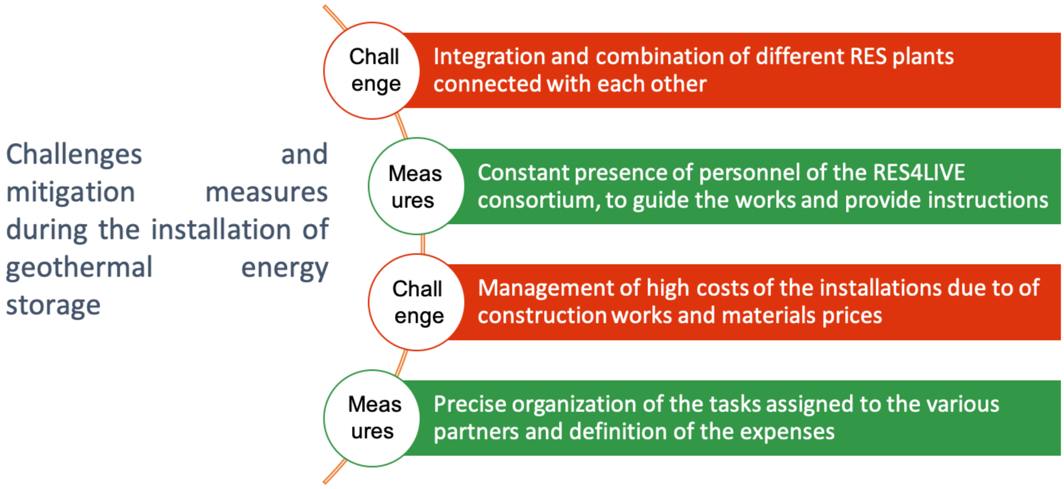

Figure 4. Challenges during the RES4LIVE installation of the geothermal energy storage system and measures to mitigate them.

3.4 Best practices of biomethane usage

The production of biogas in livestock farms using field and on-farm residues, manure and slurry represents a multifaceted option for fossil-free energy production. The most common variant is the conversion of raw biogas resulting from anaerobic digestion into heat and electricity in a combined heat and power plant (CHP). Plant sizes between 100 kWel and 250 kWel are economically feasible in practice. Another possible use of raw biogas is its purification into biomethane and then high compression to 250 bar for use as a BioCNG fuel. Vehicles then can be refuelled from the gas storage without the need for additional pumps by using the pressure differences until pressure balance is achieved.

An upgrading plant with a gas purification performance between 10 and 35 Nm^3 per hour with subsequent high compression to BioCNG that can work off the natural gas grid is available on the market for the first time within RES4LIVE project and it can economically convert 10 to 20 % of the raw biogas from the small biogas plants (100-250 kW) typical for livestock farms to BioCNG fuel. A full cost calculation for operating a 35 Nm^3/hour biogas to BioCNG plant at a capacity of 70 % results in producing BioCNG at a fuel cost of 1.51 €/kg. Any monetary benefits from GHG quotas from the production and use of biofuel have not yet been taken into account and can have an additional positive effect. A key item here is the working load of at least 70 % for the upgrade plant. Since the upgrade plant is supposed to work off-grid, it is required to provide adequate storage capacity as well as continuous and consistent usage of the BioCNG.

Another crucial point in the installation of such a plant is its licensing to become operational. This procedure is not trivial and especially in countries/regions where no such installation already exists, it should be taken into consideration that licensing might pose delays. In those cases, the time required for licensing the installation should be subtracted during the calculation of the payback period.

This particular issue posed the greatest challenge in the installation of the BioCNG plant: The approval for using the BioCNG filling station by the local authorities, took longer than expected. It took some persuasiveness and additional assessment by external reviewers to overcome this delay and get the final approval for an experimental setup. During the process, the BioCNG filling plant was located differently than originally planned, to be complied with all the fire and safety regulations. Finally, after the licensing, the BioCNG filling station was connected to the biogas plant and currently, after the RES4LIVE project ends is fully operational.

The retrofitting of diesel farm tractors for biomethane allows the substitution of fossil fuel (diesel) with renewable fuel to lower the GHG on the entire operation of the tractor. It is an economically viable option combined with a small upgrading station of biogas to biomethane when biogas is available at the farm or nearby. RES4LIVE demonstrated that diesel tractors can be converted to operate with biomethane as described above. But for a successful conversion, several criteria must be present to fit the retrofit kit, the first being the availability of biomethane conveniently and at a competitive price, the second being the price of the retrofit kit and the last an educated service network to take care of the maintenance of the tractor.

For the fueling of the converted tractor, the biomethane is stored as compressed gases up to 200 bar onboard the tractor. This makes it possible to obtain about the equivalent of 30 liters of diesel which typically allows 3 to 4 hours of operation for a farm tractor (about 60 to 80kW). Moreover, the biomethane composition can affect the engine responsivity, the biomethane production and quality must be as constant as possible, which imply to select a validated process to upgrade the biogas to biomethane.

Concerning the cost of the conversion, the cost of 50 % of the value of the tractor when it was new sounds the maximum acceptable. The only way to achieve this target is to produce a conversion kit which is compatible with different tractor models. The retrofit kit must also be certified, though no delay or possible extra cost would be hidden. This is a point of vital importance because the acceptability of the retrofit model can only be feasible if the price is affordable.

Finally, concerning the service of the retrofitted tractor, the biomethane technology is generally robust and it can last for at least 15 years. Maintenance of the tractor is required regardless of the reason. A service network with a large scope, including training the potential candidates, must be developed at the same time as the engineering work starts. The service network could also promote the sale of conversion kits.

For the tractor, though it was initially planned to have access to a John Deere electrical tractor for comparisons with the tractor that was to be converted to run with CNG, it turned out that such an electrical tractor model was not available or could not be provided, and John Deere backtracked from the project. Other farm tractor manufacturers have been contacted and asked to step in, and although they have expressed great interest, nothing tangible is still available after the end of the project.

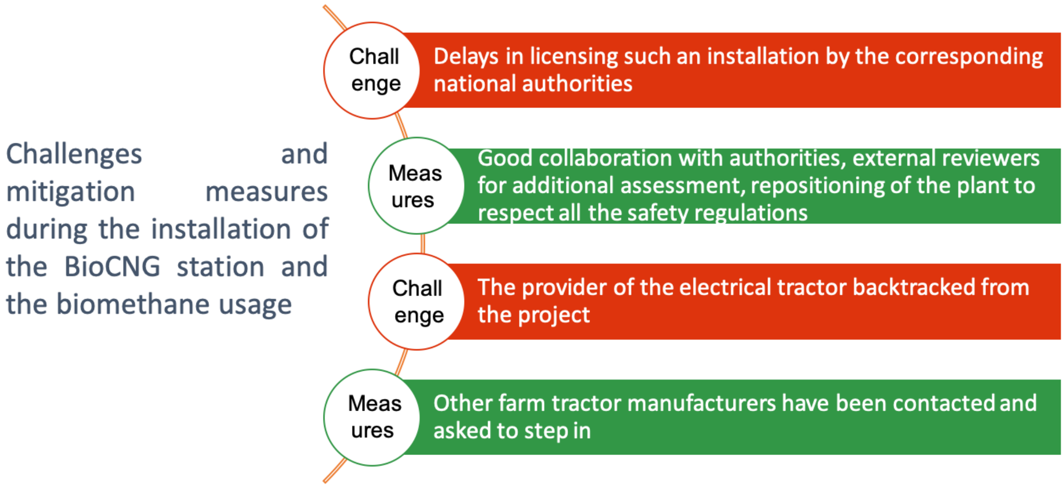

Figure 5. Challenges during the RES4LIVE installation of the BioCNG plant and measures to mitigate them.

3.5 Best practices of smart control with sensors

The efficient control of ventilation systems in livestock farms as well as of the heat pumps requires a sensor network along with a control unit for their proper usage and adjustment in real farm conditions. For the ventilation systems, sensors are required to measure temperature and relative humidity as well as the rotational speed of the fans, while the control unit regulates the mixing of ambient and pre-cooled air as well as the speed of the fans to provide an adequate volume flow rate inside the ventilation tubes, even if the system is not perfectly maintained. Concerning the control of heat pumps, utilization of smart controls are used to automatically adjust the system based on real-time conditions, such as indoor and outdoor temperature fluctuations, or occupancy levels in the livestock farm. This ensures the system runs only when necessary to provide the necessary thermal loads, saving energy – while at the same time - extending the life of the heat pump and accompanying equipment. Seasonal adjustments are important too; the system should be set up to optimize performance based on the season, switching energy sources as needed to maintain efficiency.

