# Economic assessment report

## Deliverable 5.2

## WP5. Technical, socio-economic and environmental assessment

**Project title**

RES4LIVE - Energy Smart Livestock Farming towards Zero Fossil Fuel Consumption

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# ABBREVIATIONS

| | | |
|---|---|---|
| **AIMSFS** | : | After Interventions Medium Sized Fan System |
| **AISSFS** | : | After Interventions Small Sized Fan System |
| **BioCNG** | : | Biogas-Based Compressed Natural Gas |
| **BOM** | : | Bill of Materials |
| **BTES** | : | Borehole Thermal Energy Storage |
| **CHP** | : | Combined Heat and Power |
| **CNG** | : | Compressed Natural Gas |
| **DPBP** | : | Discounted Payback Period |
| **EcICI** | : | Economic Impact Category Indicator |
| **FU** | : | Functional Unit |
| **FYAIS** | : | First Year After Intervention(s) System |
| **HP** | : | Heat Pump |
| **HVAC** | : | Heating Ventilation Air Conditioning |
| **LC** | : | Life Cycle |
| **LCA** | : | Life Cycle Assessment |
| **LPG** | : | Liquefied Petroleum Gas |
| **PV** | : | Photovoltaics |
| **PVT** | : | Photovoltaic-Thermal |
| **ROI** | : | Return on Investment |
| **RS** | : | Reference System |
| **SB** | : | System Boundary |
| **SEcS** | : | Single Economic Score |

# 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

RES4LIVE, an H2020-funded project, aims to advance the adoption of renewable energy solutions that support fossil-free livestock farming. The "Economic Assessment Report" (Deliverable D5.2) focuses on evaluating the economic impact of RES4LIVE's integrated renewable energy systems (RES) at four pilot farms, with assessments based on life cycle models and inventory data collected before and after the RES4LIVE interventions. This data included initial investments, annual maintenance costs, operational energy and fuel expenses, and yearly product sales, offering a comprehensive view of the economic performance of each livestock pilot farm after the installation and operation of the new systems.

Economic models, derived from primary data on the pilot farms as well as consortium technology developers and supplemented with data from literature and established databases, extended environmental life cycle assessment (LCA) models to further consider economic performance. The farm-level LCA models resulted in midpoint cost categories such as direct production and overhead costs and were used to estimate metrics such as net income and discounted payback period (DPBP), helping identify the potential for cost savings or increases of various pilot farm sub-systems, due to the RES4LIVE interventions.

Results show that costs per kg of sow at the GOLINELLI hog barn gate rose after implementing the new technologies. While gross output increased by approximately 15%, energy costs rose by around 38%, slightly diminishing overall economic performance. Although the system investments alone do not yield a return, improved barn climate conditions could enhance sow welfare and productivity, positively impacting the farrowing process. In contrast, economic performance in the GOLINELLI nursery barn improved by nearly 14%, with ROI achievable in 33 years, or as early as 13-14 years if supported by 20% to 40% subsidies.

The economic performance of the EV ILVO farm increased by nearly 3.5 times, mainly due to a 41.34% increase in gross output. While energy and machinery/building costs rose slightly, the integrated RES system could provide an ROI within 18 years or sooner (13-14 years, or as quickly as 9-10 years with 20% to 40% subsidies).

At the AUA poultry farm, the gross output rose by about 25%, yet a sevenfold increase in overhead costs - mainly from energy, machinery, and building costs - reduced the economic performance. Improving energy efficiency, especially in ventilation, could help, although performance remains below the baseline system (before the RES4LIVE interventions). Achieving a reasonable DPBP here would require significant subsidies and an increase in product sale prices.

For the LVAT dairy farm, the integration of a BioCNG unit resulted in a slight reduction in CHP plant economic performance, while the BioCNG unit itself generated around €0.8 per Nm³, with a DPBP of 10 years. Tractor adaptation eliminated fuel purchase costs, saving approximately €4.88 per hour of operation, and could be paid back within an additional 2-year period after the payback of the BioCNG unit. Increasing the BioCNG unit's capacity could improve profitability. Integration of a PVT system alongside an existing e-boiler yielded annual savings of around €2,200; however, due to high initial investment costs for the PVT system, the DPBP still exceeds the PVT system's lifespan, even with subsidies.

Overall, the economic assessment suggests that while RES4LIVE technologies offer positive outcomes, success varies across cases. GOLINELLI's nursery barn and EV ILVO farm achieved significant improvements, while in LVAT, expanding certain subsystems could improve economic

performance. For GOLINELLI's hog barn and especially AUA's poultry farm, addressing high energy costs and initial investments will be essential to enhancing economic performance.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# 1 INTRODUCTION

Deliverable D5.2, the "Economic Assessment Report," presents the outcomes of T5.2 activities, which focused on evaluating the economic effects of the RES4LIVE integrated solutions. The primary objective was to create life cycle (LC) models and inventories using site-specific data from the four pilot farms, collected both before and after the RES4LIVE interventions. This data covered aspects such as initial investment, annual maintenance for RES4LIVE systems, and operational energy and fuel costs, along with yearly product sales figures.

Relying on primary data from both the pilot farms and the consortium’s technology developers, as well as supplementary data from literature and established databases, the Life Cycle Assessment (LCA) models initially developed for environmental performance were expanded to capture additional economic flows as well.

Various midpoint cost categories (direct production costs, overhead costs, and gross output) were assessed as well as measurable economic performance indicators (e.g., net income) and metrics like the discounted payback period (DPBP). Emphasis was placed on identifying the cost savings or increases of various pilot farms’ subsystems, with the goal of quantifying the potential economic benefits of the proposed technologies and energy efficiency measures.

The deliverable is structured as follows: Section 2 details the methodological approach, outlining the study’s goal and scope, functional units (FU), system boundaries (SB) used in each case, the data collection and modelling procedures, main limitations encountered, and economic indicators used. Sections 3, 4, 5, and 6 present the economic assessments of the pilot farms - GOLINELLI (swine), EV ILVO (swine), AUA (poultry), and LVAT (dairy cattle), respectively - covering results, key findings, and discussions. Section 7 concludes with the key outcomes and recommendations for future applications of these technologies in similar livestock farming environments.

# 2 METHODOLOGY

In general, the economic assessment conducted in the context of RES4LIVE follows the Life Cycle Assessment (LCA) principles and framework, as presented in Deliverable 5.3 'Environmental Assessment Report', focusing on gate-to-gate assessments at the farm level. A Life Cycle Costing method was developed in SimaPro software (SimaPro 9.6.0.1 version), qualitatively defining cost and gross output elements relevant to the systems of interest. The relevant cost elements were quantitatively characterized for each system of interest and included accordingly in the relevant farm-level LCA datasets (see Deliverable 5.3). The SimaPro output was used for addressing profitability indicators such as economic return, profit, income and product sales and efficiency indicators such as cost efficiency and productivity. These economic indicators were adjusted in agreement with the system of interest. Almost in all cases, estimating the net income of the process of interest at the farm level was equivalent to a simple cost-benefit analysis. Finally, the present analysis focused on estimating the Discounted Payback Period (DPBP) connected to the RES4LIVE technologies which started operating in the context of the project. The DPBP is a financial metric used to determine how long it takes for an investment to recover its initial cost when accounting for the time value of money. It differs from a simple payback period by discounting the future cash flows (income or savings) back to their present value using a discount rate (which reflects the cost of capital or expected rate of return). By summing these discounted cash flows year by year, the discounted payback period identifies the point in time when the accumulated present value of these cash flows equals the initial investment cost. This approach provides a more accurate picture of an investment's profitability, as it considers not only the cash inflows but also how the value of money changes over time. A shorter discounted payback period indicates a quicker recovery of the investment, while a longer period suggests a slower return, which could be riskier.

More details about the methodological aspects of economic assessment are provided in the following sub-sections 2.1 to 2.5.

## 2.1 Goal and scope

Perfectly aligned with the environmental LCA, the goal of the economic assessment - in the framework of the RES4LIVE project – is to estimate the economic effect of implementing specific Renewable Energy Sources (RES) technologies interventions in different livestock facilities. Thus, the focus is on estimating the difference in the economic indicator values between the system after the installation and operation of these technologies and the system before the implementation of these technologies.

## 2.2 System boundary (SB) and Functional unit (FU)

The functional unit (FU) and the system boundary (SB) in this economic assessment serve the same purpose as in the environmental assessment and more details are available in Deliverable 5.3. 'Environmental Assessment Report'.

The economic assessment was performed for all pilot farms considered in the RES4LIVE project:

1. The commercial swine farm GOLINELLI (Italy)

2. The experimental swine farm ILVO (Belgium)
3. The experimental poultry farm of the AUA (Greece)
4. The experimental dairy cattle farm LVAT (Germany)

For all cases, a gate-to-gate SB approach is followed, as it was not in the goals of the RES4LIVE project to define and quantify economic issue elements for processes prior to the farm-level process of interest in the relevant cradle-to-farm-gate system. This implies that the SBs for the economic assessment do not agree with the SBs for the environmental assessment. Nevertheless, the FUs are in perfect agreement between economic and environmental assessments.

The geographical scope of each study is pilot farm-specific, with a temporal boundary established for 1 year of operation.

The relevant farm-level comparisons (RES4LIVE technologies installed, and technologies substituted) for all pilot farms are presented in detail in Deliverable 5.3 ‘Environmental Assessment Report’ (see sections 3.1, 4.1, 5.1, and 6.1).

## 2.2 Data collection procedure

As for the environmental assessment, it was attempted to quantify the economic elements for the reference system(s) of all pilot farms using average data (years 2020-2022), whereas for the systems after installing and operating the RES4LIVE interventions, using the most recent 2023 and 2024 data.

Primary data collection was carried out in two distinct phases; the first phase (RP1-RP2) focused on gathering foreground data on the reference systems, specifically the pilot farms prior to the RES4LIVE interventions. The necessary numerical data for the quantities of material and energy inputs and product outputs were necessarily the same for both environmental and economic assessment. In addition to quantity data, numerical data about inputs’ purchase and product selling prices were necessary. In the first phase, only product selling prices in the reference systems were possible to be collected for almost all pilot farms, facilitating the implementation of an economic allocation approach to product outflows when applicable (i.e. ILVO and GOLINELLI pilots). Collection of primary economic value data for existing equipment and machinery in the on-farm processes of interest was impossible.

The second phase (RP2-RP3) involved: (i) updating the environmental LCA questionnaires with economic data requirements, (ii) collecting economic data related to the RES (Renewable Energy Systems) technologies and (iii) finalizing the collection of numerical data about inputs’ purchase and product selling prices for the farm-level systems both before and after the installation and operation of the RES4LIVE interventions.

Regarding the data related to the installed and operating RES4LIVE technologies, we emphasized communicating with the responsible partners (GOLINELLI/UNIBO, ILVO/UGENT, AUA, and LVAT/ATB) to collect primary data about:

- the purchase and on-farm installation costs of the RES4LIVE technology
- the annual maintenance costs of the RES4LIVE technology and
- the salvage value of the RES4LIVE technology (i.e the estimated value at the end of its useful life)

More in detail, cost information was obtained by:

- ATB – for the BioCNG unit in LVAT farm
- MG Sustainable – for the PVT systems in GOLINELLI, ILVO, and LVAT farms
- PSYCTOTHERM – for the heat pump in GOLINELLI, ILVO, and AUA farms
- CRMT – for the adapted biomethane tractor
- PLEGMA – for the smart control systems in all four pilot farms
- UNIBO – for the BTES system in GOLINELLI farm
- AUA – for the PV and LED systems in the AUA farm

Regarding the inputs' purchase price data at the farm level (both systems before and after the installation and operation of the RES4LIVE technologies), the inputs were separated into fuel, electricity and the rest of the materials. The purchase price of the fuel and electricity inputs was given increased attention, and the data was mostly obtained from Eurostat (especially electricity, natural gas and diesel for transport), in cases where farm-level data was not sufficient. Electricity[1] and natural gas[2] prices were selected for the respective country and non-household consumers considering the size of consumption in the pilot farm. The price for diesel for transport was also selected for the respective country, using the relevant Eurostat dataset for agricultural production[3]. Purchase prices for the rest of material inputs such as compound feeds and bedding materials were selected based on provided data from pilot farms and expert judgement.

## 2.3 Modelling process

The modelling work involved, in all cases, the development of the farm-level economic LCA model of the Reference System (RS) and the farm-level economic LCA model of the First Year After the Interventions System (FYAIS). These economic models were embedded in the respective farm-level environmental LCA models in the SimaPro software (see sections 2.4, 3.1, 4.1, 5.1, and 6.1 of Deliverable 5.3).

### 2.3.1 "Reference" model

The farm-level economic LCA models of the RS for the livestock houses in GOLINELLI, ILVO and AUA include economic flows such as: sold animal live-weight (denoted as a negative cost), purchased feedstuffs, other direct production costs (e.g. bedding materials), transport costs - related to production costs, heating fuels, transport costs - related to energy costs and electricity.

[1] Source for non-household consumers' electricity prices:
https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205/default/table?lang=en
[2] Source for non-household consumers' natural gas prices:
https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_203/default/table?lang=en
[3] Source for prices for means in European agricultural production:
https://ec.europa.eu/eurostat/databrowser/view/apri_ap_ina/default/table?lang=en

In the farm-level sub-systems of the LVAT farm, there are costs associated with the existing machinery/equipment (CHP unit, farm tractor, electric boiler), such as annual depreciation costs, maintenance costs and insurance costs. According to the process, motor fuel and electricity costs can also be defined.

### 2.3.2 “After interventions” model

In addition to the economic flows defined in the RS farm-level economic LCA models, economic flows related to the installed and operating RES4LIVE technologies were necessary to be defined in the After Interventions’ Systems’ (AIS) models for all pilot farms. These essentially include the annual depreciation costs, maintenance costs and insurance costs for each RES4LIVE technology as well as their annual operating costs (e.g., electricity consumption). In addition, the operation of the installed RES4LIVE technologies is responsible for on-farm electricity or bio-fuel production which in some cases has the potential to offer the gross output of the pilot farm (e.g., in the case of LVAT pilot, the BioCNG unit could produce an additional quantity of biomethane to the retrofitted farm tractor annual needs that could be supplied to the market). In such cases, a relevant economic flow was included in the model.

## 2.4 Main limitations and assumptions

The farm-level economic LCA models were used to estimate annual economic flows for the farm-level processes of the pilots for a reference scenario and a scenario for the first year after the installation and operation of the RES4LIVE technologies. Both the absolute values and differences in these economic flows, in the economic impact categories defined (see section 2.5) and in the total economic scores are highly dependent on the average purchase and sale prices which were used for their estimation. A complete economic analysis would require implementing proper modelling work for forecasting the purchase prices for all the involved material, fuel and electricity inputs and sale prices for all product outputs (animal live-weight sales, electricity and bio-fuel sales) for the next 25-30 years (i.e. the expected lifetime for the installed RES4LIVE technologies). This was not conducted in the context of the present analysis as it fell outside the scope of the project. However, an estimation of the difference in the annual economic impact category indicators (EcICIs) and the total economic score, as well as an estimation of the difference in additional dedicated farm-level economic indicators (profitability indicators such as economic return, profit, income and product sales and efficiency indicators such as cost efficiency and productivity), considering only the first year of the RES4LIVE technologies’ operation, is an acceptable, initial indication of the effect of the RES4LIVE technologies on the economic performance of the farm-level systems of interest. Finally, the additional estimation of the Discounted Payback Period (DPBP) connected to the RES4LIVE technologies is valuable for the stakeholders wishing to invest in such technologies. This latter indicator is provided by this analysis, completing the initial, necessary information on the effect on the economic performance of the livestock systems implementing such technologies.

## 2.5 Economic indicators

Midpoint and endpoint economic assessment at the farm level was conducted after having developed a Life Cycle Costing method in SimaPro. At the **midpoint level**, this method includes the estimation of 5 cost impact categories on an annual basis:

1. Direct production costs: They include economic flows such as purchased feedstuffs, purchased livestock, veterinary and reproduction expenses, transport costs related to these inputs and other direct production costs related to livestock.
2. Energy costs: They include economic flows such as the purchase of motor fuels and lubricants, heating fuels and electricity. The transport costs related to these material inputs are further included.
3. Gross output: This category includes economic flows such as sold animal live-weight and eggs at the livestock housing level, sold electricity from renewable energy sources and sold biofuel at the gate of the BioCNG unit. Considering that the values for the costs have a positive sign, the values for gross output have a **negative** sign.
4. Machinery and building costs: They include economic flows such as machinery and equipment purchase allocated to the period of lifetime of the machinery and equipment (i.e. the *annual depreciation expense of the machinery purchase over the lifetime of the machinery = [(cost of machinery purchase) - (salvage value at the end of the useful lifespan)]/(useful lifespan of the machinery*) plus the *annual depreciation expense of the installation costs over the lifetime of the machinery = [(cost of machinery installation / (useful lifespan of the machinery)]*), the current upkeep costs of the machinery and equipment, the insurance costs of machinery and equipment and the transport costs related to machinery and equipment.
5. Other costs: They include economic flows such as costs for water, advisory and accountants' fees.

Cost categories 2, 4 and 5 are summed up to the **overhead costs**. All economic flows receive the same characterization factor (1 €/€) in each cost impact category and all cost impact categories are measured in €.

Gross output, overhead costs and direct production costs are associated with an equivalent weighting factor in the process of estimating the Single Economic Score (SEcS (in Pt) - **Endpoint level assessment**).

# 3 GOLINELLI COMPARATIVE ECONOMIC ASSESSMENT

## 3.1 Farm-level economic LCA models - GOLINELLI

### 3.1.1 Reference system and system after interventions - GOLINELLI

The reference systems and the systems after installing and operating the RES4LIVE technologies involving the hog barn (B.12) and the nursery barn (B.16) of the GOLINELLI commercial pig farm, are described in Deliverable 5.3: "Environmental Assessment Report" (Sections 3.1.1 and 3.1.2).

For further details on the RES systems, please refer to deliverables D4.1: "Design of integrated systems in pilot farms", D4.2: "The installed pilot systems", D4.3: "Report with the test results obtained on energy and production performances of RES and energy efficiency solutions".

## 3.2 Farm-level economic LCA datasets - GOLINELLI

The annual economic flows due to the product sales at the hog barn (B.12) and nursery barn (B.16) gates in the reference system (RS) and the First Year After RES4LIVE Interventions System (FYAIS), as introduced into the SimaPro software (part of the wider farm-level LCA dataset), are shown in Table 1.

*Table 1. Annual sales of products before and after the RES4LIVE interventions in the GOLINELLI pilot farm.*

| **GOLINELLI - HOG BARN (B.12)** | **Unit** | **Reference System (RS - GOLI - HB)** | **First Year After Interventions System (FYAIS - GOLI - HB)** |
|---|---|---|---|
| Sold animal live-weight - cull sows (swine) | €/year | 62,625.00 | 72,000.00 |
| Sold animal live-weight - boars (swine) | €/year | 450.00 | 450.00 |
| **GOLINELLI - NURSERY BARN (B.16)** | **Unit** | **Reference System (RS - GOLI - NB)** | **First Year After Interventions System (FYAIS - GOLI - NB)** |
| Sold animal live-weight - piglets after the nursery stage (swine) | €/year | 1,243,807.65 | 1,451,940.00 |

The product sales in Table 1 are estimated using the data supplied by the GOLINELLI farm managers regarding the number of animal heads sold annually and the average sale price per head. Table 1 suggests an increase in the product sales in the FYAIS for both the hog barn and the nursery barn in the GOLINELLI farm in comparison to the RS.

Table 2 presents key economic flows at the GOLINELLI pilot farm buildings, used to estimate the economic performance before and after the RES4LIVE interventions.

*Table 2. Annual key economic flows before and after the RES4LIVE interventions in the GOLINELLI pilot farm.*

| GOLINELLI - HOG BARN (B.12) | Unit | Reference System (RS - GOLI - HB) | First Year After Interventions System (FYAIS - GOLI - HB) |
|---|---|---|---|
| Barn retrofit (New windows and opening system) - Annual depreciation expense [a] | €/year | - | 933.07 |
| Barn retrofit (New windows and opening system) - Annual maintenance expense | €/year | - | 200.00 |
| Barn retrofit (New windows and opening system) - Annual insurance expense | €/year | - | 125.00 |
| Barn retrofit (New windows and opening system) - Annual operating expense (electricity) | €/year | - | 127.40 |
| Smart control system - Annual depreciation expense [b] | €/year | - | 168.75 |
| Smart control system - Annual maintenance expense | €/year | - | 60.00 |
| Smart control system - Annual insurance expense | €/year | - | 16.80 |
| Smart control system - Annual operating expense (electricity) | €/year | - | 13.03 |
| LPG consumption (gas boiler) - heating fuels' cost | €/year | 0.00 | 0.00 |
| Electricity cost - electricity consumed for the operation of the rest of the consuming equipment of the hog barn | €/year | 25,768.32 | 41,264.63 |
| **GOLINELLI - NURSERY BARN (B.16)** | **Unit** | **Reference System (RS - GOLI - NB)** | **First Year After Interventions System (FYAIS - GOLI - NB)** |
| Heat pump - annual depreciation expense [c] | €/year | - | 1,774.00 |
| Heat pump - annual maintenance expense | €/year | - | 1,000.00 |

*Table 2. Annual key economic flows before and after the RES4LIVE interventions in the GOLINELLI pilot farm (continued).*

| GOLINELLI - NURSERY BARN (B.16) | Unit | Reference System (RS - GOLI - HB) | First Year After Interventions System (FYAIS - GOLI - HB) |
|---|---|---|---|
| Heat pump - annual insurance expense | €/year | - | 512.50 |
| Heat pump - annual operating expense (electricity) | €/year | - | 2,106.21 |
| PVT and solar station - annual depreciation expense [c] | €/year | - | 1,778.00 |
| PVT and solar station - annual maintenance expense | €/year | - | 400.00 |
| PVT and solar station - annual insurance expense | €/year | - | 445.00 |
| PVT and solar station - annual operating expense (electricity) | €/year | - | 60.31 |
| Borehole heat exchanger, for TES - annual depreciation expense [d] | €/year | - | 555.00 |
| Borehole heat exchanger, for TES - annual maintenance expense | €/year | - | 200.00 |
| Borehole heat exchanger, for TES - annual insurance expense | €/year | - | 300.00 |
| Smart control system - Annual depreciation expense [b] | €/year | - | 393.75 |
| Smart control system - Annual maintenance expense | €/year | - | 140.00 |
| Smart control system - Annual insurance expense | €/year | - | 39.20 |
| Smart control system - Annual operating expense (electricity) | €/year | - | 30.41 |
| Heating fuels' cost - LPG consumption (gas boiler) | €/year | 9,255.00 | 0.00 |
| Electricity cost - electricity consumed for the operation of the rest of the equipment of the nursery barn | €/year | 97,216.86 | 104,289.18 |

*[a] Considering 30 years of lifetime and a salvage value of 1000€ for the polycarbonate windows equipment at the end of its lifetime.*
*[b] Considering 10 years of lifetime and salvage values of 187.5€ (Hog barn) and 437.5€ (Nursery barn) for the equipment of the smart climate control system at the end of its lifetime.*
*[c] Considering 25 years of lifetime and salvage values of 1750€ and 550€ for the equipment of the heat pump and the PVT and solar station, respectively, at the end of their lifetime.*
*[d] Considering 50 years of lifetime and a salvage value of 2250€ for the equipment of the BTES at the end of its lifetime.*

## 3.3 Additional farm-level economic indicators - GOLINELLI

### 3.3.1 Profitability – GOLINELLI

**Economic return: Difference in gross output**

This indicator is expressed per kg of cull sows at the gate of the hog barn and per kg of weaned piglets at the nursery barn, for the hog and nursery barn of the GOLINELLI farm, respectively. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Profit: Difference in gross margin**

This indicator is expressed per kg of cull sows at the gate of the hog barn and per kg of weaned piglets at the nursery barn, for the hog and nursery barn of the GOLINELLI farm, respectively. Gross margin equals the gross output minus the direct production costs. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Income: Difference in net income**

This indicator is expressed per kg of cull sows at the gate of the hog barn and per kg of weaned piglets at the nursery barn, for the hog and nursery barn of the GOLINELLI farm, respectively. Net income is given by Eq. 1:

***Net income (before depreciation) = (Gross margin - Overhead costs - External costs - Taxes + Subsidies) (Eq. (1))***

Considering negligible differences in external costs, taxes and subsidies, the difference in net income is finally estimated by Eq. 2:

$[\text{Net income (before depreciation)}_{FYAIS\text{-}GOLI} - \text{Net income (before depreciation)}_{RS\text{-}GOLI}] =$

$= [(\text{Gross margin - Overhead costs})_{FYAIS\text{-}GOLI} - (\text{Gross margin - Overhead costs})_{RS\text{-}GOLI}]$ *(Eq. (2))*

Therefore, the estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro. By definition, this net income indicator represents a simple cost-benefit economic analysis.