A challenge posed to the installation of a sensors' network to the LVAT farm was that the gas sensors in the welfare barn turned out not to be well suited for the naturally ventilated dairy barn environment. In particular, the NH_3 concentration is usually relatively low at that place and hence, the sensors may not be able to provide correct values in this low concentration range. To overcome the difficulty, the sensors were replaced with more appropriate ones that were already used on the farm. The new sensors were also connected to the cloud used to monitor the gases' concentration.

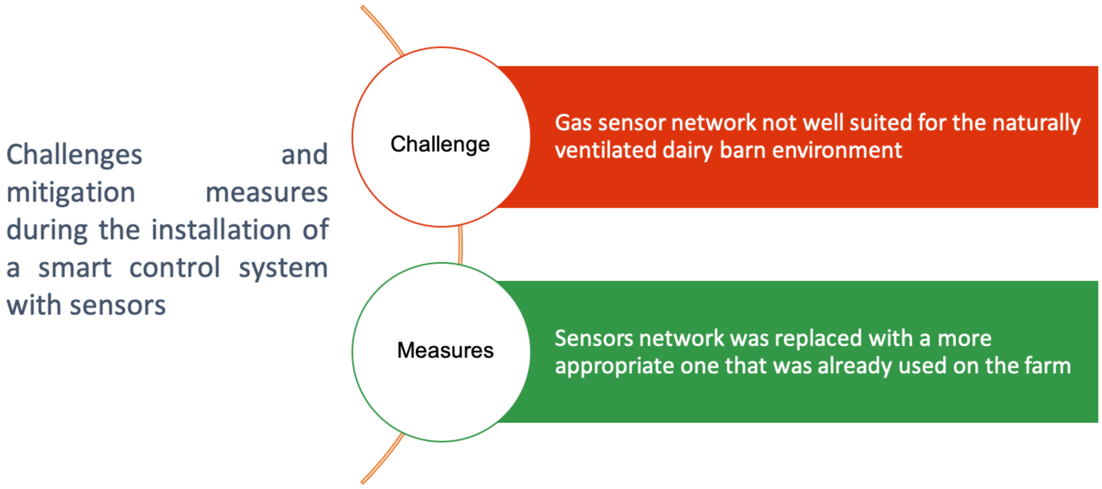

Figure 6. Challenges during the RES4LIVE installation of the smart control system with sensors and measures to mitigate them.

3.6 Conclusions on the best practices concerning RES4LIVE technologies

During RES4LIVE, several RES technologies were developed including PV and PVT systems, heat pumps geothermal energy storage, a bioCNG station and a retrofitted tractor combined with smart control-sensor systems. Those technologies were evaluated and assessed technologically, environmentally, financially and socially, and out of this evaluation best practices were developed and presented in detail in deliverable D6.5. Each renewable energy system analyzed presents peculiar strengths and weaknesses in the context of livestock farms. A common characteristic of all systems is the high initial cost and operational complexities.

The research and the installations carried out led to the definition of technical parameters useful for the design and implementation of the above best practices. Moreover, the performances of the RES systems installed were measured and assessed thus, providing a quantitative indication of the most suitable solutions that can be considered for various application contexts, with a focus on livestock farms. However, the design and the implementation of the proposed RES systems were not straightforward from the beginning and many challenges were faced to reach the final result. To overcome the challenges, re-adaptation of the initial ideas or designs was required towards the efficient installation and also, on-the-fly solutions due to either inefficient performance of installed technologies (sensors) or due to long procedures related to the acceptance and licensing of the installed systems by national authorities. In all cases, the close cooperation of RES4LIVE partners to challenges that occurred during the project assisted in overcoming all the issues and difficulties.

4 BEST PRACTICES OF RES4LIVE INSTALLATIONS AND TESTING

The best practices of RES4LIVE technologies' installations and testing are presented in detail in deliverables D4.2 and D4.3. In this handbook of best practices, a brief overview of those installations and testing summarises the methodology followed.

4.1 Best practices in EV ILVO farm

In the EV ILVO farm, the integrated system installed includes a rooftop PVT system, a multi-source heat pump and a sensor-based smart control system. To control the installed systems, a former meeting room of the farm was converted to the RES technical room. This technical room is presented in Figure 7. Inside the room the buffer tank (1), multi-source heat pump (2), and the solar station unit (4) with its electrical cabinet (5), have been installed. The main electrical cabinet (3) supplies all the above, as well as other equipment in the installation room, while it also connects the inverter to the grid. The electric consumption of the heat pump and the solar station unit is measured with an energy meter installed in the electrical cabinet. Outside the room, the dry cooler (9), as well as its hot and cold lines dry cooler (6) and its power supply (7) are shown. Moreover, the hot and cold lines from the PVTs (8) and the Solar inverter outside the RES installation room (10) can be also seen.

Figure 7. The EV ILVO RES4LIVE installation room - final implementation inside (left) and outside (right).

The modular heat pump installed at EV ILVO, with the respective piping and control system, is shown in Figure 8. The unit consists of the electrical panel and control system (1), and the main heat pump components (2) (e.g., compressor, heat exchangers, etc.). The pipe connections to and from the heat pump and the buffer tank (3), the return and supply connections to the existing technical room at (4), and the three expansion tanks on the heat pump ciruit (5) are also presented. Finally, the thermal and electrical connections were installed.

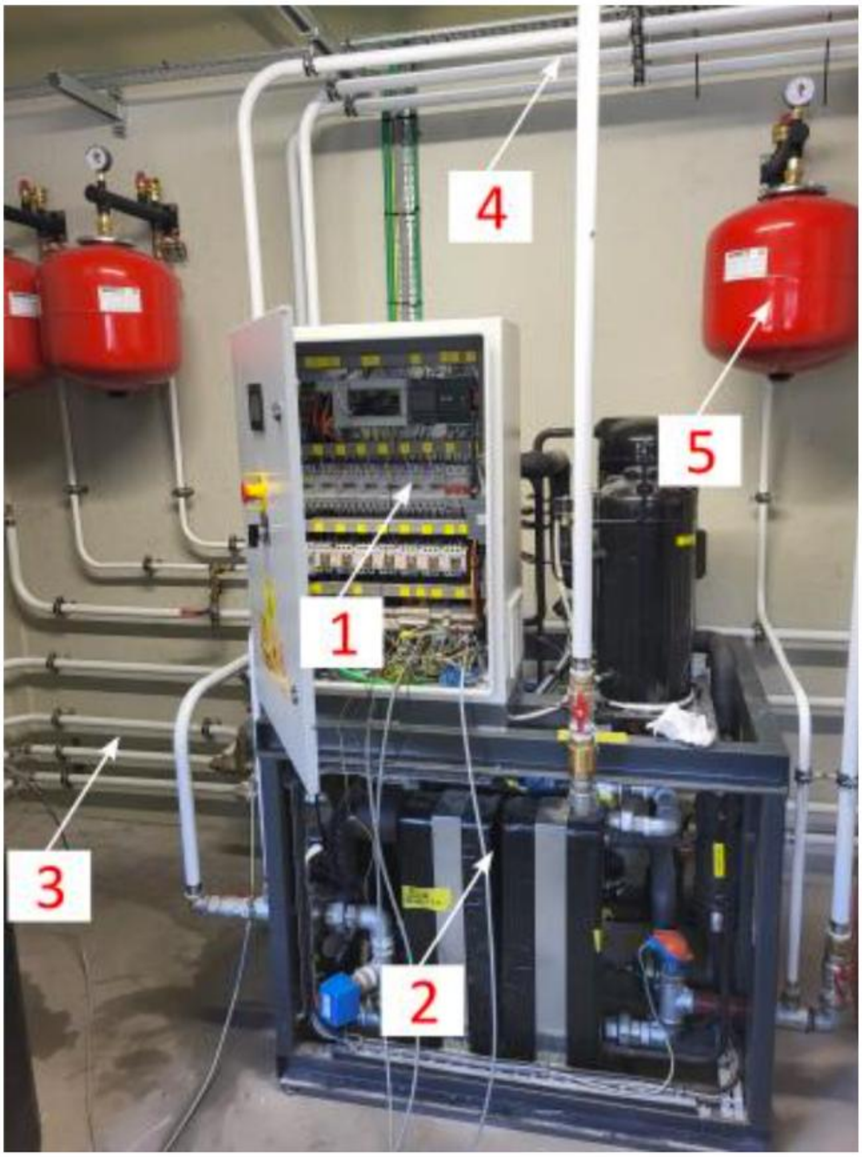

Figure 8. The heat pump installed at EV ILVO with the necessary piping and control system.