**Product sales: Difference in product sales**

This indicator is expressed per head of sows and boars (hog barn) and per head of weaned piglets (nursery barn). It can be estimated directly from the relevant primary data collected by the GOLINELLI farm.

### 3.3.2 Efficiency – GOLINELLI

**Cost efficiency: Difference in direct production costs per gross output**

This indicator is expressed per kg of cull sows at the gate of the hog barn and per kg of weaned piglets at the nursery barn, for the hog and nursery barn of the GOLINELLI farm, respectively. It is calculated by simply dividing the direct production costs by the gross output for each system, as extracted from the results of the farm-level LCA models in SimaPro.

**Productivity: Difference in pork produced per sow**

For the hog barn, this indicator is estimated as the total, annual sow live-weight output divided by the number of sows sold annually. For the nursery barn, it is estimated as the total annual weaned piglet live-weight output divided by the number of sows producing piglets annually.

### 3.3.3 Discounted Payback Period (DPBP) of the RES4LIVE technologies – GOLINELLI

To estimate the DPBP, the following procedure was followed:

1. Create a list of all the RES4LIVE technologies installed in the GOLINELLI pilot farm (for the hog barn: Polycarbonate windows and smart climate control system; for the nursery barn: BTES, heat pump, PVT and solar station and smart climate control system).
2. Connect each RES4LIVE technology with its total initial investment.
3. Estimate the total amount of money saved due to the electricity produced on-farm using the RES4LIVE technologies after the first year of operation and allocate this amount to the different RES4LIVE technologies. The allocation factor for each technology was based on the fraction of each technology's initial investment to the overall investment of the RES4LIVE technologies. This step was only valid for the nursery barn, as there was no electricity production related to the hog barn after the installation of the RES4LIVE technologies.
4. Estimate the total amount of money saved from the avoided fossil fuel due to the operation of the RES4LIVE technologies after the first year of operation and allocate this amount to the different RES4LIVE technologies. Again, the allocation factor for each technology was based on the fraction of each technology's initial investment to the overall investment of the RES4LIVE technologies. This step was only valid for the nursery barn, as there was no fossil fuel (LPG) used for heating the hog barn, neither before nor after the installation of the RES4LIVE technologies.
5. Use the annual, operating (electricity), maintenance and insurance costs for each RES4LIVE technology as shown in Table 2.
6. Estimate the net cash flow for each RES4LIVE technology ($NCF_T$) and the first year of operation by subtracting the total costs (operating, maintenance and insurance) from the savings (electricity and fossil fuels).
7. Estimate the Discounted Net Cash Flow for each RES4LIVE technology ($DNCF_T$), by using Eq. 3:

$$DNCF_{y,T} = (NCF_T / (1 + DR)^y) \text{ (Eq. 3)}$$

DR: The considered discount rate on an annual basis (= 0.05)

8. Add the annual $DNCF_{y,T}$ and estimate the number of years after which the total initial investment for all RES4LIVE technologies is returned, considering subsidies covering either 20% or 40% of the total RES4LIVE technology investment costs to support decarbonization.

# 3.4 Economic impact assessment: Findings and discussion - GOLINELLI

## 3.4.1 Gate-to-gate Life Cycle Costing: Hog barn (B.12)

**Midpoint level assessment**

A comparison (relative % difference) of the annual costs per FU between the FYAIS-GOLI-HB and the RS-GOLI-HB is presented in Figure 1. It can be noticed that in the first year of the operation of the polycarbonate windows and the smart climate control system in the hog barn, there was an increase in all cost categories per kg of cull sows' live-weight at the hog barn gate, but also an increase in the gross output of the system. The largest increase was found in the energy costs (approximately 38%), in line with the increase in the electricity price and electricity consumption in the FYAIS-GOLI-HB in comparison to the RS-GOLI-HB. It has to be noticed that the 0% in the machinery and building costs in the RS-GOLI-HB does not mean that there are no such costs. It rather reflects the installation and operation of the polycarbonate windows and the smart climate control system in the FYAIS-GOLI-HB, equipment which did not operate in the RS-GOLI-HB.

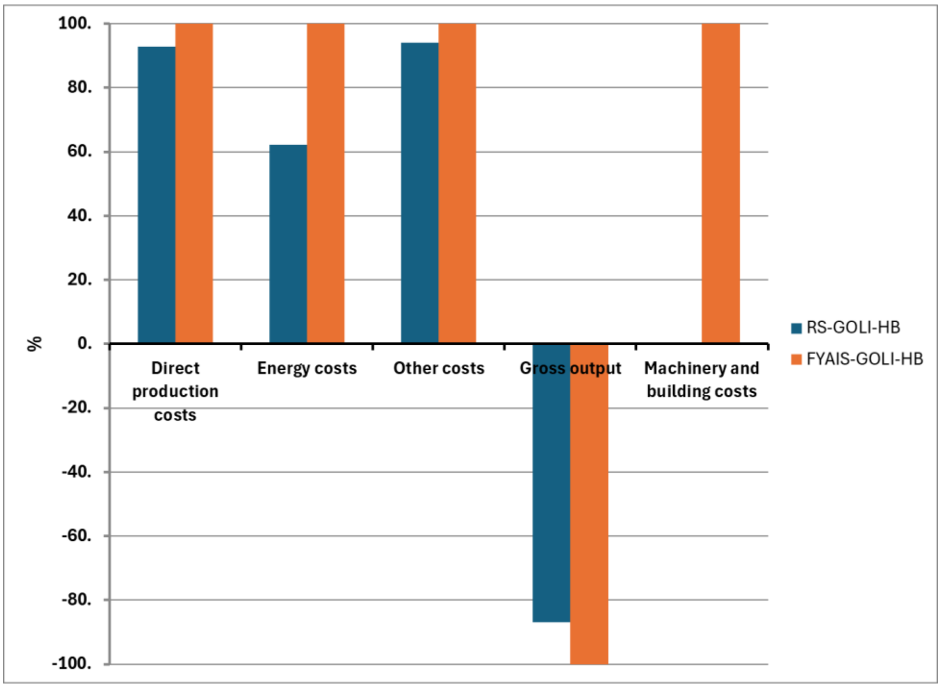


*Figure 1. Relative % difference of the costs per kg of cull sows' live-weight at the hog barn gate between the FYAIS-GOLI-HB and the RS-GOLI-HB.*

In addition to the relative % differences presented in Figure 1, absolute differences in the cost categories (in €/kg cull sows' live weight at the hog barn gate) are presented in Table 3.

*Table 3. Differences in the various cost types expressed in €/kg cull sows' live weight at the hog barn gate between the after-interventions system (FYAIS-GOLI-HB) and the reference system (RS-GOLI-HB).*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE COSTS (€/kg cull sows' live weight at the hog barn gate) | DIFFERENCE IN COSTS (€/kg cull sows' live weight at the hog barn gate) |
|---|---|---|
| Direct production costs | 0.77 | 0.06 |
| Overhead costs | 0.36 | 0.24 |
| Energy costs | 0.36 | 0.22 |
| Other costs | 4E-4 | 2.6E-05 |
| Machinery and building costs | 0.00 | 0.02 |
| **Gross output** | **-0.87** | **-0.13** |

The difference in the energy costs (mainly electricity) is the largest and together with the difference in the gross output mostly defines the difference in the economic performance between FYAIS-GOLI-HB and RS-GOLI-HB.

**Endpoint level assessment**

Table 4 and Figure 1 suggest a 64.30% increase (41.49 mPt/kg cull sows' live weight at the hog barn gate) in the SEcS of the FYAIS in comparison to the RS. This implies a decrease in the total economic performance of the FYAIS in comparison to the RS. The increase in the overhead costs (mainly electricity costs) is mostly responsible for this result, with the increase in the gross output not being adequate to compensate for the increase in costs.

*Table 4. Difference in the Single economic score (SEcS) per kg culled sows' live weight at the hog barn gate between the after-interventions system (FYAIS-GOLI-HB) and the reference system (RS-GOLI-HB) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE SECS (mPt/kg cull sows' live weight at the hog barn gate) | DIFFERENCE IN SECS (mPt/kg cull sows' live weight at the hog barn gate) | CONTRIBUTION TO THE TOTAL SECS DIFFERENCE (%) |
|---|---|---|---|
| Direct production costs | 192.96 | 14.87 (7.70%) | 35.84 |
| Overhead costs | 88.90 | 59.28 (66.68%) | 142.88 |
| Gross output | -217.35 | -32.66 (15.03%) | -78.72 |
| **Total** | **64.51** | **41.49 (64.30%)** | **100.00** |

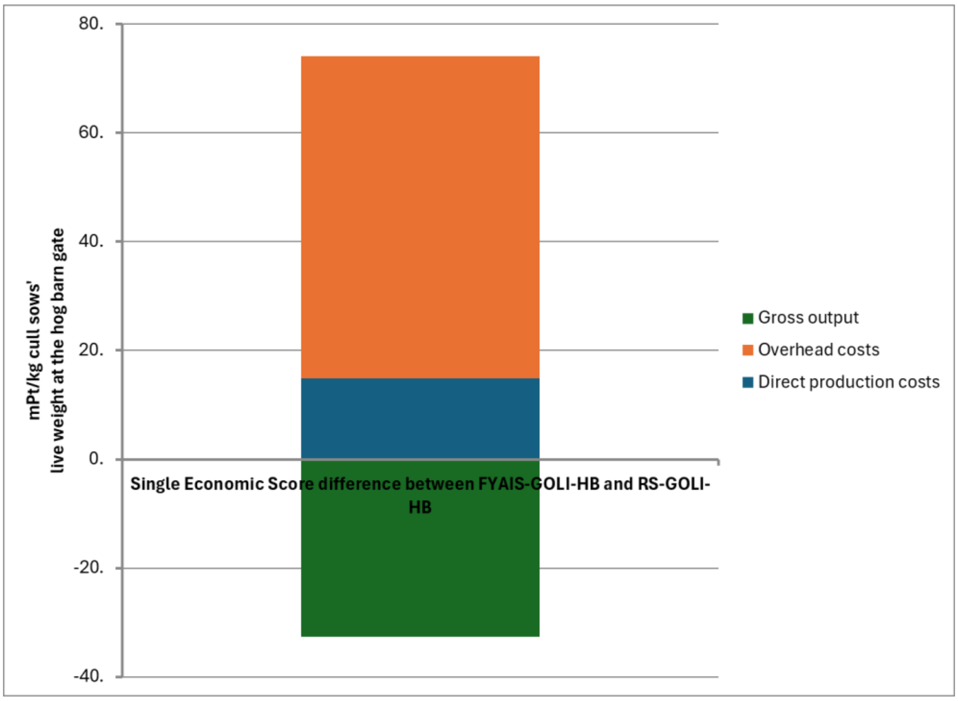


*Figure 2. Graphical representation of the difference in the Single economic score (SEcS) per kg of culled sows' live weight at the hog barn gate between the after-interventions system (FYAIS-GOLI-HB) and the reference system (RS-GOLI-HB).*

## 3.4.2 Additional economic indicators: Hog barn (B.12)

Table 5 presents the results for the additional economic indicators, as estimated for the GOLINELLI hog barn. As expected from the gate-to-gate Life Cycle Costing, an increase in the gross margin is observed in the FYAIS-GOLI-HB, as a result of the increase in the gross output and the sales of sows. Nevertheless, cost efficiency was increased (reduction in the indicator) as a result of the transition from the RS-GOLI-HB to the FYAIS-GOLI-HB. A similar observation can be also made for the net income, indicating an increased negative cost-benefit balance for the GOLINELLI hog barn, especially in the first year after the installation and operation of the RES4LIVE solutions (polycarbonate windows and smart climate control system).

*Table 5. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-GOLI-HB and the RS-GOLI-HB.*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| Profitability: Economic return; gross output | 0.13 (15.03%) | € / kg sow live weight at hog barn gate |
| Profitability: Profit; gross margin | 0.07 (72.96%) | € / kg sow live weight at hog barn gate |
| **Profitability: Income; net income** | **-0.17 (64.40%)** | **€ / kg sow live weight at hog barn** |

| | | |
|---|---|---|
| | | **gate** |

*Table 5. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-GOLI-HB and the RS-GOLI-HB (continued).*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| Profitability: Product sales; sows | 31.25 (14.97%) | € / head sold |
| Profitability: Product sales; boars | 0.00 | € / head sold |
| Efficiency: Cost efficiency; direct production costs per gross output | -0.06 (-6.36%) | - |
| Efficiency: Productivity; pork sold per sow | 0.00 | kg/sow |

**Discounted Payback Period (DPBP)**

Table 6 shows the estimated net cash flows from the first year and the discounted net cash flows from the second year of operation of the RES4LIVE technologies installed in the GOLINELLI hog barn. Since electricity production or reduction of fossil fuel consumption cannot be attributed to the operation of either the polycarbonate windows or the smart climate control system, there is no positive economic inflow to the hog barn due to their operation. This explains the negative net cash flows and discounted net cash flows for both technologies. Thus, the sum of the discounted net cash flows for each of these technologies (but also when considering both) is not expected to become positive within the next 30 years (expected lifespan of the polycarbonate windows, the largest of the two technologies).

*Table 6. First year net cash flows and second year discounted net cash flows from the RES4LIVE technologies installed and operating in the GOLINELLI hog barn.*

| RES4LIVE TECHNOLOGY | INITIAL INVESTMENT (€) | COST FOR ANNUAL ELECTRICITY CONSUMPTION (€/year) | ANNUAL MAINTENANCE COST (€/year) | ANNUAL INSURANCE COST (€/year) | NET CASH FLOW FROM THE TECHNOLOGY INSTALLED (€/year) | DISCOUNTED NET CASH FLOW FROM THE TECHNOLOGY INSTALLED - 2nd YEAR OF OPERATION (€/year) |
|---|---|---|---|---|---|---|
| Polycarbonate windows | 28,992.00 | 127.44 | 200.00 | 124.44 | -451.88 | -430.36 |
| Smart climate control system | 1,875.00 | 13.03 | 60.00 | 16.80 | -89.83 | -85.56 |
| **Total** | **30,867.00** | **140.47** | **260.00** | **141.24** | **-541.71** | **-515.91** |

This is confirmed by the information presented in Table 7, which suggests that even with a 40% subsidy support, it would not be possible to return the investment of these technologies from their operation only (the sum of the discounted net cash flows is negative and impossible to become equivalent with the remaining amount of money from the initial investment after a 40% subsidy support).

*Table 7. Amount of money to be paid back, considering a 20% and 40% subsidy support for the GOLINELLI hog barn case.*

| RES4LIVE TECHNOLOGY | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 20% SUBSIDY SUPPORT (€) | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 40% SUBSIDY SUPPORT (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 25 YEARS OF OPERATION (€) |
|---|---|---|---|
| Polycarbonate windows | 23,193.60 | 17,395.20 | -6,687.15 |
| Smart climate control system | 1,500.00 | 1,125.00 | -1,329.41 |
| **Total** | **24,693.60** | **18,520.20** | **-8,016.56** |

While the interventions resulted in improved operational capabilities, lower economic performance is estimated after the first year of their operation. The investment made for the polycarbonate windows and the smart climate control system in the hog barn cannot be returned by only considering the operation of these technologies. However, improving the internal climate conditions in the hog barn could result in an improvement in the sows' and boars' welfare and productivity, positively affecting the preparation of the farrowing process of the sows. This could imply an improvement in the qualitative characteristics of the sow and boar meat, allowing the farmer to increase the price of sale of sows' and boars' live weight and thus the gross output from the hog barn. There could also be a positive effect on the number of piglets born alive and healthy, potentially increasing the product output from the nursery barn with the potential to improve the economic performance per kg of weaned piglets at the nursery barn gate.

## 3.4.3 Gate-to-gate Life Cycle Costing: Nursery barn (B.12)

**Midpoint level assessment**

A comparison (relative % difference) of the annual costs per FU between the FYAIS-GOLI-NB and the RS-GOLI-NB is presented in Figure 3. In the first year of the operation of the integrated system (PVT/BTES/HP) in the GOLINELLI farm, a minor increase is observed in the direct production and other cost categories per kg of weaned piglets' live-weight at the nursery barn gate (5.24% and 3.78%, respectively), while machinery and building costs appear to mark an 100%, as expected, only because of the introduction of the new systems. On the other hand, the energy cost category decreased by 2.31%, and - most notably - gross output increased by 14.23%.

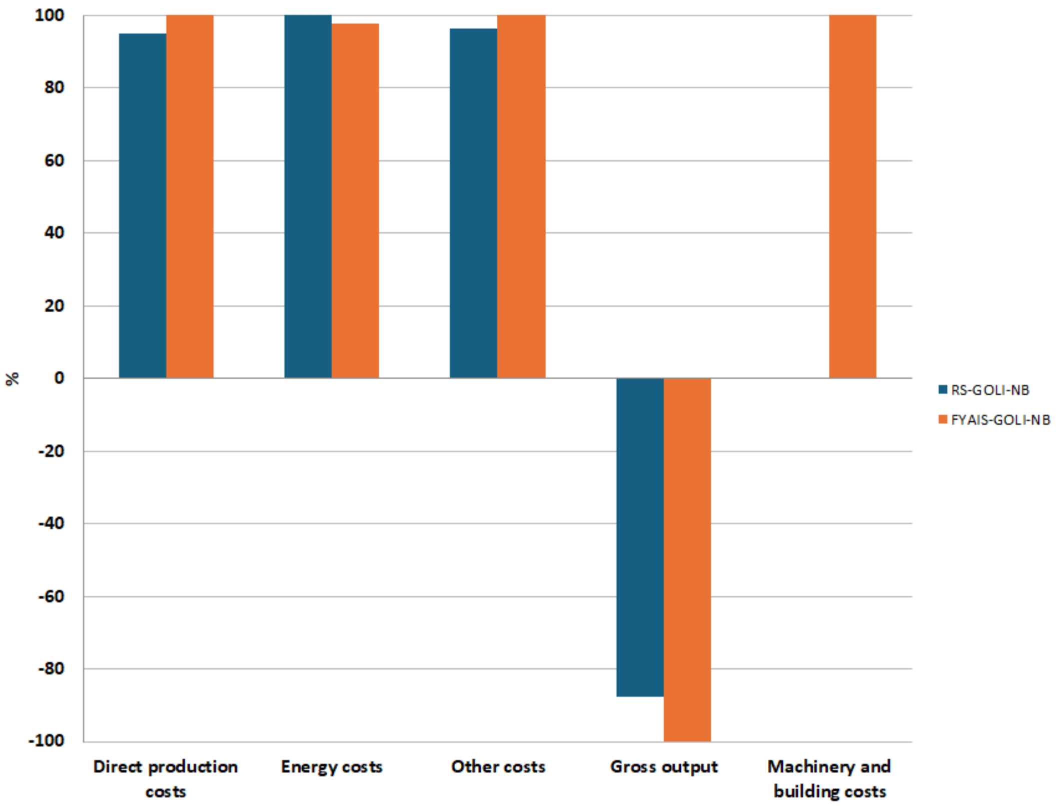


*Figure 3. Relative % difference of the costs per kg of weaned piglets' live-weight at the nursery barn gate between the FYAIS-GOLI-NB and the RS-GOLI-NB.*

In addition to the relative % differences presented in Figure 3, absolute differences in the cost categories (in €/kg weaned piglets' live weight at the nursery barn gate) are presented in Table 8.

*Table 8. Differences in the various cost types expressed in €/kg weaned piglets' live weight at the nursery barn gate between the after interventions system (FYAIS-GOLI-NB) and the reference system (RS-GOLI-NB).*

| MIDPOINT COST IMPACT CATEGORY | DIFFERENCE IN COSTS (€/kg weaned piglets' live weight at the nursery barn gate) | DIFFERENCE IN COSTS (€/kg weaned piglets' live weight at the nursery barn gate) |
|---|---|---|
| Direct production costs | 0.31 | 0.02 |
| Overhead costs | 0.28 | 0.01 |
| Energy costs | 0.28 | -0.01 |
| Other costs | 2E-4 | 9.7E-06 |
| Machinery and building costs | 0.00 | 0.02 |
| **Gross output** | **-3.48** | **-0.49** |

The direct production cost category marks the largest increase, while the decrease in energy costs is primarily due to the fuel savings achieved by substituting the LPG boiler with the heat pump. Finally, the difference in the gross output mostly showcases the enhanced economic performance of FYAIS-GOLI-NB compared to RS-GOLI-NB.

**Endpoint level assessment**

Table 9 and Figure 4 suggest a 13.95% decrease (-116.17 mPt/kg weaned piglets' live weight at the nursery barn gate) in the SEcS of the FYAIS in comparison to the RS. This implies an increase in the total economic performance of the FYAIS in comparison to the RS. Though the direct production costs and overhead cost categories increase slightly, the gross output also increases by 12.45%.