Figure 9 shows the farm's roof where the PVTs were placed on it. As can be seen all the 24 PVTs are placed together on one horizontal rail, not grouped. The gaps between the vertical rails were not uniform throughout the whole installation length. The gaps as well as the way that their load was distributed to the roof, caused a huge bend at the end of the vertical support rails, as mentioned above, thus new, stronger steel beams, as well as a different installation scheme were proposed, to overcome this challenge. The solar station unit was moved to the installation room and the pipe connection was conducted. A solar inverter was separately installed on the wall of the installation room. The solar station unit installed at EV ILVO premises, as well as its piping connections to the buffer tank and the PVTs, are also shown in Figure 9.

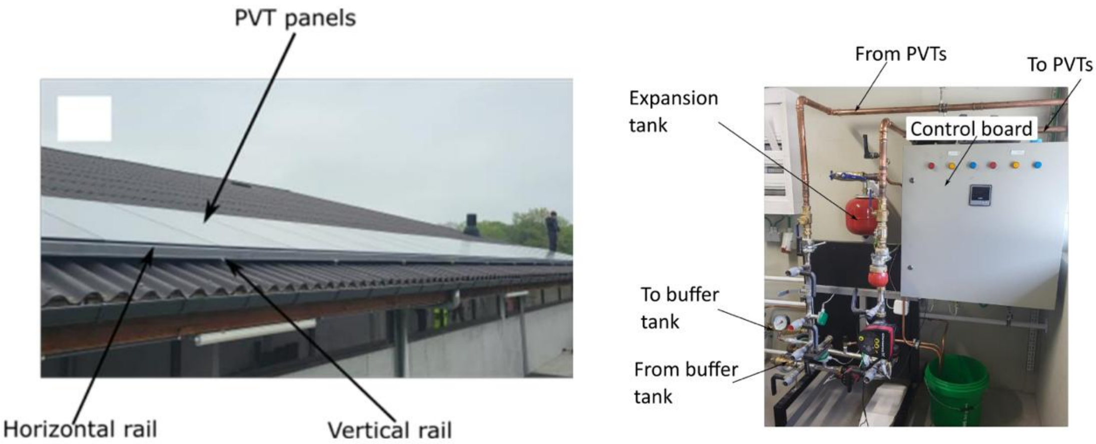

Figure 9. The placement of the PVT panels on the Varkenscampus roof (left) and the solar station unit (right).

The schematic overview of the installed RES system is presented in Figure 10.

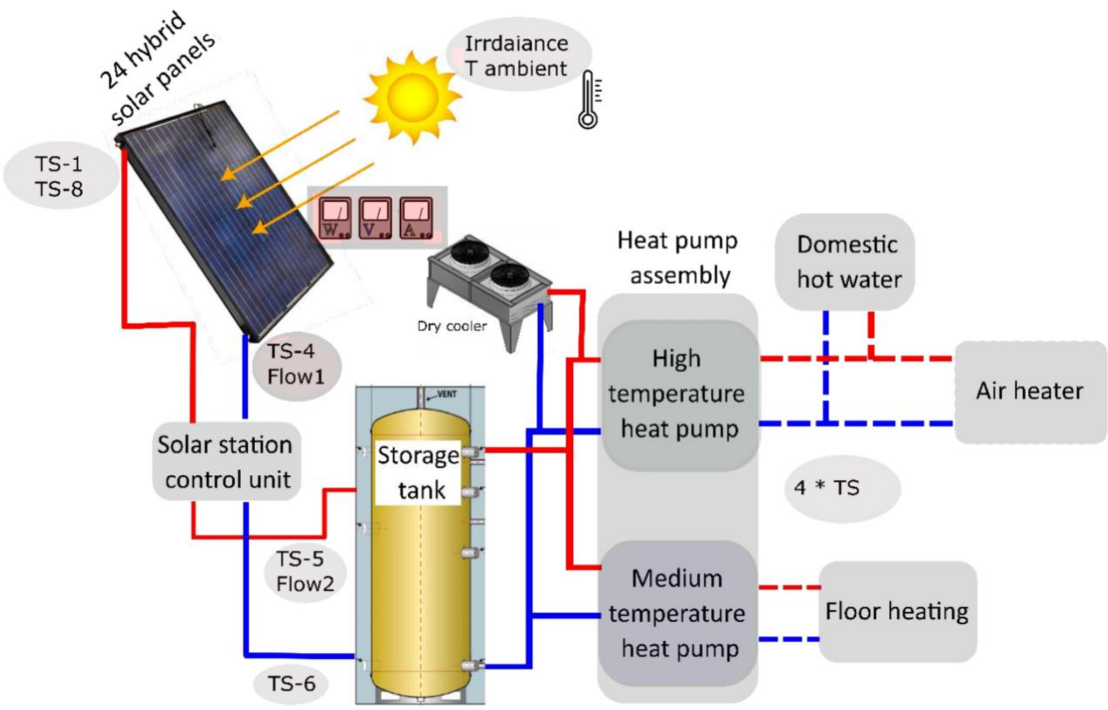

Figure 10. Schematic overview of the installed solar-thermal system at the EV ILVO premises.

The installed system was tested to validate its performance. Figure 11 shows the daily amount of electrical energy produced by the hybrid solar system during the measurement period from October 2023 to February 2024. There were days when the daily electrical energy production was not recorded as the integrated system was on performance tests. Likewise, the heat energy production and the electrical energy production of the hybrid solar system vary in relation to the solar insolation.

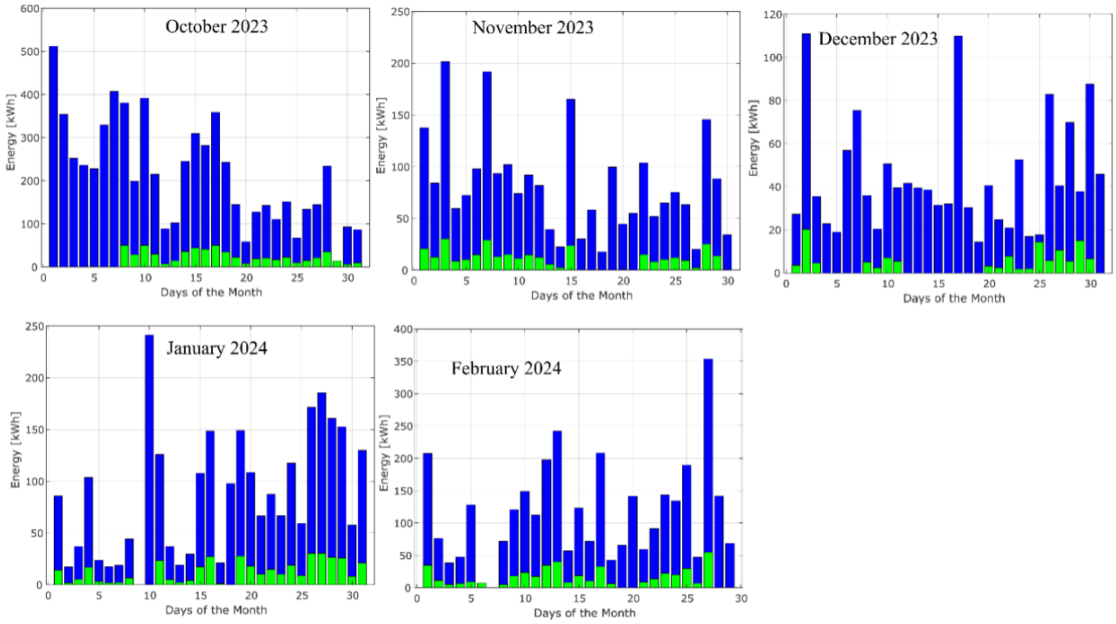

Figure 11. Daily electrical energy production (green bars) and insolation (blue bars) from October 2023 and February 2024.