*Table 9. Difference in the Single economic score (SEcS) per kg weaned piglets' live weight at the nursery barn gate between the after-interventions system (FYAIS-GOLI-NB) and the reference system (RS-GOLI-NB) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE SECS (mPt/kg weaned piglets' live weight at the nursery barn gate) | DIFFERENCE IN SECS (mPt/kg weaned piglets' live weight at the nursery barn gate) | CONTRIBUTION TO THE TOTAL SECS DIFFERENCE (%) |
|---|---|---|---|
| Direct production costs | 78.48 | 4.12 (4.98%) | 10.95 |
| Overhead costs | 74.63 | 3.44 (4.40%) | 10.42 |
| Gross output | -869.62 | -123.73 (-12.45%) | -121.37 |
| **Total** | **-716.50** | **-116.17 (-13.95%)** | **100.00** |

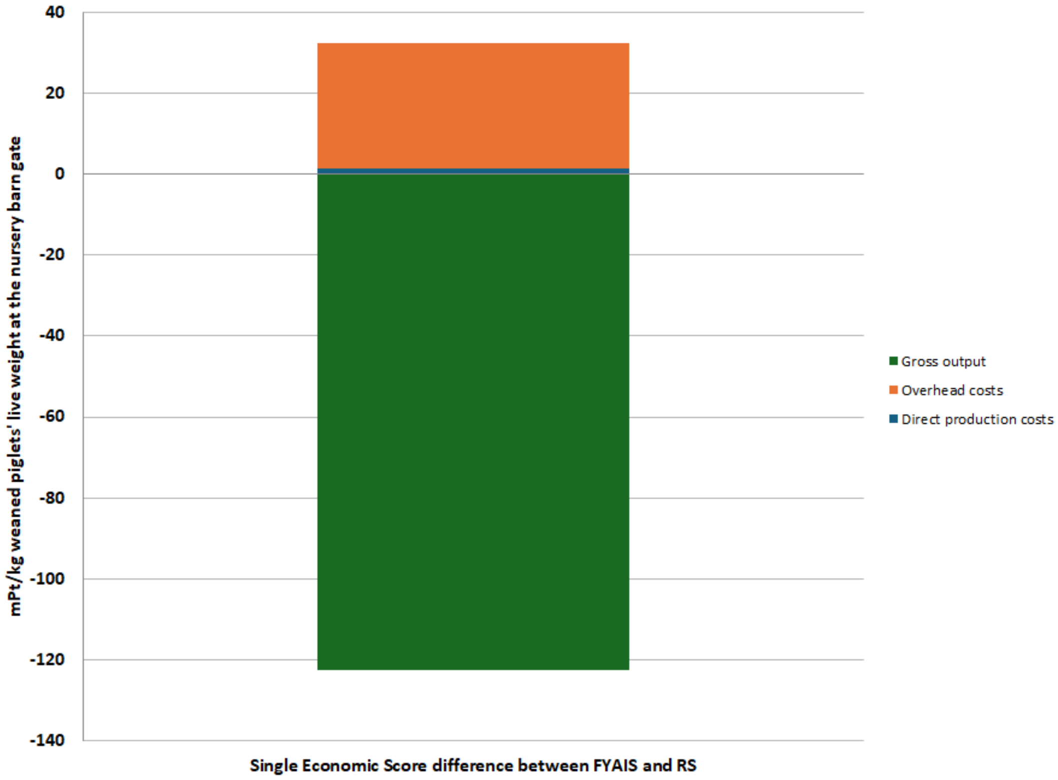


*Figure 4. Graphical representation of the difference in the Single economic score (SEcS) per kg of weaned piglets' live weight at the nursery barn gate between the after-interventions system (FYAIS-GOLI-NB) and the reference system (RS-GOLI-NB).*

### 3.4.4 Additional economic indicators: Nursery barn (B.12)

Table 10 presents the results for the additional economic indicators, as estimated for the GOLINELLI nursery barn. As expected from the gate-to-gate Life Cycle Costing, an increase in the gross margin is observed in the FYAIS-GOLI-NB, as a result of the increase in the gross output and the sales of GOLINELLI nursery barn. Cost efficiency was also enhanced as a result of the transition from the RS-GOLI-NB to the FYAIS-GOLI-NB. A similar observation can be also made for the net income, indicating an increased cost-benefit balance (+16.21%) following the first year after the installation and operation of the RES4LIVE solutions.

*Table 10. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-GOLI-NB and the RS-GOLI-NB.*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| Profitability: Economic return; gross output | 0.49 (14.23%) | € / kg weaned piglets' live weight at nursery barn gate |
| Profitability: Profit; gross margin | 0.48 (15.12%) | € / kg weaned piglets' live weight at nursery barn gate |

*Table 10. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-GOLI-NB and the RS-GOLI-NB (continued).*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| **Profitability: Income; net income** | **0.46 (16.21%)** | **€ / kg weaned piglets' live weight at nursery barn gate** |
| Profitability: Product sales; weaned piglets | 13.05 (14.19%) | € / head sold |
| Efficiency: Cost efficiency; direct production costs per gross output | -7.10E-03 (-7.86%) | - |
| Efficiency: Productivity; pork sold per sow | 50.36 (2.23%) | kg/sow |

**Discounted Payback Period (DPBP)**

Table 11 shows the estimated net cash flows from the first year and the discounted net cash flows from the second year of operation of the RES4LIVE technologies installed in the GOLINELLI nursery barn. The reduction of fossil fuel consumption and energy production due to the operation of the BTES/PVT/HP system causes positive net cash flows and discounted net cash flow for both of them. The same holds for the integrated RES system (sum of the discounted net cash flows) as well.

*Table 11. First year net cash flows and second year discounted net cash flows from the RES4LIVE technologies installed and operating in the GOLINELLI nursery barn.*

| RES4LIVE TECHNOLOGY | INITIAL INVESTMENT (€) | ELECTRICITY SAVINGS (€/year) | FOSSIL FUEL SAVINGS (€/year) | COST FOR ANNUAL ELECTRICITY CONSUMPTION (€/year) | ANNUAL MAINTENANCE COST (€/year) | ANNUAL INSURANCE COST (€/year) | NET CASH FLOW FROM THE TECHNOLOGY INSTALLED (€/year) | DISCOUNTED NET CASH FLOW FROM THE TECHNOLOGY INSTALLED – 2nd YEAR OF OPERATION (€/year) |
|---|---|---|---|---|---|---|---|---|
| BTES | 30,000.00 | 621.46 | 2,370.59 | 0.00 | 200.00 | 300.00 | 2,492.05 | 2,373.38 |
| Heat pump | 46,100.00 | 954.97 | 3,642.81 | 2,106.21 | 1,000.00 | 512.50 | 979.07 | 932.44 |
| PVT and solar station | 45,000.00 | 932.18 | 3,555.89 | 60.31 | 400.00 | 445.00 | 3,582.77 | 3,412.168 |
| Smart control system | 4,375.00 | 90.63 | 345.71 | 30.41 | 140.00 | 39.20 | 226.73 | 215.93 |
| **Total** | **125,475.00** | **2,599.24** | **9,915.00** | **2,196.93** | **1,740.00** | **1,269.70** | **7,280.61** | **6,933.92** |

From the operation of the integrated RES system, the return on investment (ROI) in the case of the GOLINELLI nursery barn would be possible after 33 years. However, the amortisation period for the HP, PVT and smart control system is approximately 20 years. Considering a scenario of 20% or 40% subsidy support to the initial investment (Table 12), the ROI could be possible between 21-22 and 13-14 years from the installation, respectively.

*Table 12. Amount of money to be paid back, considering a 20% and 40% subsidy support for the GOLINELLI nursery barn case.*

| RES4LIVE TECHNOLOGY | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 20% SUBSIDY SUPPORT (€) | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 40% SUBSIDY SUPPORT (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 22 YEARS OF OPERATION (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 14 YEARS OF OPERATION (€) |
|---|---|---|---|---|
| BTES | 24,000.00 | 18,000.00 | 34,442.98 | 25,901.28 |

*Table 12. Amount of money to be paid back, considering a 20% and 40% subsidy support for the GOLINELLI nursery barn case (continued).*

| RES4LIVE TECHNOLOGY | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 20% SUBSIDY SUPPORT (€) | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 40% SUBSIDY SUPPORT (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 22 YEARS OF OPERATION (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 14 YEARS OF OPERATION (€) |
|---|---|---|---|---|
| Heat pump | 36,880.00 | 27,660.00 | 13,531.84 | 10,176.01 |
| PVT and solar station | 36,000.00 | 27,000.00 | 49,517.96 | 37,237.74 |
| Smart control system | 3,500.00 | 2,625.00 | 3,133.66 | 2,356.53 |
| **Total** | **100,380.00** | **75,285.00** | **100,626.44** | **75,671.56** |

# 4 EV ILVO COMPARATIVE ECONOMIC ASSESSMENT

## 4.1 Farm-level economic LCA models – EV ILVO

### 4.1.1 Reference system and system after interventions – EV ILVO

The reference systems and the systems after the installation and operation of the RES4LIVE technologies at the EV ILVO experimental pig farm, are described in Sections 4.1.1 and 4.1.2 respectively, of Deliverable 5.3: "Environmental Assessment Report".

For further details on the RES systems, please refer to deliverables D4.1: "Design of integrated systems in pilot farms", D4.2: "The installed pilot systems", D4.3: "Report with the test results obtained on energy and production performances of RES and energy efficiency solutions".

## 4.2 Farm-level economic LCA datasets – EV ILVO

The annual economic flows due to the product sales at the EV ILVO farm gate in the reference system (RS) and the First Year After RES4LIVE Interventions System (FYAIS), as introduced into the SimaPro software (part of the wider farm-level LCA dataset), are shown in Table 13.

*Table 13. Annual sales of products before and after the RES4LIVE interventions in the EV ILVO pilot farm.*

| EV ILVO | UNIT | REFERENCE SYSTEM (RS - ILVO) | FIRST YEAR AFTER INTERVENTIONS SYSTEM (FYAIS - ILVO) |
|---|---|---|---|
| Sold animal live-weight - cull sows (swine) | €/year | 7,218.22 | 7,218.22 |
| Sold animal live-weight - boars (swine) | €/year | 481.21 | 481.22 |
| Sold animal live-weight - piglets after the nursery stage (swine) | €/year | 51,134.00 | 100,870.00 |
| Sold animal live-weight - finished pigs (swine) | €/year | 214,824.33 | 326,459.37 |

As in the GOLINELLI case, the product sales in Table 13 are estimated using the data supplied by the EV ILVO farm managers regarding the number of animal heads sold annually and the average sale price per head. Table 13 suggests a considerable increase in product sales in the FYAIS compared to the RS. Although cull sows and boars' sales remain the same, piglets and finished pigs' sales increased approximately by 97% and 52%, respectively.

Table 14 presents key economic flows at the EV ILVO pilot farm, used to estimate the economic performance before and after the RES4LIVE interventions.

*Table 14. Annual key economic flows before and after the RES4LIVE interventions in the EV ILVO pilot farm.*

| EV ILVO | UNIT | REFERENCE SYSTEM (RS - ILVO) | FIRST YEAR AFTER INTERVENTIONS SYSTEM (FYAIS - ILVO) |
|---|---|---|---|
| Heat pump - annual depreciation expense [a] | €/year | - | 2,884.84 |
| Heat pump - annual maintenance expense | €/year | - | 1,000.00 |
| Heat pump - annual insurance expense | €/year | - | 540.00 |
| Heat pump - annual operating expense (electricity) | €/year | - | 19,597.95 |
| PVT and solar station - annual depreciation expense [a] | €/year | - | 2,060.00 |
| PVT and solar station - annual maintenance expense | €/year | - | 550.00 |
| PVT and solar station - annual insurance expense | €/year | - | 58.30 |
| PVT and solar station - annual operating expense (electricity) | €/year | - | 390.00 |
| Smart control system - Annual depreciation expense [b] | €/year | - | 388.44 |
| Smart control system - Annual maintenance expense | €/year | - | 550.00 |
| Smart control system - Annual insurance expense | €/year | - | 42.00 |
| Smart control system - Annual operating expense (electricity) | €/year | - | 36.66 |
| Heating fuels' cost - Natural gas consumption (natural gas boiler) | €/year | 7,795.89 | 0.00 |
| Heating fuels' cost - Diesel consumption (heat cannon) | €/year | 572.46 | 708.37 |
| Electricity cost - electricity consumed for the operation of the rest of the equipment of the nursery barn | €/year | 16,186.94 | 30,833.02 |

*[a] Considering 25 years of lifetime and salvage values of 2250€ and 1000€ for the equipment of the heat pump and the PVT and solar station, respectively, at the end of their lifetime.*
*[b] Considering 10 years of lifetime and salvage values of 432€ for the equipment of the smart climate control system at the end of its lifetime.*

# 4.3 Additional farm-level economic indicators – EV ILVO

## 4.3.1 Profitability – EV ILVO

**Economic return: Difference in gross output**

This indicator is expressed per kg of finished pig of the EV ILVO farm gate. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Profit: Difference in gross margin**

This indicator is expressed per kg of finished pig of the EV ILVO farm gate. Gross margin equals the gross output minus the direct production costs. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Income: Difference in net income**

This indicator is expressed per kg of finished pig at the EV ILVO farm gate. Net income is given by Eq. 4:

***Net income (before depreciation) = (Gross margin - Overhead costs - External costs - Taxes + Subsidies) (Eq. (4))***

Considering negligible differences in external costs, taxes and subsidies, the difference in net income is finally estimated by Eq. 5:

*[Net income (before depreciation)$_{FYAIS\text{-}LVO}$ - Net income (before depreciation)$_{RS\text{-}ILVO}$] =*

*= [(Gross margin - Overhead costs)$_{FYAIS\text{-}ILVO}$ - (Gross margin - Overhead costs)$_{RS\text{-}ILVO}$] (Eq. (5))*

Therefore, the estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro. By definition, this net income indicator represents a simple cost-benefit economic analysis.

**Product sales: Difference in product sales**

This indicator is expressed per head of finished pigs, per head of piglets after the nursery stage, per sow and boar. It can be estimated directly from the relevant primary data collected by the EV-ILVO pilot farm.

## 4.3.2 Efficiency – EV ILVO

**Cost efficiency: Difference in direct production costs per gross output**

This indicator is unitless.  It is calculated by simply dividing the direct production costs by the gross output, as extracted from the results of the farm-level LCA models in SimaPro.

**Productivity: Difference in pork produced per sow**

This indicator is estimated as the total, annual pig live-weight output (finished pigs plus piglets after the nursery stage) divided by the number of sows producing piglets annually.

### 4.3.3 Discounted Payback Period (DPBP) of the RES4LIVE technologies – EV ILVO

To estimate the DPBP, the following procedure was followed:

1. Create a list of all the RES4LIVE technologies installed on the EV ILVO pilot farm (heat pump, PVT and solar station, and smart climate control system).
2. Connect each RES4LIVE technology with its total initial investment.
3. Estimate the total amount of money saved due to the electricity produced on-farm using the RES4LIVE technologies after the first year of operation and allocate this amount to the different RES4LIVE technologies. The allocation factor for each technology was based on the fraction of each technology's initial investment to the overall investment of the RES4LIVE technologies.
4. Estimate the total amount of money saved from the avoided fossil fuel due to the operation of the RES4LIVE technologies after the first year of operation and allocate this amount to the different RES4LIVE technologies. Again, the allocation factor for each technology was based on the fraction of each technology's initial investment to the overall investment of the RES4LIVE technologies.
5. Use the annual, operating (electricity), maintenance and insurance costs for each RES4LIVE technology as shown in Table 14.
6. Estimate the net cash flow for each RES4LIVE technology ($NCF_T$) and the first year of operation by subtracting the total costs (operating, maintenance and insurance) from the savings (electricity and fossil fuels).
7. Estimate the Discounted Net Cash Flow for each RES4LIVE technology ($DNCF_T$), by using Eq. 6:

$$DNCF_{y,T} = (NCF_T / (1 + DR)^y) \text{ (Eq. 6)}$$

   DR: The considered discount rate on an annual basis (= 0.05)

Add the annual $DNCF_{y,T}$ and estimate the number of years after which the total initial investment for all RES4LIVE technologies is returned, considering subsidies covering either 20% or 40% of the total RES4LIVE technology investment costs to support decarbonization.

## 4.4 Economic impact assessment: Findings and discussion – EV ILVO

### 4.4.1 Gate-to-gate Life Cycle Costing: EV ILVO farm

**Midpoint level assessment**

A comparison (relative % difference) of the annual costs per FU between the FYAIS-ILVO and the RS-ILVO is presented in Figure 5. After the first year of the operation of the RES integrated system, a noticeable increase in the energy costs category can be observed (approximately 46.00%), due to the electricity consumption - primarily - of the heat pump. Direct production costs are approximately the same, while machinery and building costs appear to mark 100%, as expected, only because of the introduction of the new systems. Finally, noteworthy is the 29.25% increase in the gross output category.

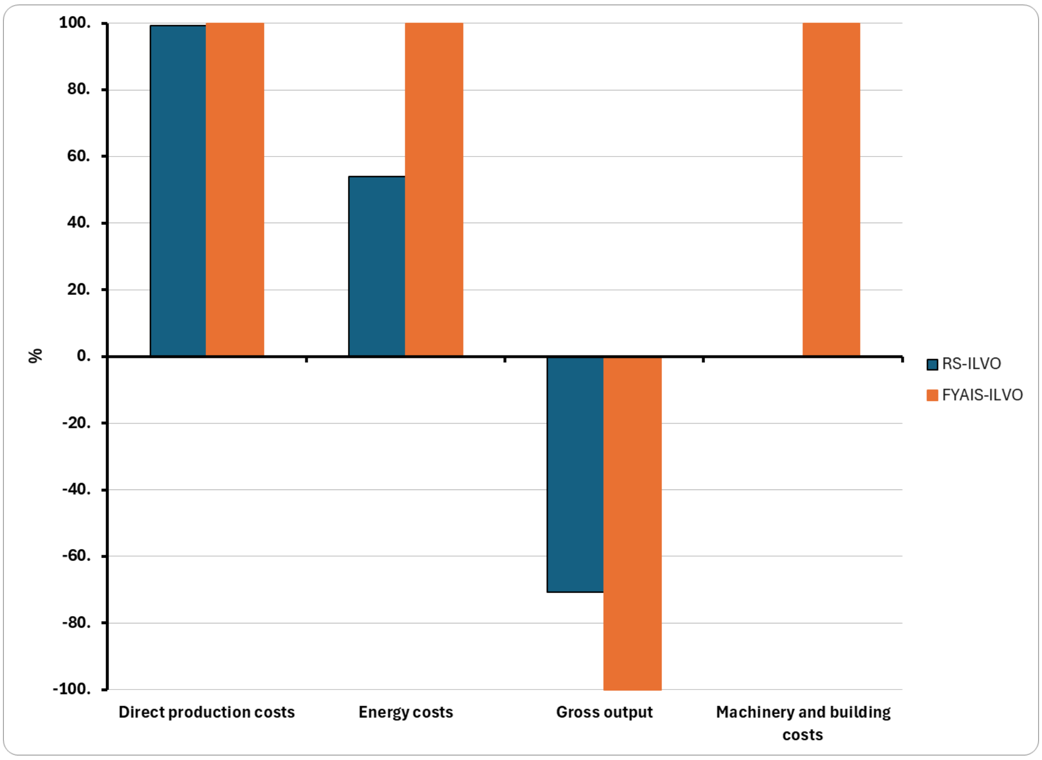


*Figure 5. Relative % difference of the costs per kg of finished pigs' live-weight at the farm gate between the FYAIS-ILVO and the RS-ILVO.*

In addition to the relative % differences presented in Figure 5, absolute differences in the cost categories (in €/kg finished pigs' live weight at the farm gate) are presented in Table 15.

*Table 15. Differences in the various cost types expressed in €/kg finished pigs' live weight at the farm gate between the after-interventions system (FYAIS-ILVO) and the reference system (RS-ILVO).*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE COSTS (€/kg finished pigs' live weight at the farm gate) | DIFFERENCE IN COSTS (€/kg finished pigs' live weight at the farm gate) |
|---|---|---|
| Direct production costs | 0.93 | 0.01 |
| Overhead costs | 0.11 | 0.12 |
| Energy costs | 0.11 | 0.09 |
| Other costs | 0.00 | 0.00 |
| Machinery and building costs | 0.00 | 0.03 |
| Gross output | -1.18 | -0.49 |

The difference in the energy costs (mainly electricity) is the largest and together with the difference in the gross output mostly defines the difference in the economic performance between FYAIS-ILVO and RS-ILVO.

**Endpoint level assessment**

Table 16 and Figure 6 suggest a 245.34% decrease (90.08mPt/kg finished pigs' live weight at the EV ILVO farm gate) in the SEcS of the FYAIS in comparison to the RS. This implies an increase in the total economic performance of the FYAIS in comparison to the RS. The increase in the gross output and the overhead costs (mainly electricity costs) is mostly responsible for this result.