Concerning the testing in the modular heat pump, 4 tests were conducted. During the first test run, some of the logging data was mislabelled and some debugging had to be done in the logging system had to be conducted. Therefore, there weren’t accurate data, on the power consumption and heating capacity. Eventually, the system had to be shut down because of a faulty resistor. The temperature inside the thermal storage tank reached below -8 °C when the outside temperature dropped to below 0 °C. For this reason, the faulty resistor was replaced.

Then, the second test run was conducted. This run, also, had to be shut down due to the fuse tripping. It was found that the defrost cycle, using the electrical resistor, cannot run in parallel with the heat pumps. Thus, ILVO upgraded its electricity network which made it feasible to operate both at the same time. After this upgrade, the boiler which was operating as a backup system, it automatically turned on when a defrost cycle was being performed.

During the third test run, everything was working as planned, although less efficiently than expected. Most of the time, the heat pump had to run in the air-water regime through the dry cooler. When it switches to water-water the dry cooler – off, a fast dip was observed in the temperature of the storage tank. There could be a more efficient operation strategy. The third test run was shut down due to noise complaints since the office of the pig farm is located next to the heat pump system. For that reason, the placement of sound isolation inside the installation room and around the compressors was conducted.

During the fourth run, the system is running as intended and the heat pump system can operate for a longer time in water-water modus, as solar irradiance increases. The average COP of the high temperature heat pump is 3.07 and for the low-temperature heat pump 5.25 during this test run.

4.2 Best practices in GOLINELLI farm

In GOLINELLI farm, the RES4LIVE interventions include a heat pump, a PVT system, a BTES system and a smart control system for the nursery barn and redesign of the building of the hog barn with replacement fo the old windiws with new equipped with an automationopening system. The schematic overview of the installed HP-PVT-BTES system at the nursery barn as well as its technical specifications are presented in Figure 12.

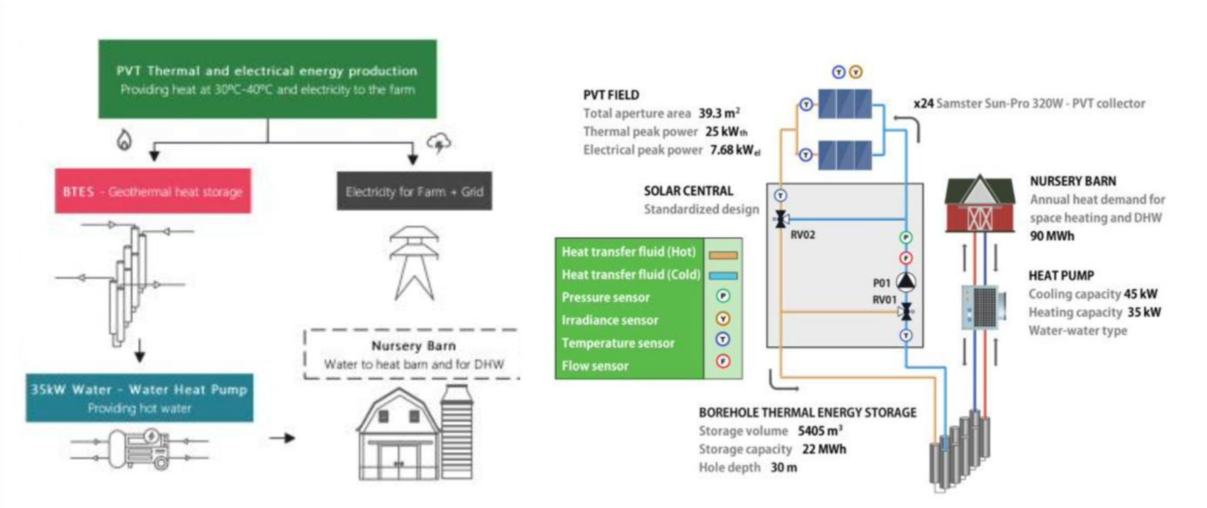

Figure 12. Schematic overview of the installed HP-PVT-BTES system at the GOLINELLI's farm nursery barn (left) along with its technical specifications (right).

The installation of th PVT system was conducted without any problem on the rooftop of the nursery barn and so did the installation of the solar station with the corresponding piping. For the BTES system, the process followed was more complicated including the design of the geothermal probes, the corresponding pressure tests, the drilling at the decided location of the farm and geological and hydrogeological analysis of the soil of that location to decide upon the positive potential and future efficiency of the BTES system. Eventually, the BTES was installed and connected to the heat pump and the PVTs through the solar station, as it can be seen in Figures 13 to 15.

Figure 13. Restoration of the geothermal area and details of the pits: geothermal probe (left) and piezometer (right).

Figure 14. Connections of the geothermal storage with the heat pump.

Figure 15. Installation and connections of the geothermal storage with the solar station.

The dual-source heat pump was installed and consecutive testing was conducted to verify the correct hydraulic tightness of all pipes in the solar and geothermal circuits. Then, the effective capacity of the heat pump to heat the finned coils of the building was proved. Furthermore, the heat pump's ability to switch from air to ground (activating and deactivating the fans), by rapidly responding to the set temperature thresholds, was confirmed. The selection between ground and air is based on the comparison between the geothermal fluid return temperature and the two temperature thresholds (decided by the user).

The integrated heating system of the nursery barn was analysed based on the temperature and humidity data recorded in the period 17-24 April 2024. This week, the outside temperature was significantly low, with 9.2 °C as the average and 2.9 °C as the minimum value, thus calling for heating almost continuously the hallway through the heat pump. The temperature in the hallway was then kept above the set point of 15 °C (with a tolerance interval of 0.5 °C) for the period considered, with the temperature in the finned pipes reaching over 50 °C in several periods. The two monitored rooms, indicated in Figure 16, hosted weaners until 17 April and room 1 also from 24 April. However, other rooms in the building hosted weaners also in the period 18-23 April, which is why the hallway was continuously kept heated during the entire period. The heating system developed proved effective also for the control of humidity conditions in the cold season, as is witnessed by the THI trends in the weaners' rooms, that is substantially kept below the alert threshold of 75.

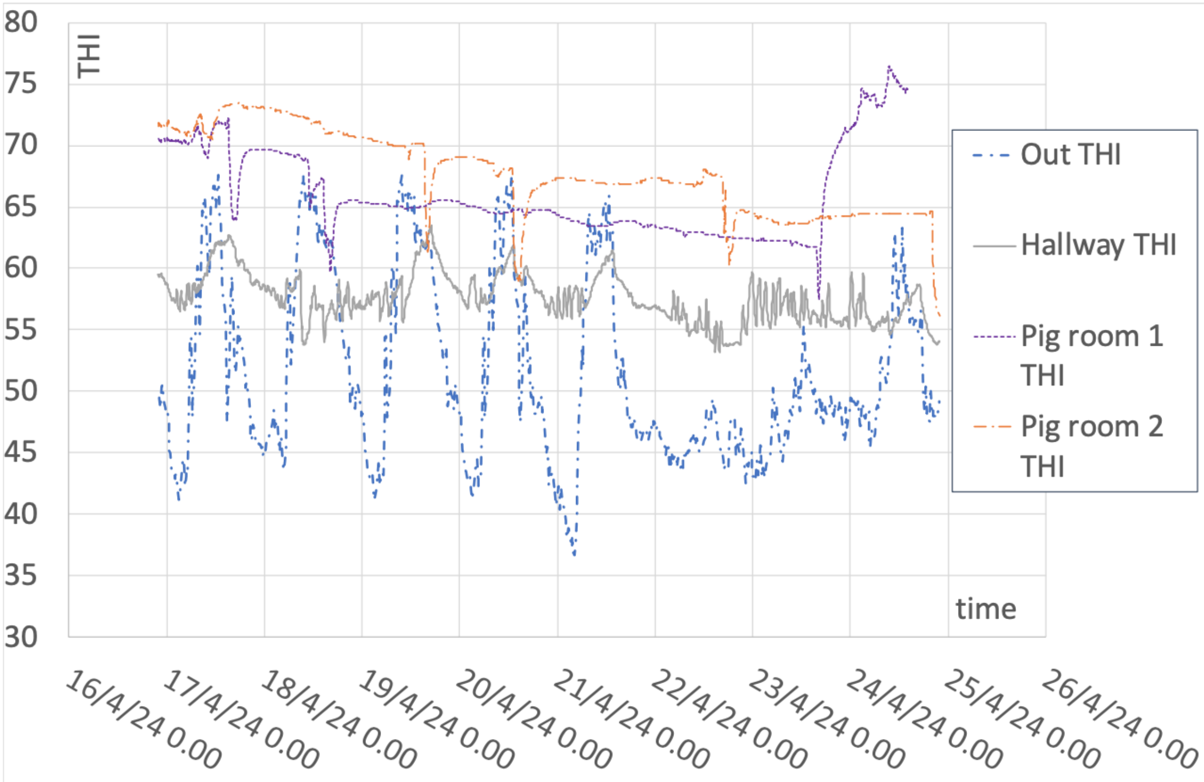

Figure 16. THI measured in the monitored indoor spaces of the nursery barn and outside.