*Table 16. Difference in the Single economic score (SEcS) per kg finished pigs' live weight at the farm gate between the after-interventions system (FYAIS-ILVO) and the reference system (RS-ILVO) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | DIFFERENCE IN SECS (mPt/kg finished pigs' live weight at the farm gate) | DIFFERENCE IN SECS (mPt/kg finished pigs' live weight at the farm gate) | CONTRIBUTION TO THE TOTAL SECS DIFFERENCE (%) |
|---|---|---|---|
| Direct production costs | 232.69 | 1.49 (0.64%) | 1.66 |
| Overhead costs | 26.70 | 30.84 (115.47%) | 34.23 |
| Gross output | -296.12 | -122.41 (-41.34%) | -135.88 |
| **Total** | **-36.71** | **-90.08 (-245.34%)** | **100** |

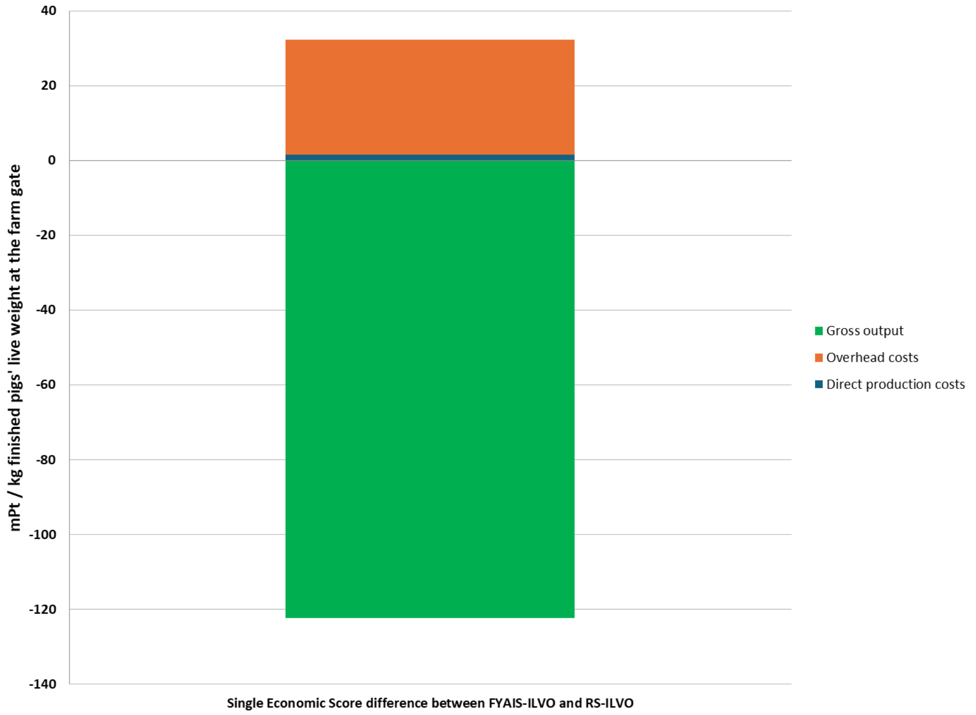

*Figure 6. Graphical representation of the difference in the Single economic score (SEcS) per kg of finished pigs' live weight at the farm gate between the after-interventions system (FYAIS-ILVO) and the reference system (RS-ILVO).*

### 4.4.2 Additional economic indicators: EV ILVO farm

Table 17 shows the results for the additional economic indicators, as estimated for the EV ILVO swine farm. As expected from the gate-to-gate Life Cycle Costing, an increase in the gross margin is observed in the FYAIS-ILVO, as a result of the increase in the gross output and the sales. Nevertheless, cost efficiency was also enhanced as a result of the transition from the RS-ILVO to the FYAIS-ILVO. A similar observation can be also made for the net income, indicating a notably increased cost-benefit balance (+245.34%) following the first year after the installation and operation of the RES4LIVE solutions. Thus, FYAIS-ILVO seems to be more profitable than RS-ILVO, although both systems are connected to a positive cost-benefit balance.

*Table 17. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-ILVO and the RS-ILVO.*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| Profitability: Economic return; gross output | 0.49 (41.34%) | € / kg finished pig live weight at farm gate |
| Profitability: Profit; gross margin | 0.48 (190.66%) | € / kg finished pig live weight at farm gate |
| Profitability: Income; net income | 0.36 (245.34%) | € / kg finished pig live weight at farm gate |
| Profitability: Product sales; sows | 0.00 (0.00%) | € / head sold |
| Profitability: Product sales; boars | 0.00 (0.00%) | € / head sold |
| Profitability: Product sales; piglets | 32.3 (97.29%) | € / head sold |
| Profitability: Product sales; finished pigs | 69.42 (51.96%) | € / head sold |
| Efficiency: Cost efficiency; direct production costs per gross output | -0.23 (-28.79%) | - |
| Efficiency: Productivity; pork sold per finished pig | 107.61 (5.30%) | kg of pork live weight sold / sow |

**Discounted Payback Period (DPBP)**

Table 18 shows the estimated net cash flows from the first year and the discounted net cash flows from the second year of operation of the RES4LIVE technologies installed on the EV ILVO swine pilot farm. The reduction of fossil fuel consumption and energy production due to the operation of the HP and the PVT system, respectively, create positive net cash flows and discounted net cash flows for both of them. The same holds for the integrated RES system (sum of the discounted net cash flows) as well.

*Table 18. First year net cash flows and second year discounted net cash flows from the RES4LIVE technologies installed and operating in the EV ILVO swine farm.*

| RES4LIVE TECHNOLOGY | INITIAL INVESTMENT (€) | ELECTRICITY SAVINGS (€/year) | FOSSIL FUEL SAVINGS (€/year) | COST FOR ANNUAL ELECTRICITY CONSUMPTION (€/year) | ANNUAL MAINTENANCE COST (€/year) | ANNUAL INSURANCE COST (€/year) | NET CASH FLOW FROM THE TECHNOLOGY INSTALLED (€/year) | DISCOUNTED NET CASH FLOW FROM THE TECHNOLOGY INSTALLED – 2nd YEAR OF OPERATION (€/year) |
|---|---|---|---|---|---|---|---|---|
| Heat pump | 74,371.11 | 1,044.10 | 10,443.69 | 5,165.64 | 1,000.00 | 2,060.00 | 3,262.15 | 3,106.81 |
| PVT and solar station | 52,.500.00 | 737.05 | 7,372.40 | 60.42 | 550.00 | 390.00 | 7,109.04 | 6,770.51 |
| Smart control system | 4,316.00 | 60.59 | 606.08 | 41.39 | 550.00 | 36.66 | 38.63 | 36.79 |
| **Total** | **131,187.11** | **1841.75** | **18,422.18** | **5,367.45** | **2,100.00** | **2,486.66** | **10,409.82** | **9,914.11** |

From the operation of the integrated RES system, the return on investment (ROI) in the case of the EV ILVO farm would be possible after 18 years. However, considering a scenario of 20% or 40% subsidy support to the initial investment (Table 19), the ROI could be as low as between 13-14 and 9-10 years from the installation, respectively.

*Table 19. Amount of money to be paid back, considering a 20% and 40% subsidy support for the EV ILVO swine farm case.*

| RES4LIVE TECHNOLOGY | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 20% SUBSIDY SUPPORT (€) | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 40% SUBSIDY SUPPORT (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 14 YEARS OF OPERATION (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 10 YEARS OF OPERATION (€) |
|---|---|---|---|---|
| Heat pump | 59,496.89 | 44,622.67 | 33,905.42 | 26,448.95 |

*Table 19. Amount of money to be paid back, considering a 20% and 40% subsidy support for the EV ILVO swine farm case (continued).*

| RES4LIVE TECHNOLOGY | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 20% SUBSIDY SUPPORT (€) | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 40% SUBSIDY SUPPORT (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 14 YEARS OF OPERATION (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 10 YEARS OF OPERATION (€) |
|---|---|---|---|---|
| PVT and solar station | 42,000.00 | 31,500.00 | 73,888.30 | 57,638.81 |
| Smart control system | 3,452.80 | 2,589.60 | 401.47 | 313.18 |
| **Total** | **104,949.689** | **78,712.27** | **108,195.19** | **84,400.94** |

# 5 AUA COMPARATIVE ECONOMIC ASSESSMENT

## 5.1 Farm-level economic LCA models - AUA

### 5.1.1 Reference system and system after interventions - AUA

The reference system and the system after installing and operating the RES4LIVE technologies regarding the AUA experimental poultry farm are described in Deliverable 5.3: "Environmental Assessment Report" (Sections 5.1.1 and 5.1.2). For the after RES4LIVE interventions system (AIS), two additional scenarios were considered in agreement with the environmental assessment: 1) the use of a 1 hp (horsepower) fan (medium size) (AIS-S1-AUA) and 2) the use of a 0.75 hp fan (small size) (AIS-S2-AUA).

For further details on the RES systems, please refer to deliverables D4.1: "Design of integrated systems in pilot farms", D4.2: "The installed pilot systems", D4.3: "Report with the test results obtained on energy and production performances of RES and energy efficiency solutions".

## 5.2 Farm-level economic LCA datasets - AUA

The annual economic flows due to the product sales at the poultry house gate in the reference system (RS), the First Year After RES4LIVE Interventions System (FYAIS) and the additional scenarios considered for the After RES4LIVE Interventions System (AIS), as introduced into the SimaPro software (part of the wider farm-level LCA dataset), are shown in Table 20.

*Table 20. Annual sales of products from the AUA pilot farm before and after the RES4LIVE interventions.*

| AUA FARM | UNIT | REFERENCE SYSTEM (RS-AUA) | FIRST YEAR AFTER INTERVENTIONS SYSTEM (FYAIS-AUA) | AFTER INTERVENTIONS SYSTEM: SCENARIO 1 (AIS-S1-AUA) | AFTER INTERVENTIONS SYSTEM: SCENARIO 2 (AIS-S2-AUA) |
|---|---|---|---|---|---|
| Eggs, sold | €/year | 9994.73 | 13665.2 | 13665.2 | 13665.2 |
| Hens, sold | €/year | 656 | 288 | 288 | 288 |
| Pullets, sold | €/year | 80 | 150 | 150 | 150 |

The product sales in Table 20 are estimated using the data supplied by the AUA farm manager regarding the number of eggs and female heads sold annually and the average sale price per egg and female head.

Table 20 shows a considerable increase in the revenue for eggs in the FYAIS-AUA in comparison to the RS-AUA, while revenue from spent hens decreases, and revenue from pullets increases slightly. The revenue remains consistent across scenarios AIS-S1-AUA and AIS-S2-AUA since no productivity changes are considered in them.

Table 21 presents key economic flows at the AUA pilot farm building, used to estimate the economic performance before and after the RES4LIVE interventions (considering the two additional scenarios for.

*Table 21. Annual key economic flows before and after the RES4LIVE interventions in the AUA pilot farm.*

| AUA FARM | UNIT | REFERENCE SYSTEM (RS-AUA) | FIRST YEAR AFTER INTERVENTIONS SYSTEM (FYAIS-AUA) | AFTER INTERVENTIONS SYSTEM: SCENARIO 1 (AIS-S1-AUA) | AFTER INTERVENTIONS SYSTEM: SCENARIO 2 (AIS-S2-AUA) |
|---|---|---|---|---|---|
| PV system - annual depreciation expense [a] | €/year | - | 283.68 | 283.68 | 283.68 |
| PV system - annual maintenance expense | €/year | - | 300.00 | 300.00 | 300.00 |
| PV system - annual insurance expense | €/year | - | - | - | - |
| PV system - annual operating expense (electricity) | €/year | - | 0 | 0 | 0 |
| Heat Pump - annual depreciation expense [b] | €/year | - | 1,790.00 | 1,790.00 | 1,790.00 |
| Heat Pump - annual maintenance expense | €/year | - | 750.00 | 750.00 | 750.00 |
| Heat Pump - annual insurance expense | €/year | - | - | - | - |
| Heat Pump - annual operating expense (electricity) | €/year | - | 2,329.12 | 2,329.12 | 2,329.12 |
| Smart control system - annual depreciation expense [c] | €/year | - | 481.23 | 481.23 | 481.23 |
| Smart control system - annual maintenance expense | €/year | - | 500.00 | 500.00 | 500.00 |

*Table 21. Annual key economic flows before and after the RES4LIVE interventions in the AUA pilot farm (continued).*

| AUA FARM | UNIT | REFERENCE SYSTEM (RS-AUA) | FIRST YEAR AFTER INTERVENTIONS SYSTEM (FYAIS-AUA) | AFTER INTERVENTIONS SYSTEM: SCENARIO 1 (AIS-S1-AUA) | AFTER INTERVENTIONS SYSTEM: SCENARIO 2 (AIS-S2-AUA) |
|---|---|---|---|---|---|
| Smart control system - annual insurance expense | €/year | - | - | - | - |
| Smart control system - annual operating expense (electricity) | €/year | - | 20.93 | 20.93 | 20.93 |
| LED system - annual depreciation expense [d] | €/year | - | 648.00 | 648.00 | 648.00 |
| LED system - annual maintenance expense | €/year | - | 100.00 | 100.00 | 100.00 |
| LED system - annual insurance expense | €/year | - | - | - | - |
| LED system - annual operating expense (electricity) | €/year | - | 76.40 | 76.40 | 76.40 |
| Electricity cost - electricity consumed for ventilation | €/year | - | 3,741.60 | 2,694.26 | 2,405.43 |
| Electricity cost - electricity consumed for the operation in the rest of the consuming equipment of the farm | €/year | 861.40 | 2,443.36 | 2,443.36 | 2,443.36 |

*[a] Considering 25 years of lifetime and a salvage value of 408€ for the PV system at the end of its lifetime.*
*[b] Considering 25 years of lifetime and salvage values of 1750€ for the Heat Pump at the end of its lifetime.*
*[c] Considering 10 years of lifetime and salvage values of 534.7€ for the Smart Control at the end of its lifetime.*
*[d] Considering 5 years of lifetime and a salvage value of 360€ for the LED System at the end of its lifetime.*

## 5.3 Additional farm-level economic indicators - AUA

### 5.3.1 Profitability – AUA

**Economic return: Difference in gross output**

This indicator is expressed per kg of eggs at the gate of the AUA pilot farm. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Profit: Difference in gross margin**

This indicator is expressed per kg of eggs at the gate of the AUA pilot farm. Gross margin equals the gross output minus the direct production costs. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Income: Difference in net income**

This indicator is expressed per kg of eggs at the gate of the AUA pilot farm. Net income is given by Eq. 7:

**Net income (before depreciation) = (Gross margin - Overhead costs - External costs - Taxes + Subsidies) (Eq. (7))**

Considering negligible differences in external costs, taxes and subsidies, the difference in net income is finally estimated by Eq. 8:

*[Net income (before depreciation)$_{FYAIS\text{-}AUA}$ - Net income (before depreciation)$_{RS\text{-}AUA}$] =*

*= [(Gross margin - Overhead costs)$_{FYAIS\text{-}AUA}$ - (Gross margin - Overhead costs)$_{RS\text{-}AUA}$] (Eq. (7))*

Therefore, the estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro. By definition, this net income indicator represents a simple cost-benefit economic analysis.

**Product sales: Difference in product sales**

This indicator is expressed per kg of eggs and kg of hens and pullets. It can be estimated directly from the relevant primary data collected by the AUA farm.

### 5.3.2 Efficiency – AUA

**Cost efficiency: Difference in direct production costs per gross output**

This indicator is unitless. It is calculated by simply dividing the direct production costs by the gross output for each system, as extracted from the results of the farm-level LCA models in SimaPro.

**Productivity: Difference in eggs produced per hen**

This indicator is estimated as the total, annual shelled egg output (in kg) divided by the number of hens producing eggs annually.

### 5.3.3 Discounted Payback Period (DPBP) of the RES4LIVE technologies – AUA

To estimate the DPBP, the following procedure was followed:

1. Create a list of all the RES4LIVE technologies installed in the AUA pilot farm (i.e. PV panels, heat pump, smart climate control system and LED system).
2. Connect each RES4LIVE technology with its total initial investment.
3. Estimate the total amount of money saved due to the electricity produced on-farm using the RES4LIVE technologies after the first year of operation.
4. Use the annual, operating (electricity), maintenance and insurance costs for each RES4LIVE technology as shown in Table 21.
5. Estimate the net cash flow for each RES4LIVE technology (NCFT) and the first year of operation by subtracting the total costs (operating, maintenance and insurance) from the savings (electricity).
6. Estimate the Discounted Net Cash Flow for each RES4LIVE technology (DNCFT), by using Eq. 9:

   $$DNCFy,T = (NCFT / (1 + DR)^{y}) \text{ (Eq. 9)}$$

   DR: The considered discount rate on an annual basis (= 0.05)

7. Add the annual DNCFy, T and estimate the number of years after which the total initial investment for all RES4LIVE technologies is returned, considering subsidies covering either 20% or 40% of the total RES4LIVE technology investment costs to support decarbonization.

## 5.4 Economic impact assessment: Findings and discussion - AUA

### 5.4.1 Gate-to-gate Life Cycle Costing – AUA

**Midpoint level assessment**

Figure 7 illustrates the comparison of the annual costs per FU (i.e. kg of egg at the AUA farm gate) between the FYAIS-AUA and the RS-AUA.

In the direct production costs category, the graph illustrates an almost 17% difference between the RS-AUA and the FYAIS-AUA, showing the effect that the feedstuff price's increase (of about 60% from the first cycle to the second) had on the farm's financial performance, overpassing the benefits from more efficient use of basic inputs (specially feedstuff) and increased productivity obtained in the FYAIS-AUA. The Energy costs, in turn, exhibit a particularly sharp increase of 81.9% in the FYAIS-AUA as well, a direct result of a significant rise in electricity costs combined with the higher amount of electricity used by the new technologies implemented. This increase in energy costs is a substantial driver of the overall rise in operational expenses.

Gross output, on the other hand, also showed an increase in the FYAIS-AUA, reflecting a higher revenue per kg of sold eggs. However, the increase in Machinery & building costs in the FYAIS-AUA is very high at 92.41%, indicating that infrastructure improvements and the installation of advanced systems required a significant investment. Other costs, which include miscellaneous and smaller-scale expenses, decreased by 24.36% in the FYAIS-AUA, suggesting minor improvements in efficiency or cost management for these types of expenses. Overall, the graph highlights the increased costs associated with modernising the farm, with particular emphasis on energy and infrastructure expenses, while also showing a corresponding rise in output reflecting improved productivity.

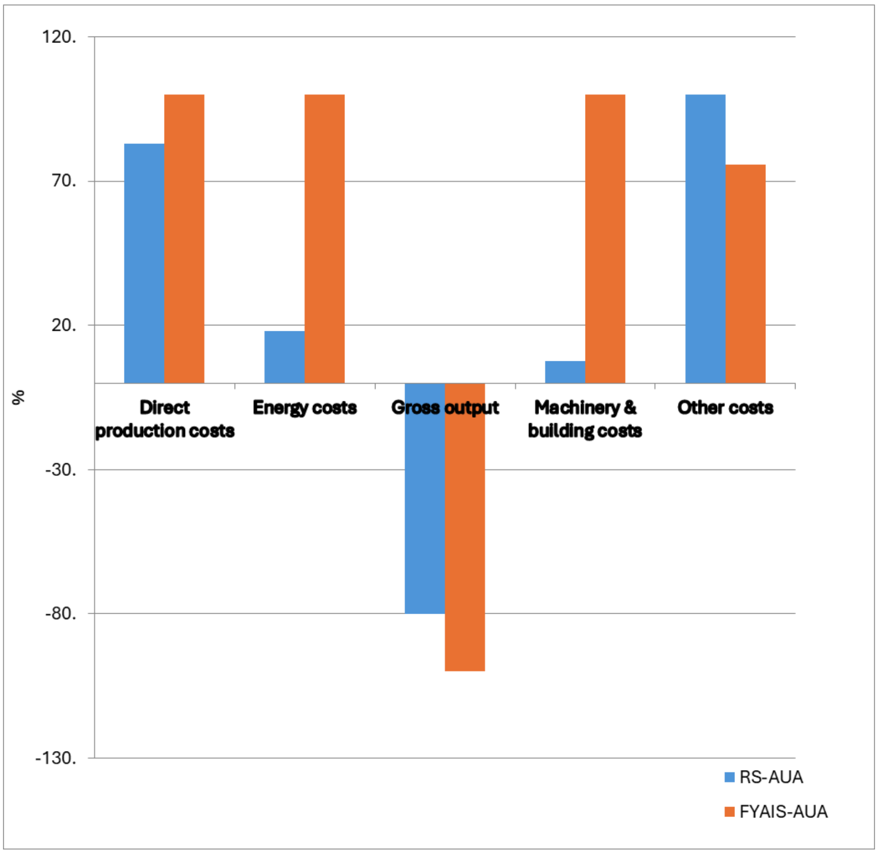


*Figure 7. Relative % difference of the costs per kg of eggs at the AUA pilot farm gate between the FYAIS-AUA and the RS-AUA.*

In addition to the relative % differences presented in Figure 7, absolute differences in the cost categories (in €/kg eggs at the AUA farm gate) are presented in Table 22.

*Table 22. Differences in the various cost types expressed in €/kg eggs at the AUA farm gate between the after-interventions system (FYAIS-AUA) and the reference system (RS-AUA).*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE COSTS (€/kg eggs at the AUA farm gate) | DIFFERENCE IN COSTS (€/kg eggs at the AUA farm gate) |
|---|---|---|
| Direct production costs | 3.09 | 0.56 |
| Overhead costs | 0.25 | 1.47 |
| Energy costs | 0.19 | 0.83 |
| Other costs | 0.01 | 1.80E-03 |

*Table 22. Differences in the various cost types expressed in €/kg eggs at the AUA farm gate between the after-interventions system (FYAIS-AUA) and the reference system (RS-AUA) (continued).*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE COSTS (€/kg eggs at the AUA farm gate) | DIFFERENCE IN COSTS (€/kg eggs at the AUA farm gate) |
|---|---|---|
| Machinery and building costs | 0.05 | 0.65 |
| Gross output | -2.33 | -0.53 |

Key cost increases in the FYAIS-AUA compared to the RS-AUA, include direct production costs (with a €0.56/kg increase), energy costs (€0.83/kg), and machinery and building costs (€0.65/kg). Minor increases are observed in the other costs category (€0.0018/kg). Despite these cost increases, the gross output per kilogram of eggs only increased by €0.53/kg. This indicates that the rise in production costs outweighed the gains in gross output obtained after interventions, leading to reduced overall financial efficiency for the farm.

**Endpoint level assessment**

Table 23 and Figure 8 suggest a 154% increase (147.55 mPt/kg of egg at the farm gate) in the SEcS of the FYAIS-AUA in comparison to the RS-AUA. This indicates a decline in the overall economic performance of the FYAIS-AUA relative to the RS-AUA. The primary factor driving this outcome is the rise in overhead costs, particularly electricity expenses, as the growth in gross output was insufficient to offset the increased costs.

*Table 23. Difference in the Single economic score (SEcS) per kg eggs at the AUA farm gate between the after-interventions system (FYAIS-AUA) and the reference system (RS-AUA) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE SECS (mPt/kg of eggs at the AUA farm gate) | DIFFERENCE IN SECS (mPt/kg of eggs at the AUA farm gate) | CONTRIB SECS |
|---|---|---|---|
| Direct production costs | 293.68 | 60.15 (20.48%) | |
| Overhead costs | 23.59 | 143.12 (606.61%) | |
| Gross output | -221.50 | -55.72 (25.15%) | |
| **Total** | **95.77** | **147.55 (154.07%)** | |

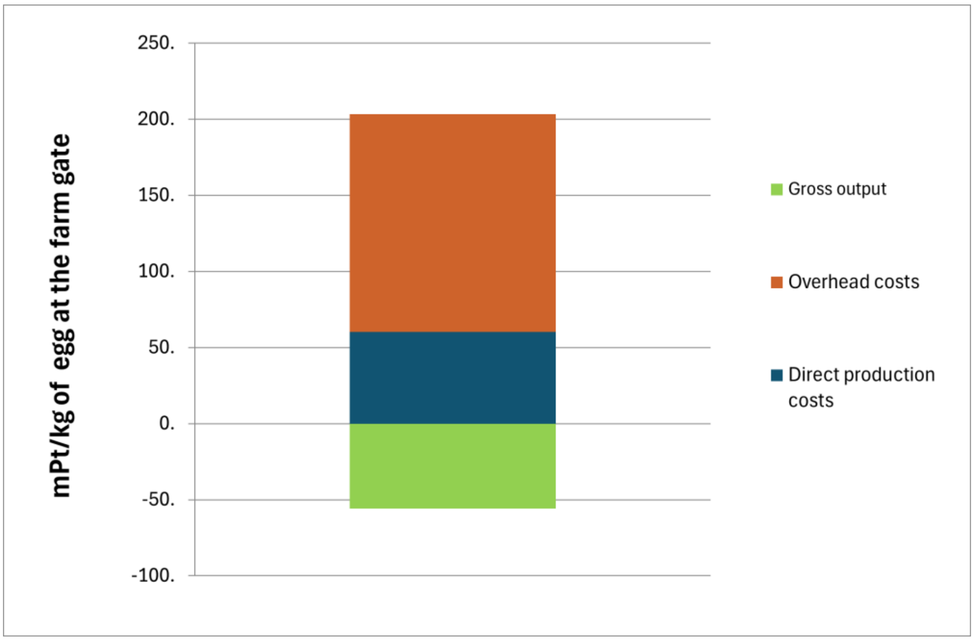


*Figure 8. Graphical representation of the difference in the Single economic score (SEcS) per kg of eggs at the AUA farm gate between the after-interventions system (FYAIS-AUA) and the reference system (RS-AUA).*

Figure 8 is broken down into three main components: gross output, overhead costs, and direct production costs, showing how each contributes to the overall cost changes. The gross output (represented in green) has a negative contribution, indicating an improvement in revenue generation per kilogram of eggs of 55.72 mPt/kg of egg, mainly due to increased efficiency or productivity gains after the interventions. However, this improvement is outweighed by the increases in both direct production costs (blue) and overhead costs (orange), which have increased by 60.15 and 143.12 mPt/kg of egg respectively. Overhead costs, particularly related to electricity, dominate the increase, representing the largest contribution to the overall cost difference. Direct production costs also increase, reflecting higher input prices, especially when it comes to feed mixes required for production.