The geothermal source was always used during the working time of the heating system and the circulation through the BHEs produced a temperature increase of up to 9.1 K in the cold side of the DSHP. The exploitation of the geothermal storage thus allowed to achieve high efficiency in the DSHP, as shown by the ratio of the heating capacity and the electric power used, reported in Figure 17. The resulting coefficient of performance (COP) is represented as well in the same diagram with hourly intervals, and the average COP in the studied period was 4.34. The COP of the DSHP when operating only in geo-source mode increased to 4.67.

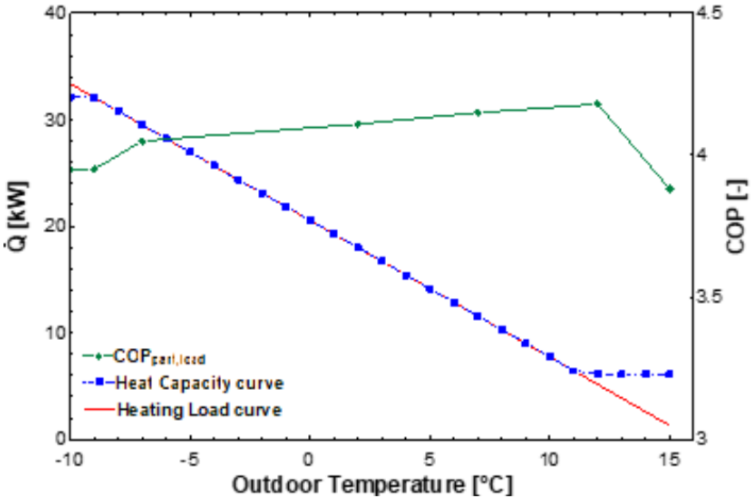

Figure 17. Heating load curve, heat capacity curve, and part load COP of the heat pump as a function of the outdoor temperature.

Concerning the intervention at the hog barn, is a retrofit of the building envelope, by the replacement of the old windows, with a new opening system, equipped with an automation opening system suitable to minimize heat loss with proper air exchange. The new windows, which are presented in Figure 18, are composed of a perimeter frame in tubular stainless steel, a frame and upper counter-frame in stainless steel, with transparent infill in 16 mm thick double chamber alveolar polycarbonate. The automation system is made of six-gear motors with a limit switch for the mechanical opening, environmental sensors, and actuators driven by temperature and air quality parameters.

Figure 18. Detail of the new windows (1) – The building after the installation (2) – Windows after actuating opening (3) - West side of the hog barn with windows open (4).

Figure 19 shows the trend of the main environmental parameters inside the hog barn during the period under analysis, characterized by high outdoor temperature in the initial two weeks and cold weather in the third one. The diagram shows that the natural ventilation system is suitable to keep the CO_2 concentration inside the building below the threshold of 3,000 ppm. During the period analysed, the barn was normally used to host hogs and gilts at its full capacity.

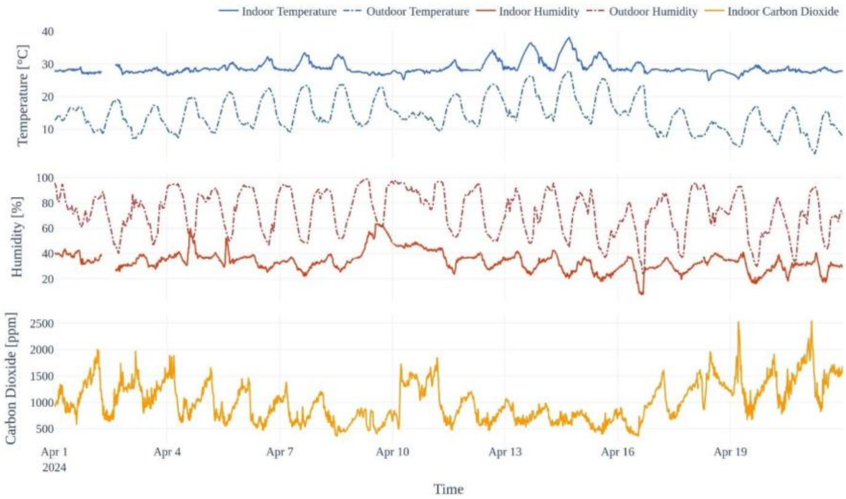

Figure 19. Indoor parameters in the hog barn after the retrofitting.

4.3 Best practices in LVAT farm

In LVAT farm, the RES4LIVE interventions include a plant for upgrading biomethane from the biogas plant to CNG and provide a filling station for the tractor that has been converted to use gas instead of diesel, a PVT system on the roof of one of the barns, the change the ventilation in the welfare barn to a tube ventilation system with the option to inject pre-cooled air into the barn and the sensors and a smart control system to regulate barn climate based on a combination of environmental condition data and animal-related data.

An overview of the components within the installation of the CNG filling station plant is shown in Figure 20 with the biogas plant (BP) in the background. The plant is composed by 2-bank gas storage for manual filling with ten gas flasks with a volume of 80 L (1), the NGV1 gas tap as a gastight connection to the tanks of the experimental tractor provided by CRMT (2), an activated carbon filter in a stainless-steel case for H_2S removal from the raw biogas (3), pipe insulation and trace heating for outside deployment without housing, making an expensive FailSave gas detection system for confined spaces unnecessary (4), the hybrid compression, three-stage biogas, and biomethane reciprocating compressor for gas purification from 53 % to 96 % methane and gas compression to up to 230 bar (5), a cold-water generator for cool drying of the raw biogas (dehumidification) (6), the electrical switchboard with an internet connection enabling online data queries for project monitoring (7),

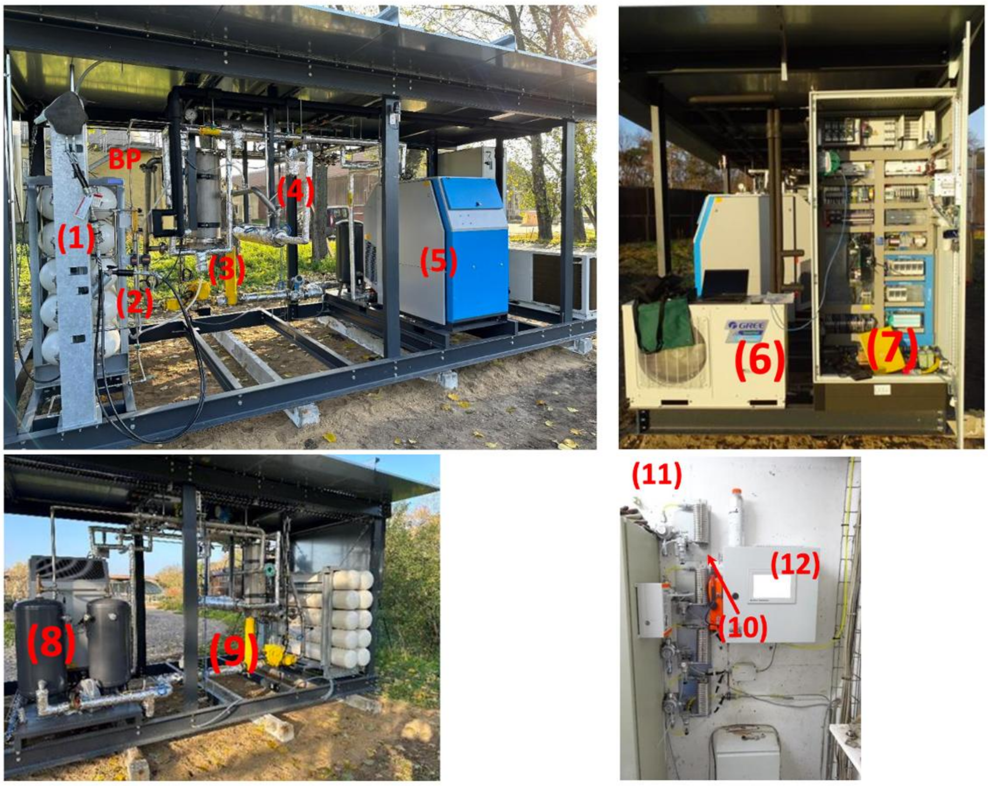

Figure 20. View of the CNG filling station with the biogas plant in the background (upper-left), side view (upper-right), rear view (lower-left) and gas component sensors (lower-right) of the biogas plant.

a dashpot and a condensate tank, both technically required for the separation of the condensate of the biogas upon compression and as a buffer on the suction side of the reciprocating compressor (8), the pressure blower with a large fine mesh filter cartridge from 0 mbar to 100 mbar that transports the raw biogas from the gas storage of the biogas plant to the compressor's suction side (9), the gas monitor in the biogas plant (10), components that are required to prepare the conditions for the gas during the measurement (11), and the calibration of the sensors (12).

The already existing biogas plant is connected to the new CNG filling station, where the biogas is then transformed into biomethane in a membrane filter system. This increases the biomethane concentration and as such produces BioCNG with a methane share of > 95 % on-farm, while the remaining gas components are led back into the biogas plant. A former diesel tractor was retrofitted for usage of the CNG from the BioCNG upgrade plant. For monitoring the performance of the CNG engine, a telemetry data logger was intended to be used. Due to incomprehensible reasons, it was not possible to connect to the data logger in the tractor at the LVAT pilot farm from CRMT in France. Only in April 2024, it was found that the UMTS technology that was the base for data transfer and that had worked during the testing in France was no longer available in Germany since 2022. Despite efforts that included the manufacturer of the data logger, the data could not be retrieved. A new solution for the telemetry was implemented, but after the installation, the tractor broke down to an unrelated gearbox damage that could not yet be repaired to date. As a result, the tractor's performance can only be assessed based on test runs at CRMT in France during and after the retrofit.

The PVT collectors were mounted on the roof of the LVAT's larger dairy cow barn (Figure 21). Twenty of the 24 modules are equipped with two layers of photovoltaic cells on the top and the bottom for increased efficiency (1) while the remaining four modules are pure thermal modules (2). The heat storage is located in the solar house, which is also connected to the heat recovery system in milk cooling. Together these systems provide hot water for the barns in a temperature range between 50 °C and 70 °C that will find use, e.g., in the automatic milking system (AMS) and the milking parlor during the cleaning operations.

Figure 21. The installed PVT system on the LVAT barn rooftop (left) and the solar station with heat storage (right).

The energy production by the PVT system during the last period of RES4LIVE (11 months) is shown in Figure 22. The total thermal energy production during that period amounted to 8,177.4 kWh, and the total electrical energy production came in at 3,002.4 kWh. The electrical energy can be used to power various devices in the daily operation of the LVAT, but synergies are expected with the tube ventilation and cooling system that is required to be used in the welfare barn under conditions that are also well suited for photovoltaic energy production: hot afternoons with lots of sunshine and therefore irradiation.

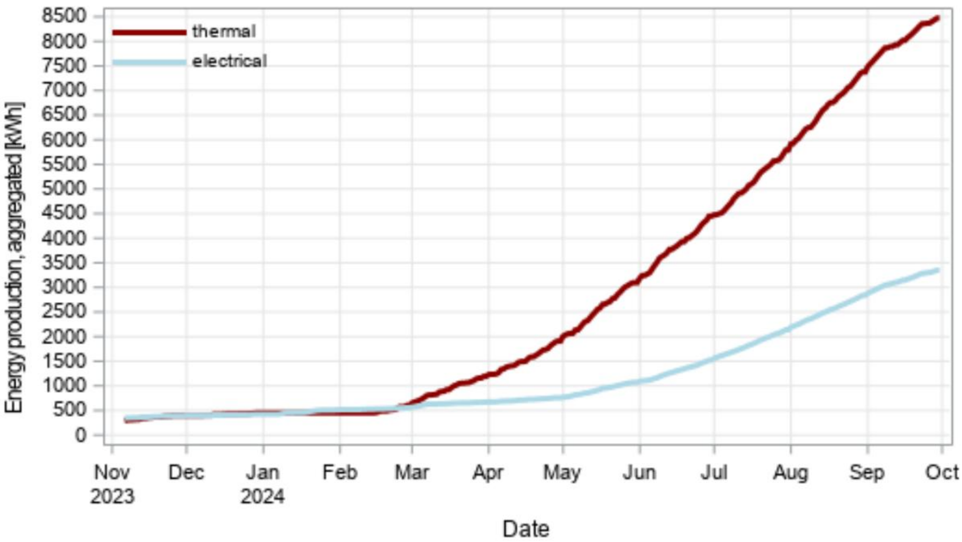

Figure 22. Cumulative energy production of the PVT system at the LVAT pilot farm during the last period of RES4LIVE (11 months).

The results of the efficiency assessment for the PVT system can be found in Figure 23.

Period		Solar irradiance		PVT production		Conversion efficiency (%)	
		kWh/m²	kWh	kWh_{el}	kWh_{th}	electrical	thermal
Whole year	November 2023 – October 2024, missing data predicted	1,092.1	60,544.4	3,164.5	8,633.4	6.80	14.26
Winter	November 2023 – February 2024	120.8	6,015.0	209.0	315.0	4.06	5.24
Summer	June 2024 – September 2024	592.3	29,487.2	2,149.0	5,102.5	8.52	17.30

Figure 23. PVT system conversion efficiency at the LVAT farm.

In the LVAT's welfare barn, the existing tube ventilation system was enhanced to provide the option to mix in pre-cooled air. To achieve this, evaporation coolers were installed at the side of the barn. Evaporation coolers (1) cool down ambient air to provide pre-cooled air that can be injected into the welfare barn through a tube system. Insulated tubes (2) transport the air to the cooling lines in the barn. In the bypass boxes (3), ambient air is mixed with pre-cooled air to achieve the required temperature for the tube cooling system (4). The injection of cooled air in the welfare barn above the lying cubicles and the feeding table provides additional comfort for the cows during days with higher temperatures and consequently higher risk for heat stress. Depending on ambient conditions, the ventilation system allows to drop the temperature in the welfare barn by 5 to 10 K.

Figure 24. The evaporation cooler (upper-left), insulated influx tubes (upper-middle), bypass boxes inside (upper-right) and outside (lower-left) the welfare barn at LVAT, mixing ambient air with pre-cooled air and a entilation tube line above a single row of lying cubicles (lower-right).

For the ventilation system installed, occasionally there are gaps in the data that are caused by power outages in the dairy welfare barn at the LVAT. While most systems in that barn are restarted automatically, in that case, the data monitoring requires a manual restart, and depending on the environmental conditions it sometimes takes a while to notice the shutdown of the data loggers. This also led to implausible data when the cooling system was shown as running while the fans were not, which by the settings of the system is impossible. This occurred during 20 days in the measuring period. In these cases, it can be deduced that based on the system settings the fans are also running at full volume flow, hence this missing data could be inserted retrospectively. The energy consumption monitored for a specific period is shown in Figure 25.