Overall, Figure 8 suggests that while the interventions led to productivity improvements (as shown by the negative gross output impact), these were not sufficient to counteract the significant cost increases in overheads and direct production, resulting in a higher total cost per kilogram of eggs in the post-intervention year. This highlights the need for future efforts to address overhead costs.

### 5.4.2 Gate-to-gate Life Cycle Costing: Scenarios assessment – AUA

**Midpoint level assessment**

Figure 9 illustrates the comparison of the annual costs per FU (i.e., kg of egg at the AUA farm gate) between the FYAIS-AUA, the AIS-S1-AUA, the AIS-S2-AUA and the RS-AUA. This comparison highlights the differences in costs associated with each scenario, showing how the RES4LIVE interventions and adjustments in the system affect the overall cost structure.

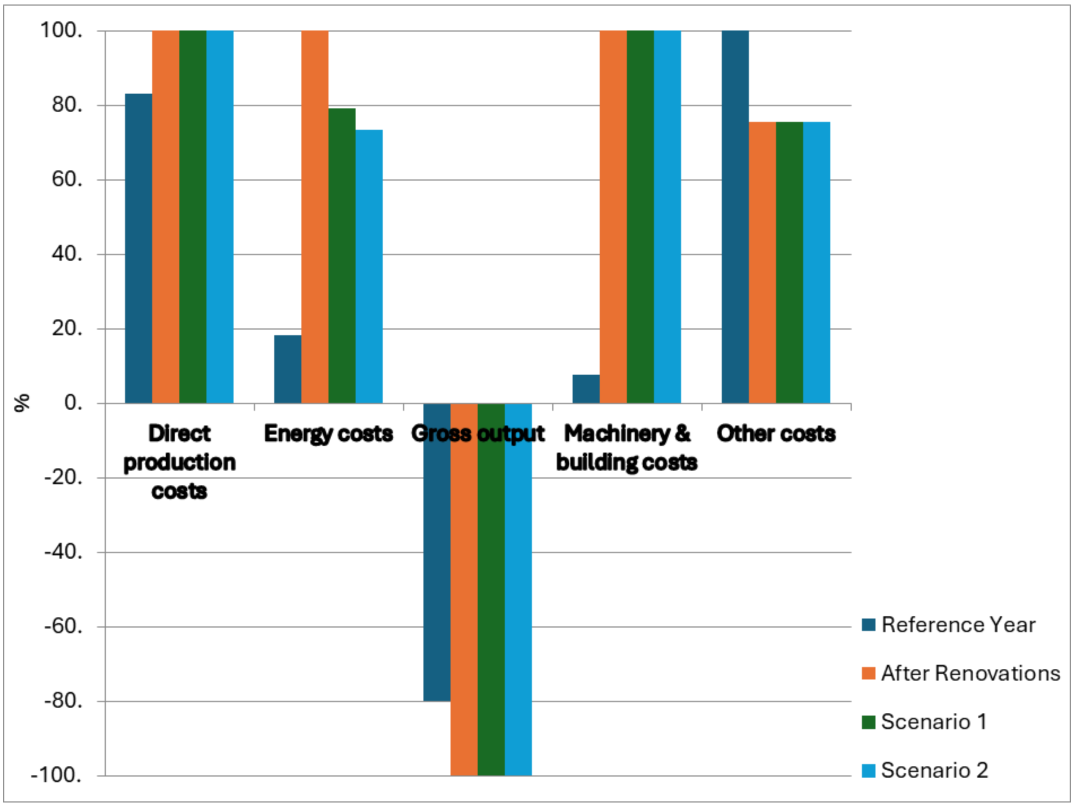


*Figure 9. Relative % difference of the costs per kg of eggs at the AUA pilot farm gate between the FYAIS-AUA, the AIS-S1-AUA, the AIS-S2-AUA and the RS-AUA.*

As is easily observable, the key changes can be found in the energy costs, which show the most significant variation across the scenarios. In the RS-AUA, energy costs are relatively low, reflecting the less energy-intensive systems in place at that time. However, after the interventions, energy costs substantially increased, driven by a step increase in electricity consumption by the new technologies implemented after renovations and the considerable general rise in electricity costs. In AIS-S1-AUA and AIS-S2-AUA, where smaller-sized fans with lower electricity consumption for the ventilation system have been used, energy costs are reduced by 20.95% and 26.73%, respectively, compared to the FYAIS-AUA, but remain noticeably higher than in the RS-AUA. These reductions in AIS-S1-AUA and AIS-S2-AUA show that the efforts to optimize energy usage through smaller and more efficient ventilation systems have a potential, positive impact on the overall financial performance of the experimental poultry farm, although this impact is still not enough to return to the low energy costs observed before renovations. Any further attempts at optimizing the energy usage and the energy management of the farm, therefore, would be needed to bring energy costs closer to the RS.

In addition to the relative % differences presented in Figure 9, absolute differences in the cost categories (in €/kg eggs at the AUA farm gate) are presented in Table 24.

*Table 24. Differences in the various cost types expressed in €/kg eggs at the AUA farm gate between the after-interventions system (FYAIS-AUA) and the reference system (RS-AUA), the after-interventions system-Scenario 1 (AIS-S1-AUA) and the reference system (RS-AUA) and the after interventions system-Scenario 2 (AIS-S2-AUA) and the reference system (RS-AUA).*

| MIDPOINT COST IMPACT CATEGORY | DIFFERENCE IN COSTS (€/kg eggs at the AUA farm gate) - FYAIS | DIFFERENCE IN COSTS (€/kg eggs at the AUA farm gate)- AIS-S1 | DIFFERENCE IN COSTS (€/kg eggs at the AUA farm gate)- AIS-S2 |
|---|---|---|---|
| Direct production costs | 0.56 | 0.56 | 0.56 |
| Overhead costs | 1.47 | 1.26 | 1.20 |
| Energy costs | 0.83 | 0.62 | 0.56 |
| Other costs | 1.80E-03 | 1.80E-03 | 1.80E-03 |
| Machinery and building costs | 0.65 | 0.65 | 0.65 |
| Gross output | -0.53 | -0.53 | -0.53 |

Direct production costs remain constant across all scenarios, increasing by €0.56/kg. Overhead costs vary, with the highest increase in the FYAIS-AUA (€1.47/kg), followed by AIS-S1-AUA (€1.26/kg) and AIS-S2-AUA (€1.2/kg). The largest component of overhead costs is energy costs, which decrease across the scenarios, from €0.83/kg in FYAIS-AUA to €0.56/kg in AIS-S2-AUA. Machinery and building costs consistently increase by €0.65/kg, while other costs contribute minimally (€0.0018/kg). Despite a €0.53/kg improvement in gross output across all scenarios, the increased costs, particularly electricity costs, outweigh this benefit, leading to higher overall costs.

**Endpoint level assessment**

Table 25 and Figure 10 show that, while there was a 154% increase (147.55 mPt/kg of egg) in the SEcS of the FYAIS in comparison to the RS, this difference is reduced in the 2 considered scenarios, with AIS-S1 presenting a difference of 132.6% (126.96 mPt/kg of egg) and AIS-S2 obtaining a difference of 126.65% (121.28 mPt/kg of egg). This indicates that, although the overall economic performance of the 2 additional scenarios is still lower than the RS as a result of still high electricity costs, both of them obtain a higher performance than FYAIS.

*Table 25. Difference in the Single economic score (SEcS) per kg eggs at the AUA farm gate between: (1) the after-interventions system (FYAIS-AUA) and the reference system (RS-AUA), (2) the after-interventions system - scenario 1 (AIS-S1-AUA) and the reference system (RS-AUA) and (3) the after-interventions system - scenario 2 (AIS-S2-AUA) and the reference system (RS-AUA), for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | DIFFERENCE IN SECS (mPt/kg of eggs at the AUA farm gate) - FYAIS | Contribution to the total SEcS difference (%) - FYAIS | Difference in SEcS (mPt/kg of eggs at the AUA farm gate) - AIS-S1 | Contribution to the total SEcS difference (%) - AIS-S1 | Difference in SEcS (mPt/kg of eggs at the AUA farm gate) - AIS-S2 | Contribution to the total SEcS difference (%) - AIS-S2 |
|---|---|---|---|---|---|---|
| Direct production costs | 60.15 (20.48 %) | 40.76 | 60.15 (20.48 %) | 47.38 | 60.15 (20.48 %) | 49.60 |
| Overhead costs | 143.12 (606.61 %) | 97.00 | 122.53 (519.35%) | 96.51 | 116.85 (495.29%) | 96.35 |
| Gross output | -55.72 (-25.15 %) | -37.76 | -55.72 (-25.15 %) | -43.89 | -55.72 (-25.15 %) | -45.94 |
| Total | 147.55 (154.07%) | 100.00 | 126.96 (132.57%) | 100.00 | 121.28 (126.65 %) | 100.00 |

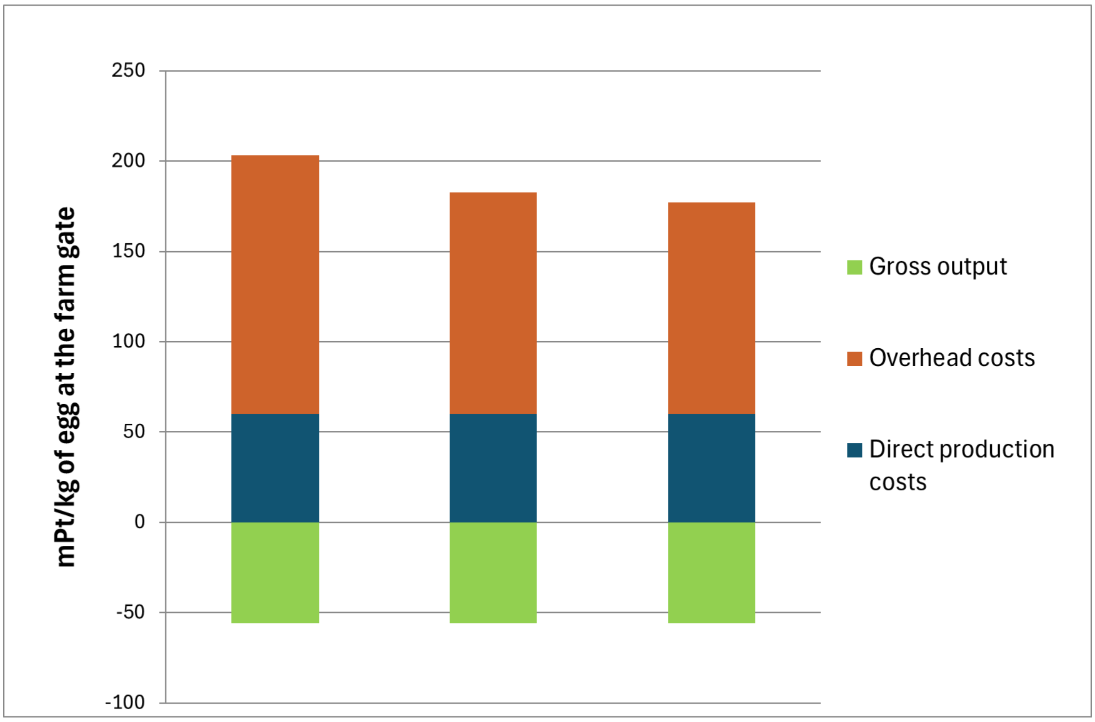


*Figure 10. Graphical representation of the difference in the Single economic score (SEcS) per kg of eggs at the AUA farm gate between: (1) the after-interventions system (FYAIS-AUA) and the reference system (RS-AUA); (2) the after-interventions system - scenario 1 (AIS-S1-AUA) and the reference system (RS-AUA) and (3) the after-interventions system - scenario 2 (AIS-S2-AUA) and the reference system (RS-AUA).*

As seen both in Table 25 and Figure 10, across all scenarios Overhead Costs represent the largest contributor to the difference in total costs compared to the RS. This difference in Overhead costs, however, reaches its peak in FYAIS-AUA, where it contributes 143.12 mPt/kg of egg to the total SEcS difference, while this contribution decreases in AIS-S1 to 122.53 mPt/kg of egg and in AIS-S2 to 116.85 mPt/kg of egg. This reduction is the result of the lower electricity consumption thanks to the use of smaller-sized fans and the consequent reduction of overall electricity costs in both additional scenarios.

To better appreciate how the employment of smaller-sized fans can obtain notable reductions in the SEcS due to reductions in electricity consumption and costs, Figure 11 compares the differences in SEcS that can be attributed to the energy costs for three scenarios—FYAIS, AIS-S1, and AIS-S2—in comparison to the RS.

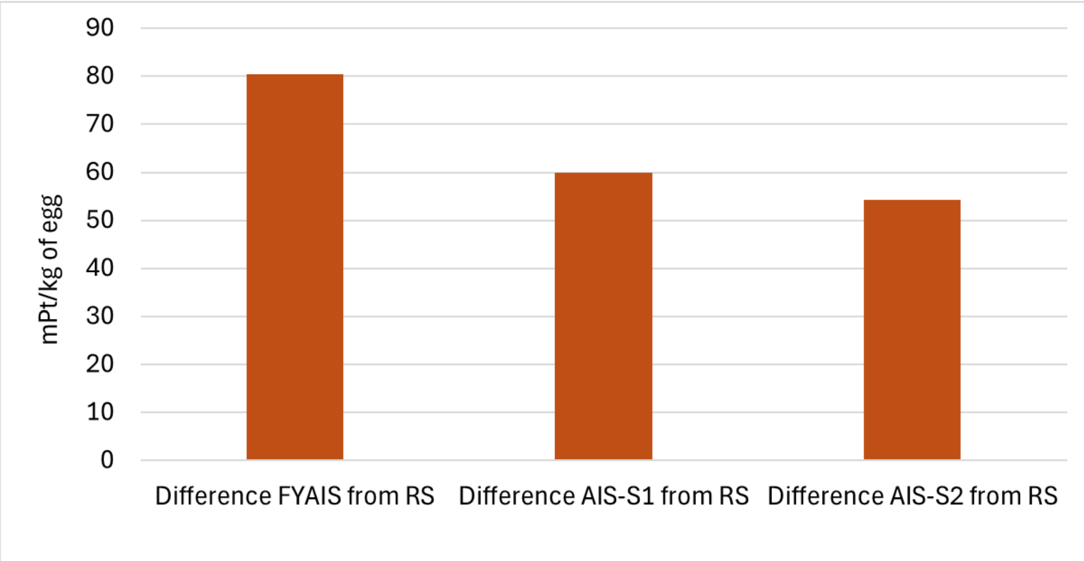


*Figure 11. Difference in Single Economic Score (SEcS) attributed to the energy costs in the examined systems (FYAIS-AUA vs. RS-AUA, AIS-S1-AUA vs. RS-AUA and AIS-S2-AUA vs. RS-AUA).*

As can be observed in Figure 11, the largest difference is observed in the FYAIS scenario, with a value of 80.46 mPt/kg, indicating the highest deviation from the reference. AIS-S1 shows a smaller difference of 59.88 mPt/kg, followed by AIS-S2 with the lowest difference of 54.20 mPt/kg.

### 5.4.3 Additional economic indicators – AUA

Table 26 presents the differences in economic indicators for the FYAIS and the two additional scenarios, namely AIS-S1, and AIS-S2, relative to the baseline RS system. The content of this table allows for the evaluation of profitability, efficiency, and productivity metrics in terms of their absolute difference and percentage change. Key metrics include profitability indicators such as economic return, gross margin, net income, and product sales (eggs, spent hens, and pullets). Efficiency indicators examine cost efficiency and productivity in egg production per hen.

The data shows that economic return (gross output) increases consistently by 0.53 €/kg of egg (22.73%) across all scenarios after interventions. However, net income experiences a notable decrease, with the FYAIS scenario showing the largest drop at -1.51 €/kg (-49.41%), followed by AIS-S1 (-1.27 €/kg, -26.29%) and AIS-S2 (-1.21 €/kg, -20.47%). These negative values indicate that, in all scenarios, the farm's costs exceed its benefits, meaning it is operating at a loss. This decline after the RES4LIVE interventions and in the two scenarios suggests that the interventions and changes in these scenarios have not yet led to enough financial improvements. Instead, they have increased costs relative to the revenue generated. This implies that while the renovations and scenarios might aim to optimise productivity or efficiency, they are not yielding sufficient economic benefits yet to offset the higher costs incurred, signalling a need for further adjustments to improve the farm's economic viability. At the same time, however, the lower difference in net income for the AIS-S1 and AIS-S2 relative to the RS, shows that the reduction in electricity consumption and costs associated with the use of smaller fans contributes considerably to reducing the negative net income level.

Considering the product sales from the AUA pilot farm, the main product in question (i.e. eggs) and two co-products (i.e. spent hens and pullets) need to be considered. When it comes to the main product, eggs, there is a significant increase of 27.81% in the sale price from the RS-AUA to the FYAIS-AUA, going from 2.17€ to 2.81€ per kg of eggs. Regarding the sale of spent hens at the end of their laying period, on the other hand, there is a sharp decrease of almost 50%, going from 0.88€ / kg spent hen live weight to just 0.45€ / kg. This lower price per unit combines with the lower total output of spent hens in the FYAIS-AUA to considerably reduce the income associated with the selling of spent hens. As for the sale of pullets, the FYAIS-AUA sees a 25% increase in the price per kg of pullet sold, going from 4.21€/kg of pullet live weight to 5.26€/kg. The overall effect of this increase, however, is almost irrelevant given the very low output of this co-product.

*Table 26. Difference (absolute values and relative %) in the values of the additional economic indicators between: (1) the FYAIS-AUA and the RS-AUA, (2) the AIS-S1-AUA and the RS-AUA and (3) the AIS-S2-AUA and the RS-AUA.*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE: FYAIS-AUA | DIFFERENCE IN THE INDICATOR VALUE: AIS-S1-AUA | DIFFERENCE IN THE INDICATOR VALUE: AIS-S2-AUA | UNIT |
|---|---|---|---|---|
| Profitability: Economic return; gross output | 0.53 (22.73%) | 0.53 (22.73%) | 0.53 (22.73%) | € / kg eggs at the AUA farm gate |
| Profitability: Profit; gross margin | -0.03 (-4.19 %) | -0.01 (-1.52%) | -0.01 (-1.52 %) | € / kg eggs at the AUA farm gate |
| Profitability: Income; net income | -1.51 (-49.41 %) | -1.27 (-26.29 %) | -1.21 (-20.47 %) | € / kg eggs at the AUA farm gate |
| Profitability: Product sales; eggs | 0.60 (27.81%) | 0.60 (27.81%) | 0.60 (27.81%) | € / kg of eggs |
| Profitability: Product sales; spent hens | -0.44 (-49.54%) | -0.44 (-49.54%) | -0.44 (-49.54%) | € / kg of spent hens' live weight |

*Table 26. Difference (absolute values and relative %) in the values of the additional economic indicators between: (1) the FYAIS-AUA and the RS-AUA, (2) the AIS-S1-AUA and the RS-AUA and (3) the AIS-S2-AUA and the RS-AUA (continued).*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE: FYAIS-AUA | DIFFERENCE IN THE INDICATOR VALUE: AIS-S1-AUA | DIFFERENCE IN THE INDICATOR VALUE: AIS-S2-AUA | UNIT |
|---|---|---|---|---|
| Profitability: Product sales; pullets | 1.05 (24.94%) | 1.05 (24.94%) | 1.05 (24.94%) | € / kg of pullets' live weight |
| Efficiency: Cost efficiency; direct production costs per gross output | -0.05 (-3.77%) | -0.05 (-3.77%) | -0.05 (-3.77%) | - |
| Efficiency: Productivity; eggs produced per hen | 3.47 (30.32%) | 3.47 (30.32%) | 3.47 (30.32%) | kg of eggs / hen |

Regarding efficiency, direct production costs per gross output improve marginally by -0.05 €/kg (-3.77%) in all scenarios. Productivity, measured as eggs produced per hen, shows significant improvement across the board, increasing by 3.47 kg/hen (30.32%) in all scenarios. This improvement in productivity per hen indicates that the RES4LIVE interventions have positively impacted egg productivity. The farm produced more eggs per hen in the FYAIS-AUA, despite having a smaller flock. This suggests that the interventions may have optimised the poultry welfare in-house, thereby enhancing the overall productivity of each hen. This increase in efficiency is a positive outcome, as it shows that the farm can achieve higher output levels with fewer resources, leading to better economic performance and potential cost savings.

**Discounted Payback Period (DPBP)**

Table 27 shows the estimated net cash flows from the first year and the discounted net cash flows from the second year of operation of the RES4LIVE technologies installed in the AUA poultry farm. Since electricity production or reduction of fossil fuel consumption cannot be attributed to the operation of either the heat pump or the smart system, there is no positive economic inflow due to their operation. This explains the negative net cash flows and discounted net cash flows for both technologies. Additionally, although the LED system generates a small electricity cost saving for the farm's lightning, it is not enough to generate a positive net cash flow. Thus, the sum of the discounted net cash flows for each of these technologies is not expected to become positive within each of the technologies' life span.