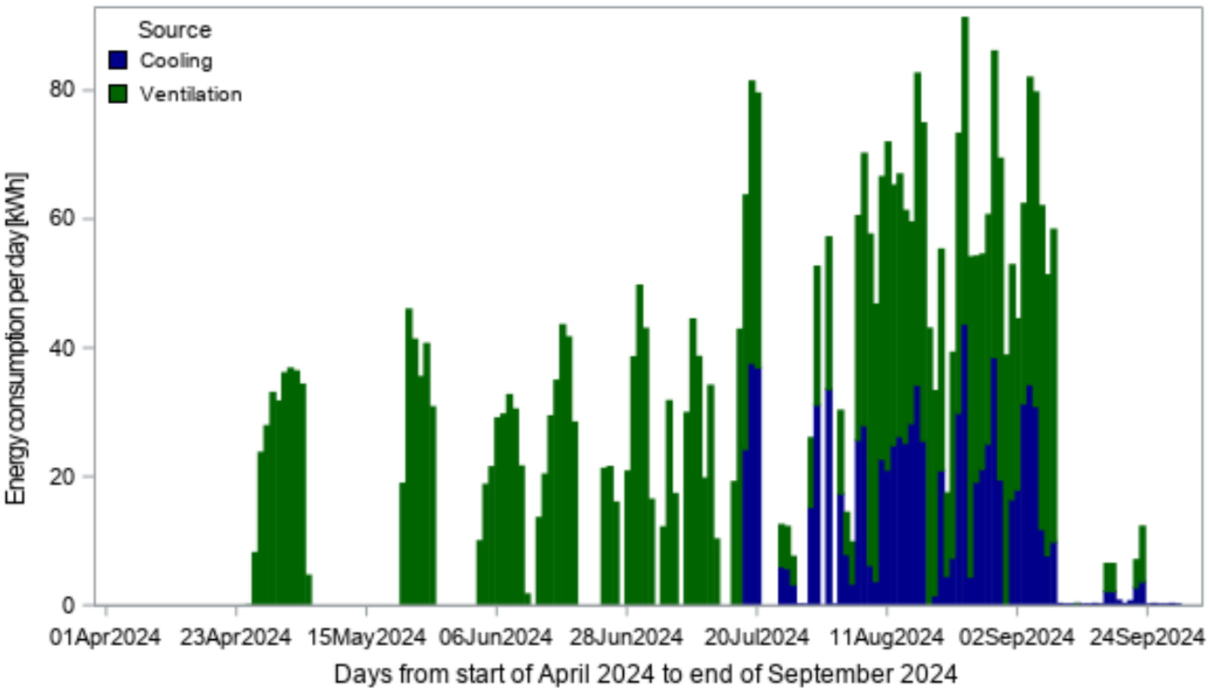

Figure 25. nergy consumption as measured from the tube ventilation and cooling system at the LVAT pilot farm during the 2024 summer season.

A challenging part of implementing the RES interventions is to analyze how they go together and complement each other, especially in the case of the LVAT where not only energy sources have been installed, but also a system that consumes more energy, with the tube ventilation and cooling system. The baseline for energy demand ranges between 60 and 80 kWh in the daily operation at LVAT and this is mostly covered by the already previously existing CHP running with biogas from the biogas plant. The thermal energy produced in the PVT system covers about 20 % of the CHP energy during the peak times around noon. Also, the earlier shutdown of thermal energy production has been observed, sometimes even before noon, compared to electrical energy production. As soon as the short-term heat storage with a volume of 1,500 L is filled, no more thermal energy is produced, while the production of photovoltaic electricity continues ideally until sunset. During the day under these conditions, the PVT system provides around 2 kW of power.

When compared to the energy consumer among the RES4LIVE interventions, the tube ventilation and cooling system, it becomes obvious that the demand for ventilation extends beyond the sunshine duration of the day. Especially during summer, there is a 24-hour demand for ventilation to provide sufficient air exchange in the welfare barn. This base load, therefore, should not be covered by a PVT system, instead, this is a task for the CHP. The cooling part, on the other hand, is usually only necessary during the daytime and also has an additional power requirement in the magnitude of electrical power the PVT system can provide. This is a clear synergy, but this requires careful prior planning on both parts to find the correct size of both systems.

4.4 Best practices in AUA farm

In the AUA farm, the RES4LIVE interventions include the installation of a PV system, the installation of a heat pump, the installation of a LED system and the installation of a sensor and smart control system.

The selected PV system was installed on the rooftop of a building nearby the poultry farm (Figure 26), and is accompanied with an inverter and an electrical panel. In particular, the produced electrical power (DC) is transferred via a cable (2), first to an electrical subpanel (3) containing the required lightning and surge protection, and then to the inverter (4). Then, the DC is inverted to AC, and it is driven back again to the subpanel via cable. Next, it is supplied to the main panel (5) where it is connected to the necessary switches and energy meter.

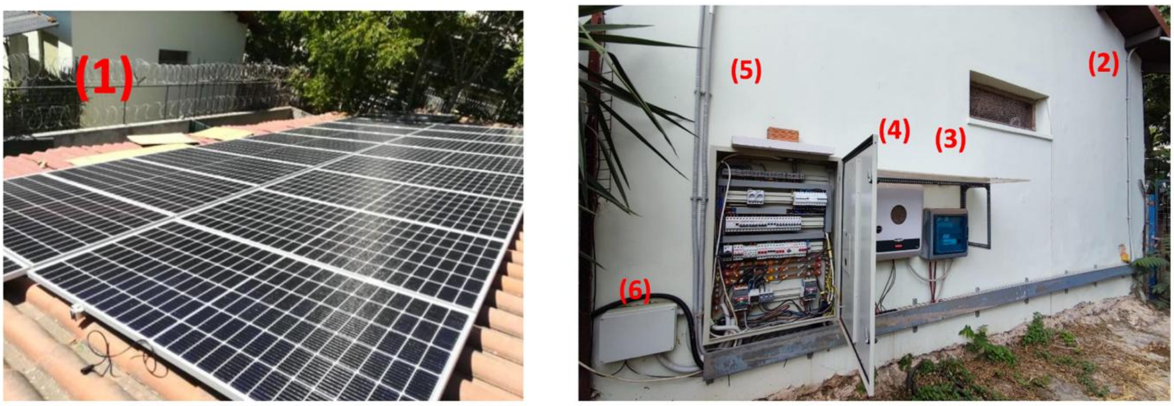

Figure 26. The PVs installed on the rooftop of a building nearby the AUA poultry farm (left) and the PV connections to the inverter and the electrical panels (right).

The produced electricity is supplied then to each room of the poultry house, as well as the heat pump. When the produced power is not enough to cover the needs of the facility, power comes from the grid. From preliminary data processing between May 2023 and April 2024 (12 months), the PV electricity production covers between 20.20 % and 68.13 % of the total energy needs on a monthly basis, and 25.25% yearly. A characteristic energy use profile for a 3-day period in July 2023 (23-25/07/2023) is presented in Figure 27. No storage system is included, so when the PV production exceeds the energy needs of the facility - though not common - the nearby auxiliary buildings are supplied with electricity.

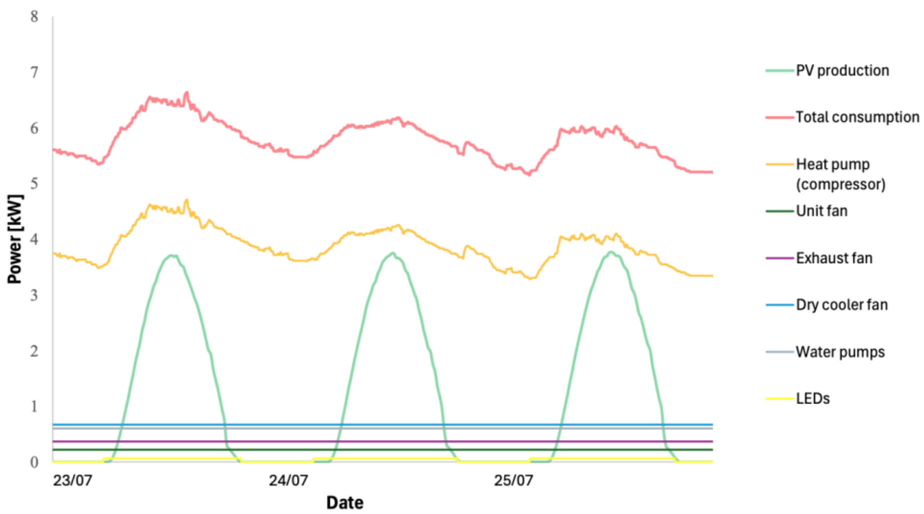

Figure 27. Energy use profiles for a 3-day period in July 2023.

The AUA heat pump for controlling the indoor environment of the poultry house by supplying the necessary heating, cooling, and dehumidifying loads, became operational in May 2023. The heat pump's operation is controlled primarily by its Programmable Logic Controller (PLC), which is fed with real-time data from the smart control systems. The main parameters of the heat pump operation can be monitored in real-time online, as well as exported in .png and .csv format. Finally, additional parameters concerning the fans' operation, such as the unit's fan capacity, allow the estimation of the energy use profile for the rest of the system's components. The testing of the heat pump evaluated that the its performance was satisfactory.