*Table 27. First year net cash flows and second year discounted net cash flows from the RES4LIVE technologies installed and operating in the AUA poultry farm.*

| RES4LIVE TECHNOLOGY | INITIAL INVESTMENT (€) | ELECTRICITY SAVINGS (€/year) | COST FOR ANNUAL ELECTRICITY CONSUMPTION (€/year) | ANNUAL MAINTENANCE COST (€/year) | ANNUAL INSURANCE COST (€/year) | NET CASH FLOW FROM THE TECHNOLOGY INSTALLED (€/YEAR) | DISCOUNTED NET CASH FLOW FROM THE TECHNOLOGY INSTALLED - 2nd YEAR OF OPERATION (€/YEAR) |
|---|---|---|---|---|---|---|---|
| Heat pump | 35,000.00 | 0 | 2,329.12 | 750 | 0 | -3,079.12 | -2,792.85 |
| PVT system | 6,000.00 | 1,186.82 | 0 | 300 | 0 | 886.82 | 804.38 |
| Smart control system | 4,847.00 | 0 | 20.93 | 500 | 0 | -520.93 | -472.5 |
| LED System | 2,100.00 | 160.06 | 76.4 | 100 | 0 | -16.35 | -14.83 |
| **Total** | **47,947.00** | **1,186.82** | **2,426.46** | **1,650.00** | **0** | **-2,713.23** | **-2,475.81** |

We find further confirmation of this in Table 28, which suggests that even with a subsidy support of 20 or 40% of the initial investment, it still would not be possible to return the investment of these 3 technologies from their operation only (the sum of the discounted net cash flows is negative and impossible to become equivalent with the remaining amount of money from the initial investment after a 40% subsidy support).

The data shows that the heat pump requires the largest initial investment (€35,000) and incurs significant annual electricity consumption costs (€2,329.12), resulting in a substantial negative net cash flow. Conversely, the PVT generates €1,186.82 in electricity savings, resulting in a positive net cash flow of €886.82. As a result, the initial investment of the PV system could be covered by year 9. Both the Smart control system and the LED system present a negative net cash flow in the first year, due to low or non-existing electricity savings, and consequently present a negative discounted net cash flow in year 2. The total investment across all technologies amounts to €47,947, with a combined net cash flow of -€2,713.23, highlighting potential areas for improvement in financial efficiency for some components.

*Table 28. Amount of money to be paid back, considering a 20% and 40% subsidy support for the AUA poultry farm case.*

| RES4LIVE TECHNOLOGY | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 20% SUBSIDY SUPPORT (€) | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 40% SUBSIDY SUPPORT (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 25 YEARS OF OPERATION (€) |
|---|---|---|---|
| Heat Pump | 28,000.00 | 21,000.00 | -43396.97 |
| PV system | 4,800.00 | 3,600.00 | 12498.85 |
| Smart climate control system | 3,877.60 | 2,908.20 | -7341.99 |
| LED system | 1,680.00 | 1,260.00 | -230.46 |
| **Total** | **38,357.60** | **28,768.20** | **-38470.58** |

Table 28 provides an analysis of the financial impact of subsidy support on the initial investment costs of the RES4LIVE technologies implemented in the AUA poultry farm and the cumulative discounted net cash flows over 25 years. It shows the remaining investment amounts after applying 20% and 40% subsidy support for each technology (heat pump, PV system, smart climate control system, and LED system). The heat pump has the highest post-subsidy costs (€28,000 after a 20% subsidy and €21,000 after a 40% subsidy). The table also highlights the sum of discounted net cash flows over 25 years, with the heat pump showing a significant negative value (-€43,396.97), as a result mainly of the considerable increased operational costs it brings upon the farm, while the PV system shows a positive return (€12,498.85). With the use of subsidies, the PV system could be repaid in year 7 if the subsidy was 20%, or in year 5 if the subsidy was as high as 40%. The total cumulative discounted cash flow across all technologies remains negative at -€38470.58.

# 6 LVAT COMPARATIVE ECONOMIC ASSESSMENT

## 6.1 Farm-level economic LCA models - LVAT

### 6.1.1 Reference system and system after interventions - LVAT

The reference systems and the systems after the installation and operation of the RES4LIVE technologies at the EV ILVO experimental pig farm, are described in Sections 6.1.1 and 6.1.2 respectively, of Deliverable 5.3: "Environmental Assessment Report".

For further details on the RES systems, please refer to deliverables D4.1: "Design of integrated systems in pilot farms", D4.2: "The installed pilot systems", D4.3: "Report with the test results obtained on energy and production performances of RES and energy efficiency solutions".

## 6.2 Farm-level economic LCA datasets - LVAT

The annual economic flows due to the energy and fuel savings or sales at the LVAT farm in the reference system (RS-LVAT) and the First Year After RES4LIVE Interventions System (FYAIS-LVAT), as introduced into the SimaPro software (part of the wider farm-level LCA dataset), are shown in Table 29.

*Table 29. Annual sales of renewable energy and fuel before and after the RES4LIVE interventions in the LVAT pilot farm.*

| LVAT | UNIT | REFERENCE SYSTEM (RS - LVAT) | FIRST YEAR AFTER INTERVENTIONS SYSTEM (FYAIS - LVAT) |
|---|---|---|---|
| **CHP unit & BioCNG upgrading unit and Filling station** | | | |
| Sold renewable electricity (CHP unit) | €/year | 63,300.00 | 49,171.53 |
| Sold BioCNG (BioCNG plant) | €/year | - | 18,494.55 |
| **Total** | **€/year** | **63,300.00** | **67,666.08** |

As discussed in more detail in D5.3, the RES4LIVE interventions in LVAT did not directly affect the main livestock products of the dairy cattle farm. The economic impact or the interventions can be showcased in the energy/ fuel savings, as well as the renewable energy/ fuel sales. Using data supplied by the LVAT farm managers regarding the sold and saved energy/ fuel quantities on an annual basis and average sale prices per case.

Table 29 suggests a decrease (22.32%) in the sale of electricity in the FYAIS-LVAT compared to the RS-LVAT. This is due to the lower amount of the biogas fed to the CHP unit, resulting in both less electricity and heat production. The introduced BioCNG sale though led to a 6.90% increase in the total annual sale of the farm, regarding bioenergy in total.

Table 30 presents key economic flows at the LVAT pilot farm, used to estimate the economic performance before and after the RES4LIVE interventions.

*Table 30. Annual key economic flows before and after the RES4LIVE interventions in the LVAT pilot farm.*

| LVAT | Unit | Reference System (RS - LVAT) | First Year After Interventions System (FYAIS - LVAT) |
|---|---|---|---|
| **BioCNG unit and filling station** | | | |
| BioCNG unit - annual depreciation expense [a] | €/year | - | 13,466.66 |
| BioCNG unit - annual maintenance expense | €/year | - | 8,280.32 |
| BioCNG unit - annual insurance expense | €/year | - | 2,090.00 |
| BioCNG unit - annual operating expense (electricity) | €/year | - | 5,319.072 |
| **Farm tractor** | | | |
| Farm tractor (diesel/ BioCNG) - annual depreciation expense [b] | €/year | 1,606.25 | 2,222.22 |
| Farm tractor (diesel/ BioCNG) - annual maintenance expense [b] | €/year | 1,500.00 | 1,525.00 |
| Farm tractor (diesel/ BioCNG) - annual insurance expense [b] | €/year | 400.00 | 457.50 |
| Farm tractor (diesel/ BioCNG) - annual operating expense (fuel, lubricants, transport) [b] | €/year | 7,231.91 | 290.81 |
| Farm tractor (diesel/ BioCNG) - annual fuel savings (diesel) | €/year | - | 9,612.32 |
| **PVT and E-boiler system** | | | |
| PVT and solar station - annual depreciation expense [c] | €/year | - | 2,172.00 |
| PVT and solar station - annual maintenance expense | €/year | - | 650.00 |

*Table 30. Annual key economic flows before and after the RES4LIVE interventions in the LVAT pilot farm (continued).*

| LVAT | Unit | Reference System (RS - LVAT) | First Year After Interventions System (FYAIS - LVAT) |
|---|---|---|---|
| **PVT and E-boiler system** | | | |
| PVT and solar station - annual insurance expense | €/year | - | 277.50 |
| Electric boiler/ PVT and solar station - annual operating expense (electricity) [d] | €/year | 1,444.35 | 52.44 |
| PVT and solar station - annual energy savings (electricity) | €/year | - | 2,191.44 |
| CHP plant - renewable energy production costs (electricity) | €/year | 18,327.65 | 16,641.67 |
| Electric boiler - heat production costs (electricity) | €/year | 1,444.35 | 52.44 |

*[a] Considering 15 years of lifetime and a salvage value of 18,000 € for the equipment at the end of its lifetime.*
*[b] Considering 15 years of lifetime and a salvage value of 500 € for the equipment at the end of its lifetime. The daily on-farm tractor operation is considered to be 3.5 h/d, for 365 days per year.*
*[c] Considering 25 years of lifetime and a salvage value of 1,200 € for the equipment at the end of its lifetime.*
*[d] The RS considers only the operational costs of the electric boiler operation.*

## 6.3 Additional farm-level economic indicators - LVAT

### 6.3.1 Profitability - LVAT

**Economic return: Difference in gross output**

This indicator is defined only for the CHP unit, and the BioCNG unit and filling station. It is expressed per kWh sold electricity and per m$^3$ biomethane for the CHP and the BioCNG units, respectively. The farm tractor itself cannot be associated with a gross output, as it does not provide a service that can be sold for the current system (a case that it could provide gross output would be, e.g., the rental of the farm tractor which is not applicable for the LVAT pilot farm). Moreover, the operation of the electric boiler cannot be connected to a gross output. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Profit: Difference in gross margin**

This indicator is again defined only for the CHP unit, and the BioCNG unit and filling station. It is expressed per kWh sold electricity and per $m^3$ biomethane for the CHP and the BioCNG units, respectively. Gross margin equals the gross output minus the direct production costs. The estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro.

**Income: Difference in net income**

Net income is defined for all the sub-systems of interest in the LVAT pilot farm (CHP unit, BioCNG unit and filling station, farm tractor and electric boiler). This indicator is expressed as:

- per kWh sold electricity (at the gate of the CHP unit of the biogas plant)
- per $m^3$ biomethane (at the gate of the filling station of the BioCNG unit)
- per hr of farm tractor's operation
- per kWh of heat (at the gate of the electric boiler)

Net income is given by Eq. 10:

***Net income (before depreciation) = (Gross margin - Overhead costs - External costs - Taxes + Subsidies) (Eq. (10))***

Considering negligible differences in external costs, taxes and subsidies, the difference in net income is finally estimated by Eq. 11:

*[Net income (before depreciation)$_{FYAIS\text{-}LVAT}$ - Net income (before depreciation)$_{RS\text{-}LVAT}$] =*

*= [(Gross margin - Overhead costs)$_{FYAIS\text{-}LVAT}$ - (Gross margin - Overhead costs)$_{RS\text{-}LVAT}$] (Eq. (11))*

Therefore, the estimation of this indicator is conducted directly from the results of the farm-level LCA models in SimaPro. By definition, this net income indicator represents a simple cost-benefit economic analysis. For the farm tractor and the electric boiler, by definition, it is expected that the net income is negative for both RS-LVAT and FYAIS-LVAT. This implies that the operation of these sub-systems is associated only with direct costs and offers no direct economic benefits.

**Product sales: Difference in product sales**

This indicator is again defined only for the CHP unit, and the BioCNG unit and filling station. It is expressed per kWh sold electricity and per $m^3$ biomethane for the CHP and the BioCNG units, respectively. It can be estimated directly from the relevant primary data collected by the LVAT farm.

## 6.3.2 Efficiency - LVAT

**Difference in cost efficiency**

Cost efficiency is defined as the direct production costs per gross output only for the CHP unit, and the BioCNG unit and filling station. For the farm tractor, cost efficiency could be equivalent to the fuel efficiency (i.e. the fuel consumption in kg/h of on- farm tractor operation), while for the electric boiler, the energy efficiency rating would not be different for the RS-LVAT and the FYAIS-LVAT. Cost efficiency is unitless for the CHP unit and the BioCNG unit and filling station, while expressed in kg of fuel (diesel or biomethane) per h of on-farm tractor operation, for the tractor. For the CHP unit, and the BioCNG unit and filling station, this indicator is calculated from the direct production costs and the gross output for each system, as extracted from the results of the farm-level LCA models in

SimaPro. For the farm tractor, the fuel efficiency is calculated using the data received after communication with the responsible partners (LVAT, ATB and CRMT SAS).

**Difference in productivity**

Productivity is defined differently for each LVAT sub-system:

- For the CHP unit: the total energy (i.e. both electricity and heat) output per unit of biogas which equals the total, annual energy output divided by the annual biogas input volume (to the CHP unit).
- For the BioCNG unit and filling station: the BioCNG yield per unit biogas, which equals the annual BioCNG output volume divided by the annual biogas input volume (to the BioCNG unit).
- For the farm tractor: the tractor utilization rate, i.e. the tractor work hours per day. This productivity indicator does not change between the RS-LVAT and the FYAIS-LVAT, as the tractor achieves similar operation needs (between 2 and 5 hr of operation daily).
- For the electric boiler and the PVT system: indicators such as heat output capacity and thermal efficiency of the electric boiler are not modified before (RS-LVAT) and after the installation of the PVT system (FYAIS-LVAT). Specifically, the thermal efficiency of the electric boiler remains unchanged at 95% of the electrical energy input to the boiler.

### 6.3.3 Discounted Payback Period (DPBP) of the RES4LIVE technologies - LVAT

To estimate the DPBP, the following procedure was followed:

1. Create a list of all the RES4LIVE technologies installed in the sub-systems of interest on the LVAT pilot farm (i.e. farm tractor: tractor retrofitting; electric boiler: PVT and solar station system; BioCNG unit and filling station: this sub-system was installed in the context of the RES4LIVE project; CHP unit: no RES4LIVE technologies involved; estimation of DPBP is irrelevant in the context of the RES4LIVE project).
2. Connect each RES4LIVE technology with its total initial investment.
3. Estimate the total amount of money saved due to the electricity produced on-farm (relevant to the electric boiler and PVT sub-system) using the RES4LIVE technologies after the first year of operation.
4. Estimate the total amount of money saved from the avoided fossil fuel due to the operation of the RES4LIVE technologies after the first year of operation (relevant to the BioCNG unit and filling station sub-system, whose operation is responsible for avoiding the production of diesel fuel for tractor transport).
5. Use the annual, operating (electricity), maintenance and insurance costs for each RES4LIVE technology as shown in Table 30.
6. Estimate the net cash flow for each RES4LIVE technology ($NCF_T$) and the first year of operation by subtracting the total costs (operating, maintenance and insurance) from the savings (electricity and fossil fuels).
7. Estimate the Discounted Net Cash Flow for each RES4LIVE technology ($DNCF_T$), by using Eq. 12:

$$DNCF_{y,T} = (NCF_T / (1 + DR)^y) \text{ (Eq. 12)}$$

DR: The considered discount rate on an annual basis (= 0.05)

8. Add the annual $DNCF_{y,\ T}$ and estimate the number of years after which the total initial investment for all RES4LIVE technologies is returned, considering subsidies covering either 20% or 40% of the total RES4LIVE technology investment costs to support decarbonization.

## 6.4 Economic impact assessment: Findings and discussion - LVAT

### 6.4.1 Gate-to-gate Life Cycle Costing: CHP unit

**Midpoint level assessment**

A comparison (relative % difference) of the annual costs per FU between the FYAIS-LVAT-CHP and the RS-LVAT-CHP for the case of CHP production is presented in Figure 12. After the first year of the operation of the CHP unit, the machinery and building costs and direct production costs increase by 3.36% and 16.01%, respectively, while energy costs decrease by 5.41%. Moreover, the gross output decreased by 0.75%. The above can be explained by the decreased biogas quantity that is directed to the CHP unit. The rest is of course utilised by the BioCNG unit.

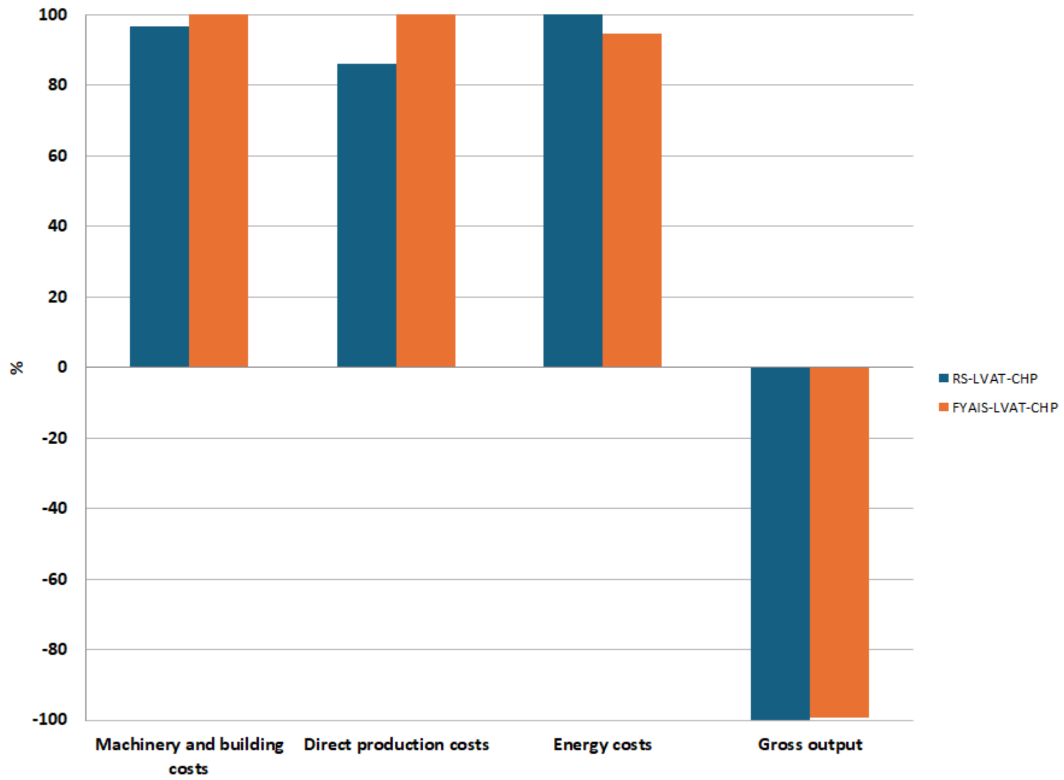


*Figure 12. Relative % difference of the costs per 1kWh of CHP produced electricity between the FYAIS-LVAT-CHP and the RS-LVAT-CHP.*

In addition to the relative % differences presented in Figure 12, absolute differences in the cost categories (in €/kWh of CHP-produced electricity) are presented in Table 31.

*Table 31. Differences in the various cost types expressed in €/kWh of CHP produced electricity between the after-interventions system (FYAIS-LVAT-CHP) and the reference system (RS-LVAT-CHP).*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE COSTS (€/kWh of CHP produced electricity) | DIFFERENCE IN COSTS (€/kWh of CHP produced electricity) |
|---|---|---|
| Direct production costs | 0.03 | 5.05E-03 |
| Overhead costs | 0.06 | 1.94E-03 |
| Energy costs | 3E-3 | -1.69E-04 |
| Machinery and building costs | 0.06 | 2.10E-03 |
| Gross output | -0.11 | 8.20E-04 |

The difference in the economic performance of the CHP unit between the FYAIS-LVAT-CHP and the RS-LVAT-CHP is quite small. The overall economic performance is defined by the difference in gross output (8.20E-04 €/kWh of CHP-produced electricity sold to the grid). The FYAIS-LVAT-CHP economic performance is affected primarily by the increase in direct production costs as well as the machinery and building costs.

**Endpoint level assessment**

In all cost categories, an increase is observed, implying a decrease in the total economic performance of the FYAIS-LVAT-CHP in comparison to the RS-LVAT-CHP (-66.69%). Table 32 and Figure 13 suggest a 66.69% decrease (1.95 mPt/kWh of CHP-produced electricity) in the SEcS of the FYAIS-LVAT-CHP in comparison to the RS-LVAT-CHP.

*Table 32. Difference in the Single economic score (SEcS) per kWh of CHP produced electricity between the after-interventions system (FYAIS-LVAT-CHP) and the reference system (RS-LVAT-CHP) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE SECS (mPt/kWh of CHP produced electricity) | DIFFERENCE IN SECS (mPt/kWh of CHP produced electricity) | CONTRIBUTION TO THE TOTAL SECS DIFFERENCE (%) |
|---|---|---|---|
| Direct production costs | 7.89 | 1.26 (16.01%) | 64.72 |
| Overhead costs | 16.44 | 0.48 (2.94%) | 24.78 |
| Gross output | -27.26 | 0.20 (-0.75%) | 10.50 |
| **Total** | **-2.93** | **1.95 (-66.69%)** | **100.00** |

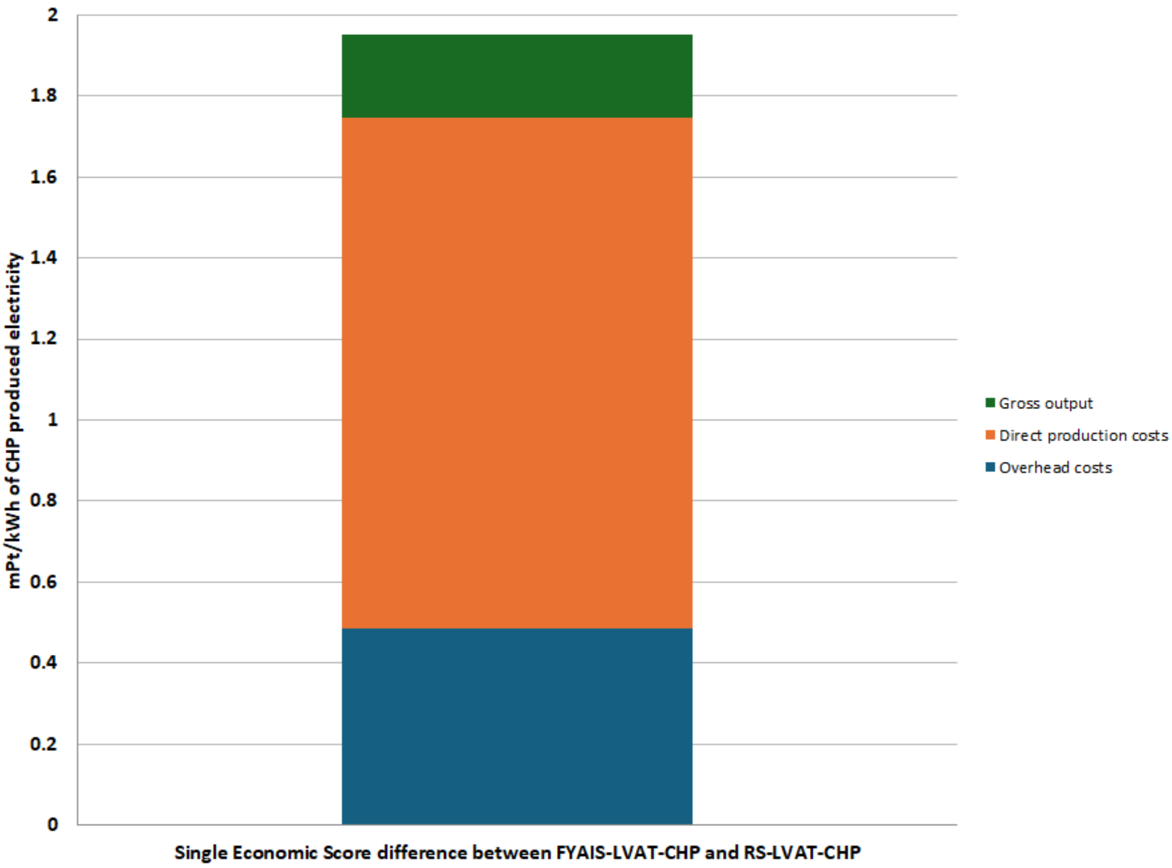


*Figure 13. Graphical representation of the difference in the Single economic score (SEcS) per kWh of CHP produced electricity between the after-interventions system (FYAIS-LVAT) and the reference system (RS-LVAT).*

## 6.4.2 Additional economic indicators: CHP unit

The information presented in Table 33 suggests a reduction in gross output (-0.75%), gross margin (-7.58%), net income (-66.69%) and cost efficiency (16.89%) in the biogas-CHP unit of the LVAT farm, in the transition from the RS-LVAT-CHP to the FYAIS-LVAT-CHP. This comes as a direct consequence of the reduction in the quantity of electricity produced and sold and it is logical after considering that a fraction of the produced biogas in the digester was used as an input to the installed BioCNG unit (FYAIS-LVAT-CHP). The increase in the price for electricity sales (0.81%) and in the energy output per unit biogas input (3.5%) were low to compensate for the decrease in the electricity quantity produced. Moreover, both FYAIS-LVAT-CHP and RS-LVAT-CHP are associated with a positive net income, suggesting that FYAIS-LVAT-CHP is still profitable, although less profitable than the RS-LVAT-CHP.

*Table 33. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-LVAT-CHP and the RS-LVAT-CHP.*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| Profitability: Economic return; gross output | -8.20E-04 (-0.75%) | € / kWh of sold electricity at the CHP unit gate |
| Profitability: Profit; gross margin | -5.87E-03 (-7.58%) | € / kWh of sold electricity at the CHP unit gate |
| **Profitability: Income; net income** | **-7.81E-03 (-66.69%)** | **€ / kWh of sold electricity at the CHP unit gate** |
| Profitability: Product sales; electricity | 2.00E-03 (0.81%) | € / kWh of sold electricity at the CHP unit gate |
| Efficiency: Cost efficiency; direct production costs per gross output | 0.05 (16.89%) | - |
| Efficiency: Productivity; energy output per unit biogas | 1.27E-04 (3.5%) | MWh / m3 biogas input at the CHP unit |

### 6.4.3 Gate-to-gate Life Cycle Costing: BioCNG unit

**Midpoint level assessment**

The annual costs per FU in the FYAIS-LVAT-BioCNG for the case of the BioCNG unit are presented in Table 34 [4]. After the first year of the BioCNG system's operation, the overhead costs were equal to 1.56 €/Nm$^3$ of BioCNG produced, primarily due to the high cost of the unit itself (Machinery and building costs: 1.31€/Nm$^3$ of BioCNG). Furthermore, the sales of the BioCNG cause a gross output of 0.79€/Nm$^3$ of sold BioCNG.

*Table 34. Various cost types expressed in €/Nm3 of BioCNG produced in the after-interventions system (FYAIS-LVAT).*

| MIDPOINT COST IMPACT CATEGORY | COSTS (€/Nm$^3$ of BioCNG produced) |
|---|---|
| Direct production costs | 0.00 |
| Overhead costs | 1.56 |
| Energy costs | 0.25 |

[4] Since prior to the RES4LIVE interventions (RS-LVAT) no similar system was present on the farm, the difference in costs presented in other cases does not apply here.

*Table 34. Various cost types expressed in €/Nm3 of BioCNG produced in the after-interventions system (FYAIS-LVAT) (Continued).*

| MIDPOINT COST IMPACT CATEGORY | COSTS (€/$Nm^3$ of BioCNG produced) |
|---|---|
| Machinery and building costs | 1.31 |
| Gross output | -0.79 |

**Endpoint level assessment**

Table 35 and Figure 14 present the SEcS per $Nm^3$ of biomethane at the gate of the filling station of the BioCNG unit. Primarily responsible for the total economic performance of the FYAIS-LVAT-BioCNG, is the high overhead costs (mainly due to the BioCNG unit's equipment purchase and installation), with the gross output from the BioCNG unit following in importance. It has to be noted that BioCNG production has a positive impact on the economic performance of the tractor operation.

*Table 35. Single economic score (SEcS) per Nm3 of BioCNG produced after the interventions (FYAIS-LVAT-BioCNG) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | SECS (Pt/$Nm^3$ of BioCNG produced) | CONTRIBUTION TO THE TOTAL SECS (%) |
|---|---|---|
| Direct production costs | 0.00 | 0.00 |
| Overhead costs | 0.39 | 202.31 |
| Gross output | -0.20 | -102.31 |
| **Total** | **0.19** | **100** |

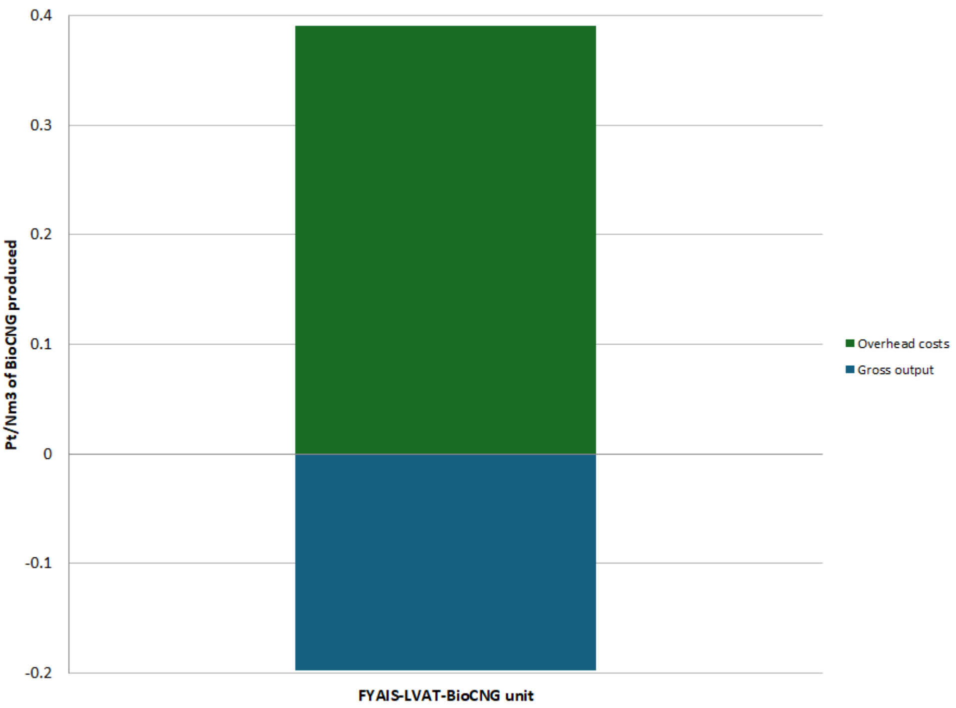


*Figure 14. Graphical representation of the Single economic score (SEcS) peNm3 of BioCNG produced at LVAT after the interventions (FYAIS-LVAT).*

## 6.4.4 Additional economic indicators: BioCNG unit

The absolute values of the additional economic indicators related to the operation of the BioCNG unit for the first year after its installation on the LVAT pilot farm (FYAIS-LVAT-BioCNG) are shown in Table 36. The LVAT farm provides the basic input to the BioCNG unit, biogas, free of charge. Thus, the direct production costs in this sub-system are minimal, resulting in a gross margin equal to the gross output and an ideal cost efficiency. The net income is negative, mainly due to the high purchase and installation costs of the BioCNG unit per $m^3$ of produced biomethane. This suggests that the operation of the BioCNG unit of this productivity (i.e. 0.56 $m^3$ biomethane / $m^3$ biogas input to the BioCNG unit) is not profitable (higher costs than economic benefits) if someone does not consider the savings from the avoided purchase of the fossil diesel which was necessary for the LVAT farm tractor's operation or does not receive a subsidy to reduce the purchase and installation costs.

*Table 36. Absolute values of the additional economic indicators of the FYAIS-LVAT-BioCNG.*

| ECONOMIC INDICATOR | INDICATOR VALUE | UNIT |
|---|---|---|
| Profitability: Economic return; gross output | 0.79 | € / $m^3$ biomethane at the gate of the BioCNG unit's filling station |
| Profitability: Profit; gross margin | 0.79 | € / $m^3$ biomethane at the gate of the BioCNG unit's filling station |

*Table 36. Absolute values of the additional economic indicators of the FYAIS-LVAT-BioCNG (continued).*

| ECONOMIC INDICATOR | INDICATOR VALUE | UNIT |
|---|---|---|
| **Profitability: Income; net income** | **-0.77** | **€ / $m^3$ biomethane at the gate of the BioCNG unit's filling station** |
| Profitability: Product sales; biomethane | 1.66 | € / $m^3$ biomethane at the gate of the BioCNG unit's filling station |
| Efficiency: Cost efficiency; direct production costs per gross output | 0.00 | - |
| Efficiency: Productivity; BioCNG yield per unit of biogas | 0.56 | $m^3$ biomethane / $m^3$ biogas input at the BioCNG unit |

**Discounted Payback Period (DPBP)**

Table 37 shows the estimated net cash flows from the first year and the discounted net cash flows from the second year of operation of the BioCNG unit sub-system of the LVAT pilot farm. The potential annual biomethane sales, as well as the potential savings from the avoided purchase of the equivalent (to the biomethane) transport diesel for the farm tractor, cause increased positive net and discounted net cash flows from the BioCNG unit sub-system (higher than 25,000€/year). This fact seems to be allowing for a short DPBP regarding the investment for the BioCNG unit installed at the LVAT pilot farm.

*Table 37. First year net cash flows and second year discounted net cash flows from the RES4LIVE technologies installed and operating in the BioCNG unit sub-system of the LVAT pilot farm.*

| RES4LIVE TECHNOLOGY | INITIAL INVESTMENT (€) | ANNUAL BIOMETHANE SALES [a] (€/year) | ANNUAL FOSSIL FUEL (DIESEL) SAVINGS (€/year) | ANNUAL ELECTRICITY CONSUMPTION COST (€/year) | ANNUAL MAINTENANCE COST (€/year) | ANNUAL INSURANCE COST (€/year) | NET CASH FLOW FROM THE TECHNOLOGY INSTALLED (€/year) | DISCOUNTED NET CASH FLOW FROM THE TECHNOLOGY INSTALLED - 2nd YEAR OF OPERATION (€/year) |
|---|---|---|---|---|---|---|---|---|
| BioCNG unit | 220,000.0 | 18,494.55 | 26,259.32 | 5,319.07 | 8,280.32 | 2,090.00 | **29,064.48** | **27,680.46** |
| [a] *Considering a price of biomethane of 2.25€/kg.* | | | | | | | | |

This is confirmed by the information presented in Table 38 which suggests a DPBP of 9 to 10 years, without considering a subsidy support. In the scenarios of subsidies with 20% and 40% of the initial investment, the DPBP decreases to 6 to 7 years and 5 to 6 years, respectively.

*Table 38. Amount of money to be paid back, considering a 20% and 40% subsidy support for the BioCNG unit sub-system of the LVAT pilot farm.*

| RES4LIVE TECHNOLOGY | Remaining amount from the initial investment after a 20% subsidy support (€) | Remaining amount from the initial investment after a 40% subsidy support (€) | Sum of discounted net cash flows from the technology installed, after 6 years of operation (€) | Sum of discounted net cash flows from the technology installed, after 7 years of operation (€) | Sum of discounted net cash flows from the technology installed, after 9 years of operation (€) | Sum of discounted net cash flows from the technology installed, after 10 years of operation (€) | Sum of discounted net cash flows from the technology installed, after 12 years of operation (€) |
|---|---|---|---|---|---|---|---|
| BioCNG unit | 176,000.00 | 132,000.00 | 154,898.49 | 176,586.85 | 216,914.43 | 235,649.65 | 270,486.12 |

## 6.4.5 Gate-to-gate Life Cycle Costing: Farm tractor

**Midpoint level assessment**

A comparison (relative % difference) of the annual costs per FU between the FYAIS-LVAT-tractor and the RS-LVAT-tractor is presented in Figure 15. After the first year of the operation of the biomethane tractor, the most important difference is the elimination of energy cost, as a result of the substitution of purchased diesel with on-farm produced BioCNG. Additionally, we observe an expected increase in the machinery and building costs category due to the retrofitting works on the farm tractor (39.30%).

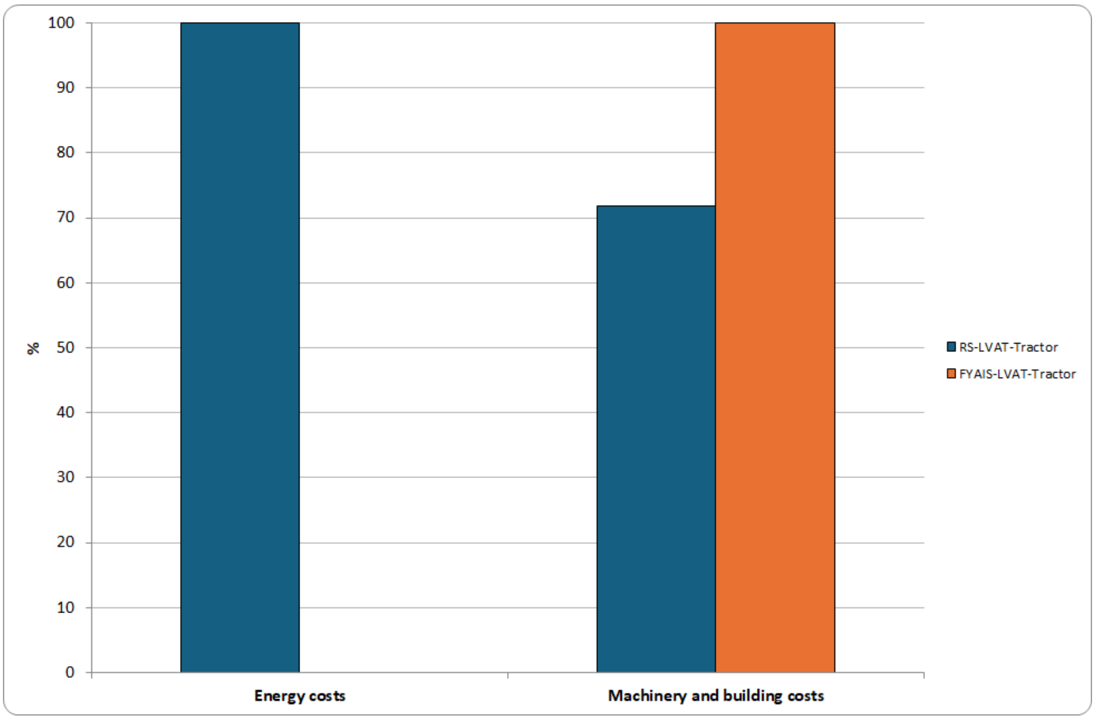


*Figure 15. Relative % difference of the costs per 1 h of tractor's on-farm operation between the FYAIS-LVAT-tractor and the RS-LVAT-tractor.*

In addition to the relative % differences presented in Figure 15, absolute differences in the cost categories (in €/h of tractor's on-farm operation) are presented in Table 39.

*Table 39. Differences in the various cost types expressed in €/h of tractor's on-farm operation between the after-interventions system (FYAIS-LVAT-tractor) and the reference system (RS-LVAT-tractor).*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE COSTS (€/h of tractor's on-farm operation) | DIFFERENCE IN COSTS (€/h of tractor's on-farm operation) |
|---|---|---|
| Overhead costs | 8.41 | -4.88 |
| Energy costs | 5.66 | -5.66 |
| Machinery and building costs | 2.74 | 0.77 |
| Gross output | - | - |

The difference in the economic performance of the farm tractor between FYAIS-LVAT-tractor and RS-LVAT-tractor is defined primarily by the difference in energy costs, i.e., elimination of diesel consumption. It should once again be noted the absence of the gross output category since the operation of the farm tractor is, by its nature, not a (final) product-oriented activity, but more of a task-oriented one.

**Endpoint level assessment**

Table 40 and Figure 16 suggest a 58.14% decrease (1.22 Pt/h of tractor's on-farm operation) in the SEcS of the FYAIS-LVAT-tractor in comparison to the RS-LVAT-tractor. This decrease in the overhead cost category, because of the elimination of fossil fuel consumption, implies an increase in the total economic performance of the FYAIS-LVAT-tractor in comparison to the RS-LVAT-tractor.

*Table 40. Difference in the Single economic score (SEcS) per hr of tractor's on-farm operation between the after interventions system (FYAIS-LVAT-tractor) and the reference system (RS-LVAT-tractor) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE SECS (Pt/h of tractor's on-farm operation) | DIFFERENCE IN SECS (Pt/h of tractor's on-farm operation) | CONTRIBUTION TO THE TOTAL SECS DIFFERENCE (%) |
|---|---|---|---|
| Direct production costs | 0.00 | 0.00 (0.00%) | 0.00 |
| Overhead costs | 2.10 | -1.22 (-58.14%) | 100.00 |
| Gross output | 0.00 | 0.00 (0.00%) | 0.00 |
| **Total** | 2.10 | -1.22 (-58.14%) | **100.00** |

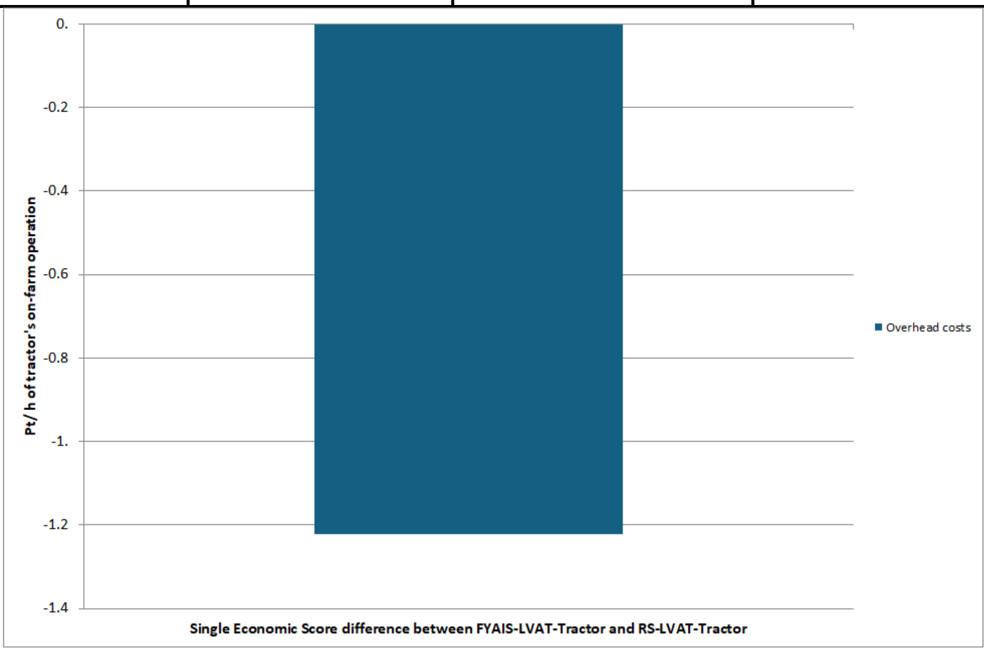


*Figure 16. Graphical representation of the difference in the Single economic score (SEcS) per hr of tractor's on-farm operation between the after-interventions system (FYAIS-LVAT-tractor) and the reference system (RS-LVAT-tractor).*

## 6.4.6 Gate-to-gate Life Cycle Costing: Farm tractor

The additional economic indicators, as estimated for the farm tractor sub-system of the LVAT pilot farm are shown in Table 41. The hourly operation of both the diesel tractor (RS-LVAT-Tractor) and the retrofitted biomethane tractor (FYAIS-LVAT-Tractor) is associated with negative net incomes. There is a negative balance between costs and benefits, as there is actually no gross output connected to the operation of the tractor. It should be noted that the retrofitting of the tractor led to an increase in the net income (58.11%), due to a decrease in the overhead costs - mostly the energy costs (as there was an elimination of the costs related to the fuel purchase). Nevertheless, it should not be neglected that the operation of the tractor replaces labour work and the associated costs have not been considered in the benefits of this analysis, as these benefits are common for both RS-LVAT-Tractor and FYAIS-LVAT-Tractor. Furthermore, regarding fuel efficiency, the RS-LVAT-Tractor consumed 3.82kg of fossil diesel/hr of tractor operation, while the FYAIS-LVAT-Tractor consumed 4.5kg of biomethane/hr of tractor operation, with a similar tractor utilization rate in both systems.

*Table 41. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-LVAT-Tractor and the RS-LVAT-Tractor.*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| **Profitability: Income; net income** | **4.88 (58.11%)** | **€ / hr of farm tractor's operation** |
| Efficiency: Cost efficiency; fuel efficiency | 3.82 vs. 4.5 | kg diesel/hr of farm tractor's operation vs. kg of biomethane/hr of farm tractor's operation |
| Efficiency: Productivity; tractor utilization rate | 0.00 (0.00%) | hr of operation/day |

**Discounted Payback Period (DPBP)**

The first-year net cash flow and the discounted net cash flow from the second year of the operation of the retrofitted tractor are provided in Table 42. These net cash flows are negative since the operation of the retrofitted tractor cannot be connected to a direct inflow of money for the LVAT farm. Indirectly, the operation of the retrofitted tractor can be associated with labour cost savings. However, such savings have not been considered in this analysis. Without considering these savings, and due to the negative annual discounted net cash flows, a return on the investment for retrofitting the farm tractor is not expected within the lifespan of the retrofitted tractor (12-15 years), if the sub-system of the retrofitted tractor is isolated from the rest of the LVAT sub-systems.