4.5 Conclusions on the RES4LIVE installations and testing best practices

The results from the installations and the testing of the RES4LIVE interventions at Four different farms demonstrate that most of the RES installations operate efficiently, significantly reducing or fully replacing the use of fossil fuels across various livestock operations. In particular, the heat pumps and PVT systems have shown strong performance, meeting expected energy efficiency targes. A promising solution is the BioCNG upgrade plant, especially when paired with CNG-powered vehicles; however, its practical viability depends on scaling the system to a size that ensures economic feasibility. However, challenges were present during the phase of installations and the monitoring of the RES performance and to overcome those challenges the RES4LIVE partners were exchanging information efficiently whereas technical partners were present at farms' locations to solve the observed problems and to monitor the smooth operation and testing of the installed technologies.

5 BEST PRACTICES OF RES4LIVE DISSEMINATION, COMMUNICATION AND EXPLOITATION STRATEGY (DCES)

The communication strategy was developed to raise awareness about the energy problems and demands in livestock farming and the potential RES solutions which can replace conventional fossil fuels. As part of the communication strategy, the first important action taken was the setting up of the RES4LIVE website and the social media accounts (Facebook, LinkedIn, and X/ Twitter) and the production of communication material such as flyers, brochures, leaflets, posters, the RES4LIVE teaser video and a roll-up banner. Attendance at events, workshops and exhibitions has been included in the communication plan as one of the main ways to promote the project activities. Moreover, from the beginning of the project, the logo and the project identity have been specified.

The communication strategy has been effectively developed during the project. Thanks to the material prepared, the website and social media accounts, key stakeholders in the farming industry and RES technologies were informed about RES4LIVE and the effective ways of reducing emissions by replacing fossil fuels with RES. The efficient development of the communication strategy is depicted from the RES4LVE website whose visibility is impressively high, as revealed by the metrics: during the 4-year project period, the website had almost 83,000 unique visits, a total number of 159,000 visits and a total number of 3,3 million hits. It is believed that those high numbers are due to the release of the website directly from the beginning of the project, its efficient promotion through the project’s social media accounts and its regular and constant updates with results following the project's progress. Furthermore, the regular release of the newsletter every six months rendered the stakeholders’ engagement feasible which is depicted in the number of 150 subscribers to newsletters and even more, the 53% open rate of the released newsletters. It is, thus, can be concluded that the use of the website as a communication tool as well as the regular release of newsletters presenting the project’s progress and the RES4LIVE team is an effective tool. The same holds for the social media accounts of RES4LIVE; with 1700 total followers on X/ Twitter, LinkedIn and Facebook and more than 30,000 profile visits, RES4LIVE is still visible to dedicated audiences such as farmers, the farming industry and the RES community, to business related with the replacement of fossil fuels with RES in livestock farming and to the public audience. For having that visibility and to ensure engagement, often posts have been published in RES4LIVE SMA’s presenting the project’s team, the main challenges, the main achievements and technological installations and the participation of project’s partners in scientific conferences, events, workshops and exhibitions.

The dissemination strategy was planned and developed to increase awareness, maximise the impact of the research improving the use of energy in livestock farming by applying RES technologies. While scientific publications are useful for reaching the academic community, the dissemination strategy has taken into account also a detailed plan for stakeholder engagement to provide the opportunity to have early feedback from experts in the field. In this context, RES4LIVE partners have held 33 presentations in the form of oral talks or posters at scientific conferences, while the presence of project partners in such conferences was even higher. Moreover, 7 peer-reviewed publications in scientific journals have been published during RES4LIVE with the project's technological results, while at least 3 more are planned after the project’s end. Participation in scientific conferences along with presentations and publications in scientific journals helped RES4LIVE to reach the scientific community and gain high visibility from this stakeholder category. To broaden the stakeholder’s engagement, newsletters have been also used to disseminate the RES4LIVE technological achievements. As already mentioned above, newsletters have been produced twice per year and the strategy of their usage as a communication/dissemination tool is successful based on the final metrics and the KPIs set at the beginning of the project.

Another way of efficient dissemination of RES4LIVE results and engagement of stakeholders was the national workshops that were organised during the project. In total, 12 such workshops were conducted, 3 in Belgium, 3 in Italy, 3 in Germany and 3 in Greece with more than 150 participants in total. During those workshops, the corresponding project partners presented to farmers and technology developers the technological RES solutions and installations developed in RES4LIVE. During the workshops, there were fruitful discussions between the project partners and participants and their input was valuable concerning the challenges in RES technologies in livestock farming.

Clustering with other projects, initiatives and stakeholders provides also an efficient manner of disseminating project results. From the early stages of the project, RES4LIVE was an active member of the AreaZero Cluster with six more EU-funded projects. The Cluster discussions focused on minimising fossil fuel use and harmful emissions in the broader agricultural sector, the common policy strategies as well as efficient dissemination of results. AreaZero cluster provided RES4LIVE the opportunity to participate in two webinars organised as separate sessions of the European Sustainable Energy Week and to participate in a common publication in the European Energy Innovation magazine.

Concerning the exploitation strategy, the best practices and lessons learnt relate to the level and nature of support that all project partners need to fully capture the concept and importance of “Exploitation” within EU-funded projects. One critical aspect is that all technical partners should be exposed to the necessity of developing a robust Exploitation Strategy, at the early stages of the project. The case is that technical partners are often not very familiar with the term “exploitation” and it is thus, rather difficult to understand the connection between exploitation-related tasks and the sustainability and replicability of the project results. By recognizing the importance of developing an individual exploitation strategy, technical partners become keener on IP issues and ways to protect their results, engage more in dissemination activities (events, publications, etc.) and express interest in clustering with other projects in similar fields. Furthermore, another aspect is that all technical partners should realize that “Exploitation” means commercial and also non-commercial, but societal, political, policy-making or knowledge transfer. It should be clearly explained that the “Exploitation” term refers to the utilization of the results in further research activities, in standardization, or in developing and creating a market product. Hence, a variety of exploitation routes is available, such as patents, trade secrets, scientific publications, spin-offs/Start-ups, contributions to standards, policy recommendations, societal activities, open licenses, newly funded projects, etc. In this way, all partners realize that the selection of the exploitation route depends on the nature of the result, the nature of the entity that produced the result, the commitment needed in terms of time and resources, the potential risks, the payback time and the potential benefits in monetary form. In this way, all project partners become aware and develop the best exploitation strategy for their results.

Across the RES4LIVE progress, the exploitation manager of the project prepared already from the early stages of the project an exploitation strategy (please, refer to D7.4 “Plan for the exploitation and the dissemination of the results) where the exploitation routes were provided to the project partners as well as the meaning of each TRL and the description of risks characterising the exploitable results. Moreover, it was devoted time for separate meetings and discussions with technical project partners to explain the various exploitation routes that they have in their toolkit for their results. Separate meetings were also organised when technical project partners were demanded to complete the Innovation Radar questionnaire; the exploitation manager associated them to do that and further, by explaining to them point-by-point the meaning of questions, it became more clear to them the steps that they should follow so as their products to reach the market. As a result, four of the RES4LIVE technologies were selected to be published by the Innovation Radar, 6 technologies are already under discussion amongst the corresponding partners to be protected as intellectual property, while one technology has been already submitted for a potential patent application.

Figure 28. Summary of the dissemination, communication and exploitation best practices.

5.1 Conclusions on the DCES-related best practices of RES4LIVE

During RES4LIVE, a dissemination, communication and exploitation strategy has been developed. The strategy is thought of as successful, taking into the metrics at the end of the project. To achieve the success of this strategy several things were important such as:

- the constant presence on social media and the continuous updates of the project's website
- the presence and presentations at scientific conferences and events, concerning communication
- the dissemination and explanation of exploitation routes, concerning exploitation.

However, the most crucial and common characteristic was the smooth cooperation between project partners who always informed the communication and dissemination managers of their results' progress and their scientific/technological achievements and asked for guidelines when that was necessary.

6 CONCLUSIONS

This report gathers together the knowledge gained throughout the project, as identified by the RES4LIVE partners, divided into general aspects, technical best practices including RES installations and teting and dissemination, communication and exploitation best practices. The report includes a detailed presentation of the lessons learnt focusing on the overall progress of the project, the RES technologies development, installation and evaluation for their technical, environmental, financial and social performance as well as useful guidelines gained for a successful and efficient dissemination, communication and exploitation strategy.