*Table 42. First year net cash flows and second year discounted net cash flows from the LVAT pilot farm's tractor operation, after retrofitting.*

| RES4LIVE TECHNOLOGY | INITIAL INVESTMENT FOR RETROFITTING (€) | COST OF BIOMETHANE FOR TRACTOR OPERATION (€/year) | ANNUAL MAINTENANCE COST (€/year) | ANNUAL INSURANCE COST (€/year) | NET CASH FLOW FROM THE TECHNOLOGY INSTALLED (€/year) | DISCOUNTED NET CASH FLOW FROM THE TECHNOLOGY INSTALLED - 2nd YEAR OF OPERATION (€/year) |
|---|---|---|---|---|---|---|
| Retrofitted tractor | 30,000.00 | 0.00 | 1,525.00 | 457.5 | -1,982.5 | -1,888.09 |

The information provided in Table 43 confirms that the sum of the discounted net cash flows after 15 years of operation of the retrofitted tractor is negative and higher than 20,000€. Even in the cases of receiving subsidies of 20% and 40% of the initial investment for tractor retrofitting, payback would not be possible for the isolated retrofitted tractor system.

*Table 43. Amount of money to be paid back, considering a 20% and 40% subsidy support for the farm tractor sub-system of the LVAT pilot farm.*

| RES4LIVE TECHNOLOGY | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 20% SUBSIDY SUPPORT (€) | REMAINING AMOUNT FROM THE INITIAL INVESTMENT AFTER A 40% SUBSIDY SUPPORT (€) | SUM OF DISCOUNTED NET CASH FLOWS FROM THE TECHNOLOGY INSTALLED AFTER 15 YEARS OF OPERATION (€) |
|---|---|---|---|
| Retrofitted tractor | 24,000.00 | 18,000.00 | -21,606.55 |

However, if the retrofitted tractor sub-system is considered in combination with the BioCNG unit and filling station sub-system, payback of the tractor retrofitting investment is possible before the end of the lifetime of the retrofitted tractor (and of the BioCNG unit, considering that the investment was completed approximately at the same period and that both the retrofitted tractor and the BioCNG unit started operating the same period). The information in Table 38 (DPBP of the investment of the BioCNG unit) suggests that the investment of the tractor retrofitting is returned in 11 to 12 years of operation of the BioCNG unit (as the difference between the sum of discounted net cash flows in the 12th and the 10th year of the operation of the BioCNG unit is higher than 30,000€). In the case of subsidies, the DPBP of the tractor retrofitting depends on the extent of the subsidies received both for the BioCNG unit and the tractor. In the case of 40% and 20% subsidies for both the BioCNG unit and the tractor, the DPBP of the tractor retrofitting could be less than 6 years and less than 9 years of the BioCNG unit's operation, respectively.

### 6.4.7 Gate-to-gate Life Cycle Costing: CHP/ Diesel tractor vs CHP/ BioCHP Plant/ BioCNG Tractor: Combined systems impact assessment

To illustrate the potential economic performance of the biogas/BioCNG-related interventions in the LVAT pilot farm, an annual operation scenario comparing the combined operation of the:

- "CHP/ Diesel tractor system" (RS), and
- "CHP/BioCHP Plant/BioCNG Tractor system" (FYAIS)

identical to that used in D5.3 (section 6.3.3), was considered. Since the Frefersonal Units (FU) of each sub-system refer to:

- 1 kWh of electric energy production for the CHP unit
- 1 h of on-farm operation for the diesel and BioCNG tractor, and
- 1 m3 of produced biomethane for the BioCNG unit

The obtained results for the SimaPro should be multiplied by the operation parameters on an annual basis. The following were assumed for an indicative year Table 44).

*Table 44. Assumptions for the annual operation of the combined system during the reference year (RS) and the first year after the interventions (FYAIS).*

| SUB-SYSTEM | UNITS | VALUE |
|---|---|---|
| CHP unit (RS) | kWh | 263,877.67 |
| CHP unit (FYAIS) | kWh | 206,533.62 |
| BioCNG (RS) | $m^3$ | 0.00 |
| BioCNG (FYAIS) | $m^3$ | 23,438.92 |
| Diesel tractor (RS)a | h | 1,277.50 |
| BioCNG tractor (FYAIS)[a] | h | 1,277.50 |
| *[a] Assuming a daily operation of 3.5h* | | |

The comparison considers the values of Table 44, as well as the annual net income for each subsystem (Table 45).

*Table 45. Annual net income from the sub-systems during the reference year (RS) and the first year after the interventions (FYAIS).*

| SUB-SYSTEM | ANNUAL NET INCOME PER UNIT (€) | ANNUAL NET INCOME (€) |
|---|---|---|
| CHP unit (RS) | 1.17E-02 | 3,090.35 |
| CHP unit (FYAIS) | 3.90E-03 | 805.70 |
| BioCNG (RS) | 0.00 | 0.00 |
| BioCNG (FYAIS) | -0.77 | -18,077.77 |

*Table 45. Annual net income from the sub-systems during the reference year (RS) and the first year after the interventions (FYAIS) (continued).*

| SUB-SYSTEM | ANNUAL NET INCOME PER UNIT (€) | ANNUAL NET INCOME (€) |
|---|---|---|
| Diesel tractor (RS) | -8.41 | -10,738.17 |
| BioCNG tractor (FYAIS) | -3.52 | -4,495.51 |

Summing the annual economic performance in terms of net income for each sub-system for the reference year (RS) and the first year after the interventions (FYAIS), we conclude with the annual net income for the combined system. The results are presented in Table 46.

*Table 46. Annual net income for the combined system during the reference year (RS) and the first year after the interventions (FYAIS).*

| SYSTEM | ANNUAL NET INCOME (€) |
|---|---|
| RS | -7,647.82 |
| FYAIS | -21,767.57 |

A deterioration in the economic performance of the FYAIS is observed compared to RS (2.85 times more expensive). This is primarily due to the high investment cost of the BioCNG unit, as well as its operation.

However, the case of a higher capacity[5] BioCNG unit could be considered as an alternative scenario. This unit would be included in a combined CHP-BioCNG-tractor system with similar annual net incomes for the CHP unit and the BioCNG tractor in a dairy cattle farm, which can supply the necessary manure substrate for a higher capacity biogas unit. The absolute values of the additional economic indicators for this unit are shown in Table 47. Taking into account an annual BioCNG production of 79,017.57m$^3$, the annual net income for this unit becomes 22,146.67€, implying a profitable operation of this unit alone. If this net income is considered for the combined system, the total net income would be 18,456.86€/year, showing a noticeable improvement in profitability in comparison to both the RS and the FYAIS.

*Table 47. Absolute values of the additional economic indicators of the higher capacity BioCNG unit.*

| ECONOMIC INDICATOR | INDICATOR VALUE | UNIT |
|---|---|---|
| Profitability: Economic return; gross output | 1.12 | € / m$^3$ biomethane at the gate of the BioCNG unit's filling station |
| Profitability: Profit; gross margin | 1.12 | € / m$^3$ biomethane at the gate of the BioCNG unit's filling station |

[5] Building on the RES4LIVE design, a higher-capacity BioCNG unit (35 m$^3$/h) was developed and tested as part of a privately funded project.

*Table 47. Absolute values of the additional economic indicators of the higher capacity BioCNG unit (continued).*

| ECONOMIC INDICATOR | INDICATOR VALUE | UNIT |
|---|---|---|
| **Profitability: Income; net income** | **0.28** | **€ / m$^3$ biomethane at the gate of the BioCNG unit's filling station** |
| Profitability: Product sales; biomethane | 1.12 | € / m$^3$ biomethane at the gate of the BioCNG unit's filling station |
| Efficiency: Cost efficiency; direct production costs per gross output | 0.00 | - |
| Efficiency: Productivity; BioCNG yield per unit of biogas | 0.56 | m$^3$ biomethane / m$^3$ biogas input at the BioCNG unit |

Moreover, the obtained results indicate that for optimising the economic performance of such interventions, further investigation of operation scenarios is deemed necessary. This could include different ranges in hours of operation, as well as energy costs and selling prices.

### 6.4.8 Gate-to-gate Life Cycle Costing: Electric boiler and PVT system

**Midpoint level assessment**

A comparison (relative % difference) of the annual costs per FU between the FYAIS-LVAT-e-boiler-PVT and the RS-LVAT-e-boiler for the electric boiler and PVT system is presented in Figure 17. After the first year of the operation of the combined system, the most important difference is the elimination of energy costs (-97.28%), as a result of the reduced operation of the electric boiler. Additionally, we observe an expected increase in the machinery and building costs category due to the introduction of the PVT system (218.09%).

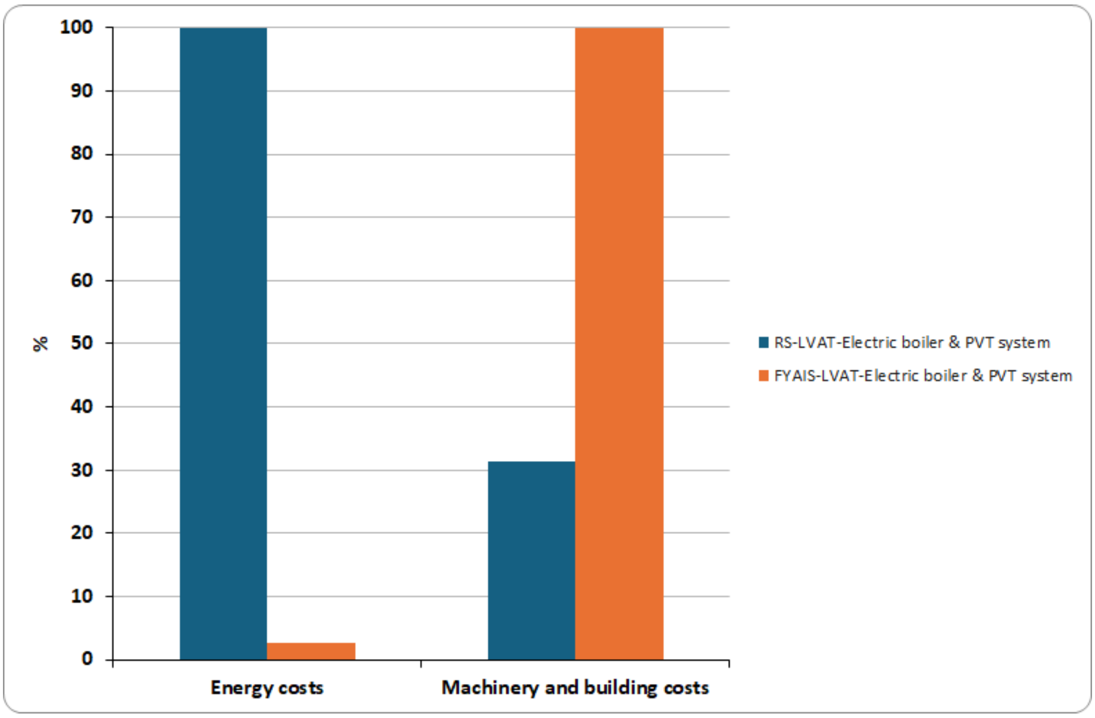


*Figure 17. Relative % difference of the costs per 1 kWh of heat produced between the FYAIS-LVAT (electric boiler and PVT system) and the RS-LVAT (electric boiler).*

In addition to the relative % differences presented in Figure 17, absolute differences in the cost categories (in €/kWh of heat produced) are presented in Table 48.

*Table 48. Differences in the various cost types expressed in €/kWh of heat produced between the after-interventions system (FYAIS-LVAT; electric boiler and PVT system) and the reference system (RS-LVAT; electric boiler).*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE COSTS (€/kWh of heat produced) | DIFFERENCE IN COSTS (€/kWh of heat produced) |
|---|---|---|
| Direct production costs | - | - |
| Overhead costs | 0.36 | 0.10 |
| Energy costs | 0.22 | -0.21 |
| Machinery and building costs | 0.14 | 0.31 |
| Gross output | - | - |

The difference in the economic performance of the electric boiler/ PVT system between FYAIS-LVAT-e-boiler-PVT and RS-LVAT-e-boiler is defined primarily by the difference in energy costs, i.e., less hours of electricity heating by the boiler. The absence of the gross output category is expected since the system does not produce a final product for sale.

**Endpoint level assessment**

Table 49 and Figure 18 suggest a 28.24% increase (115.55 instead of 90.10 mPt/kWh of heat produced) in the SEcS of the FYAIS-LVAT-e-boiler-PVT in comparison to the RS-LVAT-e-boiler. This increase in the overhead cost category, because of the increased machinery and equipment costs (PVT purchase and installation) leads to decreased total economic performance of the FYAIS-LVAT-e-boiler-PVT in comparison to the RS-LVAT-e-boiler.

*Table 49. Difference in the Single economic score (SEcS) per kWh of heat produced between the after-interventions system (FYAIS-LVAT-e-boiler-PVT) and the reference system (RS-LVAT-e-boiler) for each midpoint cost impact category.*

| MIDPOINT COST IMPACT CATEGORY | REFERENCE SECS (mPt/kWh of heat produced) | DIFFERENCE IN SECS (mPt/kWh of heat produced) | CONTRIBUTION TO THE TOTAL SECS DIFFERENCE (%) |
|---|---|---|---|
| Direct production costs | - | 0.00 (0.00%) | 0.00 |
| Overhead costs | 115.55 | 25.45 (28.24%) | 100.00 |
| Gross output | - | 0.00 (0.00%) | 0.00 |
| **Total** | **115.55** | **25.45 (28.24%)** | **100.00** |

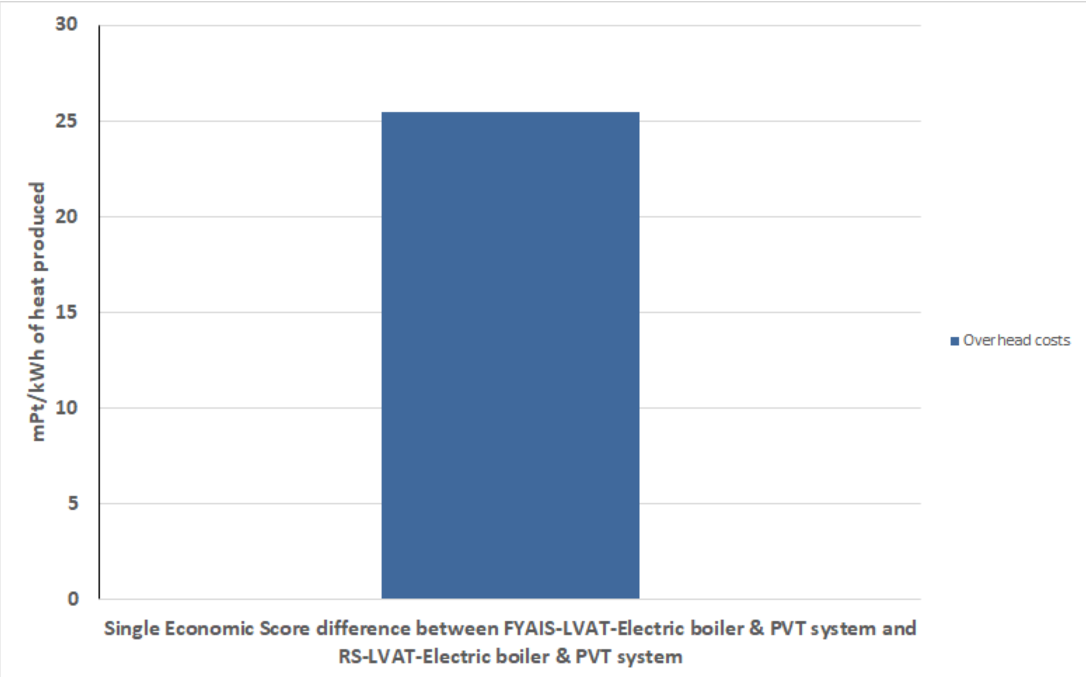


*Figure 18. Graphical representation of the difference in the Single economic score (SEcS) per kWh of heat produced between the after-interventions system (FYAIS-LVAT-e-boiler-PVT) and the reference system (RS-LVAT-e-boiler).*

### 6.4.9 Additional economic indicators: Electric boiler and PVT system

The values of the differences in the relevant additional economic indicators for the sub-system of the electric boiler (after the integration of the PVT system (FYAIS-LVAT-e-boiler-PVT) vs. before the integration of the PVT system (RS-LVAT-e-boiler)) are shown in Table 50. A negative difference in the net income is observed, suggesting a reduction in the net income for the FYAIS-LVAT-e-boiler-PVT (28.24%). This reduction can be attributed to the increase in the machinery and building costs per kWh heat at the gate of the electric boiler, due to the integration of the PVT system. Although there is a considerable reduction in energy costs, as the necessary electricity is produced by the PVT system and not purchased by the national electricity grid, this reduction cannot compensate for the increase in machinery costs. It should not be neglected that the net income is negative for both FYAIS-LVAT-e-boiler-PVT and RS-LVAT-e-boiler, suggesting a negative cost-benefit balance from the operation of this sub-system. Indeed, there is no gross output (i.e. positive economic inflow) from the operation of this sub-system, but only costs. Regarding the thermal efficiency of the electric boiler, it was considered equal to 95% for both FYAIS-LVAT-e-boiler-PVT and RS-LVAT-e-boiler. The integration of the PVT system does not affect this thermal efficiency.

*Table 50. Difference (absolute values and relative %) in the values of the additional economic indicators between the FYAIS-LVAT-e-boiler-PVT and the RS-LVAT-e-boiler.*

| ECONOMIC INDICATOR | DIFFERENCE IN THE INDICATOR VALUE | UNIT |
|---|---|---|
| **Profitability: Income; net income** | **-0.10 (28.24%)** | **€ / kWh heat at the gate of the electric boiler** |
| Efficiency: Cost efficiency and productivity; thermal efficiency of the boiler | 0.00 % | fraction of the electricity consumed, turned to heat output |

**Discounted Payback Period (DPBP)**

The first year net cash flow and the discounted net cash flow from the second year of the operation of the integrated PVT system (electric boiler sub-system of the LVAT pilot farm) are provided in Table 51. These net cash flows are positive, showing that the electricity savings due to the operation of the PVT system are higher than the costs (operating, maintenance, insurance) on an annual basis. Despite the positive net cash flows, this inflow of money due to the operation of the isolated electric boiler-PVT system is not high enough to return the investment of the PVT and solar station system within the useful lifespan of the PVT system (25 years).

*Table 51. First year net cash flow and second year discounted net cash flow from the PVT and solar station installed and operating in the electric boiler sub-system of the LVAT pilot farm.*

| RES4LIVE TECHNOLOGY | INITIAL INVESTMENT (€) | ELECTRICITY SAVINGS (€/year) | COST FOR ANNUAL ELECTRICITY CONSUMPTION (€/year) | ANNUAL MAINTENANCE COST (€/year) | ANNUAL INSURANCE COST (€/year) | NET CASH FLOW FROM THE TECHNOLOGY INSTALLED (€/year) | DISCOUNTED NET CASH FLOW FROM THE TECHNOLOGY INSTALLED – 2nd YEAR OF OPERATION (€/year) |
|---|---|---|---|---|---|---|---|
| PVT and solar station | 55,500.00 | 2,191.44 | 52.44 | 650.00 | 277.50 | 1,211.5 | 1,153.81 |

This is also confirmed by the information shown in Table 52, which presents the sum of the discounted net cash flows from the integrated PVT-electric boiler system after 25 years of operation of the PVT system. Even in the cases of subsidy support, covering 20% and 40% of the initial PVT system investment, the return on investment does not seem possible within the expected lifespan of the PVT system.

*Table 52. Amount of money to be paid back, considering a 20% and 40% subsidy support for the PVT system integrated in the electric boiler sub-system of the LVAT pilot farm.*

| RES4LIVE TECHNOLOGY | Remaining amount from the initial investment after a 20% subsidy support (€) | Remaining amount from the initial investment after a 40% subsidy support (€) | Sum of discounted net cash flows from the technology installed after 25 years of operation (€) |
|---|---|---|---|
| PVT and solar station | 44,400.00 | 33,300.00 | 17,928.55 |

# 7 CONCLUSIONS

The main findings from the Life Cycle Costing (LCC) analysis, which estimates the economic impact of the systems with the RES4LIVE technologies after one year of operation (FYAIS) compared to a reference system (RS) before the RES4LIVE interventions, are outlined below.

The results indicate a rise in cost per kg of sow at the GOLINELLI hog barn gate following the installation of new technologies. Although there is an approximate 15% increase in gross output, energy costs for operating the installed systems rise by about 38%, leading to a decline in overall economic performance. The investment in these technologies alone does not generate a return; however, enhancements in barn climate could improve the welfare and productivity of sows and boars, potentially benefiting the sows' farrowing process preparation. In the nursery barn, direct production and overhead costs increase slightly, yet overall economic performance in FYAIS compared to RS improves by nearly 14%. The discounted payback period (DPBP) for the nursery barn is projected at 33 years, but with 20% to 40% subsidy support, the DPBP could be achieved in 21-22 years or as early as 13-14 years after installation, respectively.

At EV ILVO farm, overall economic performance increased nearly 3.5 times, driven primarily by a 41.34% rise in gross output. Energy and machinery/building costs increase by €0.09 and €0.03 per kg of finished pig live weight at the farm gate, respectively. The integrated RES system could enable a DPBP for the EV ILVO farm in 18 years; with 20% or 40% subsidy support, the DPBP could be reached in 13-14 years or as quickly as 9-10 years, respectively.

The new systems at AUA increased gross output by approximately 25% after one year of operation. However, a sevenfold increase in overhead costs - primarily energy, machinery, and building costs - significantly reduced economic performance. Improved outcomes could be achieved by adjusting on-farm energy consumption, especially in ventilation, though even with adjustments, the economic performance remains lower than the one of the RS. Achieving a reasonable payback period (DPBP) at AUA would require substantial subsidies along with an increase in the relatively low sale price.

Integrating a BioCNG unit at LVAT farm causes only a slight decrease in CHP plant economic performance, while the BioCNG unit itself generates approximately €0.8 per $Nm^3$ of BioCNG produced, resulting in a DPBP of 10 years in the worst-case scenario. Modifying the farm tractor eliminates fuel purchase costs, adding €4.88 per hour of on-farm operation, with a potential payback in around an additional 2 years (12 years in total for both BioCNG unit and tractor retrofitting investment). However, the high investment cost of the BioCNG unit and its operational expenses led to a reduction in the overall economic performance of FYAIS compared to RS. Increasing the BioCNG unit's capacity could enhance profitability compared to both RS and FYAIS. Lastly, while the PVT system integration at LVAT alongside an existing e-boiler yields annual savings of nearly €2,200, the DPBP - despite subsidy support - still exceeds the PVT system's expected lifespan due to high initial costs.

Overall, the economic assessment suggests that implementing new technologies in intensive livestock facilities can yield positive results, though this is case-dependent. Notable economic improvements were observed at the GOLINELLI nursery barn and EV ILVO farm. At LVAT, expanding the capacity of the BioCNG unit could boost economic performance. Conversely, in the GOLINELLI hog barn and especially at the AUA poultry farm, increased energy consumption and high investment costs must be addressed to unlock future economic potential.