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A blueprint for developing and applying precision livestock farming tools: A key output of the EU-PLF project

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Introduction

The latest projections from the United Nations Population Division indicate that the world population is expected to grow to 9.15 billion inhabitants by 2050, implying an increase of more than 34% from the current 7 billion people. This growing population is likely to have greater economic possibilities, especially in previously lower-income countries. This is expected to drive worldwide demand for animal products that is estimated to increase by more than 40% in the next 15 yr (FAO, 2007). Satisfying this demand will lead to a significant increase of the worldwide number of livestock, especially in the BRIC (Brazil, Russia, India, and China) countries (Alexandratos and Bruinsma, 2012).

Economy of scale and intensification/specialization will lead to increasingly larger farms and fewer farmers. Higher demand for meat will exert an even stronger pressure on industry consolidation and efficiency, engendering the creation of larger farms. Modern farmers will be confronted with increasing pressure to care for a larger number of animals per farm to have an economically viable business, which will become more acute in future years (EU, 2014). In China, the first pig "farm" of 300,000 fattening pigs in one location will become a reality (Godfrey, 2015).

Today, technical support can bring the animals closer to the farmer by assisting the farmer in gathering information about the animals and presenting it in a workable way. Closer attention to the animal does not only impact animal welfare and health but also the economic advantages for the farmer. At the same time, there are increasing concerns about animal health in relation to human health issues with the potential for pandemic outbreaks continuously looming over the industry (Dawood et al., 2011). In addition to health, other aspects of animal welfare have become an important point.

Today's European stakeholders in the livestock sector are more conscious about keeping animals for food production: they should be raised, treated, and slaughtered in a more animal-friendly way and should have a life worth living (Miele and Bock, 2007). Moreover, livestock production today has to combine several requirements such as:

· guaranteed food safety and quality
· improved animal welfare and health
· reduced environment impact
· improved sustainability and efficiency

As a consequence, many variables need to be monitored during the production process at the animal, farm, and food chain level.

Livestock management decisions are mostly based on the observation, judgment, and experience of the farmer. However, with the increased scale of the farms and the corresponding higher number of animals, it is increasingly difficult for farmers to monitor their animals in a satisfactory way. Moreover, it is impossible for a person to monitor the animals continuously, during 24-h a day. The objective of this paper is to introduce a formalized approach to assist farmers in applying the philosophy of precision livestock farming in the management of their herds. This tool, called the EU-PLF Blueprint, was one of the key outputs from the EU-PLF project (www.eu-plf.eu), a €8 million Framework 7 project funded by the EU commission.

Precision Livestock Farming in Practice

Berckmans (2006) identified the main objective of (**PLF**) as developing technology and tools for online, continuous monitoring of animals. Precision livestock farming exists to better inform farmers on the current status of the animals and their environment and help them make quick and evidence-based decisions to adjust to changes in animal requirements, health, and behavior. Modern technology now makes it possible to use cameras, microphones, and sensors sufficiently close to, and sometimes on, the animal so that they can, in effect, assist the farmers' eyes and ears in everyday farming. In livestock production today, farmers have access to different technologies that allow them to follow the production performance of the farm. For example, book-keeping software allows overall economic improvement on the farming system level, whereas automation of feeding, climate control, and harvesting (e.g., milking) enables local control of on-farm processes. However, it is still true that these tools are often more focused on optimizing/automating of the process for labor reduction rather than focusing on the needs of the animal, the central part of the process. Precision livestock farming is based on the philosophy that fully automated

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continuous monitoring of animals will enable farmers to monitor the health and welfare status of their animals continuously and automatically.

Enabling real-time management is core to PLF, and it is this approach that helps to secure improved health, welfare, and yields as well as reduce environmental impact. In fact, it is this real-time aspect and being part of the management system that makes it quite different from other solutions like the use of so-called Iceberg indicators (FAWC, 2009). Similar to an iceberg, in which the visible part is only a small part of what is hidden under the water, a bitten tail in the slaughterhouse is an indication of a bigger problem of tail biting during the fattening period. Instead, PLF aims to help and adapt the process management on the spot in real time for the animal that is followed continuously during the production process and warn the farmer immediately. Many PLF solutions are now robust and are commercially available on the market. During the EU-PLF project, significant effort was focused on the return on investment potential of PLF on commercial farms (Hogeveen, 2016). For example, the SOMO Respiratory Distress Monitoring system of Soundtalks NV was found to identify respiratory problems up to 2 wk before a disease outbreak, potentially increasing the feed margin (income minus feed cost) by €6.5 per pig place per year if this is used as an early warning tool (Carpentier et al., 2016). An example of PLF in an integrated management solution is reported in Figure 1.

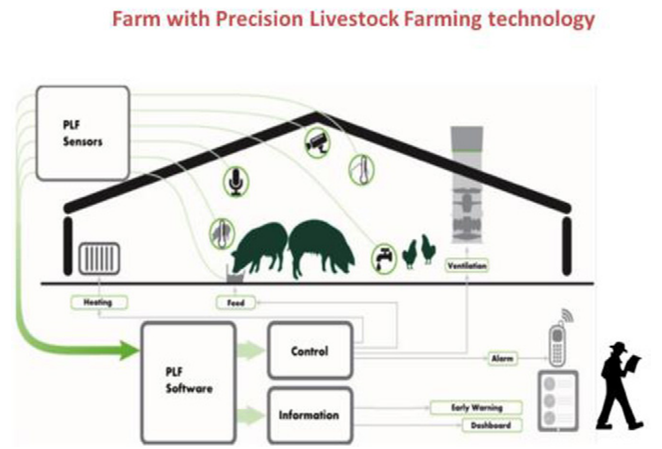

Figure 1. Vision of precision livestock farming technology implementation.

Supporting Farmers in Adopting Precision Livestock Farming

Traditionally, livestock production has been based around small-scale family farming, and what was grown on the farm was used to feed the family and local community. Modern intensive livestock production is extremely different as farmers need to exploit economies of scale by increasing animal numbers to dilute the fixed costs and buffer against volatility in the meat, milk, feed, and energy markets. As a consequence, production is moving toward fewer and larger farms across the world. A key question now is how can farmers manage their ever-growing production systems to achieve high quality, sustainable, and safe meat production that can meet this demand.

Due to the large farm sizes, farmers have less time to care for each individual animal while European society demands that animals are entitled to receive individual attention. Especially for the production-intensive sectors like fattening pigs, economy-of-scale makes it more and more difficult for European farmers to continuously pay attention to individual animals and build a stronger relationship with them. This has social and economic consequences for all stakeholders involved, first and foremost for animals and farmers. Good care is precisely the key for good productivity, health, and welfare, and thus for both a business that is accepted by society as well as economically viable.

Recent studies have indicated that achieving scale-dependent benefits in agriculture requires new production technologies (Sheng et al., 2015). An example of this is seen in how the ability to monitor the health and well-being of the animals changes with increasing farm size. Previously, farmers could monitor the animals by observing and interacting with individuals and make farming decisions based on experience and historical knowledge about the particular animals. However, such a direct relationship may be difficult to build in modern large-scale production facilities due to the number of animals in the herd (Berckmans, 2006). The transition from PLF products from laboratory research into viable commercial products has started. Precision livestock farming systems are becoming available in products and are now operational in commercial farms. From there, we have to discover how they can create value for the animals and the farmers by saving labor time, saving time in detecting problems, giving less stress to the farmer, solving problems on the spot immediately instead of later for other animals, giving social recognition to the farmer, and giving quantitative numbers about what happens to the animals and others. However, many farmers across the world do not understand how PLF solutions can create such value for them. This was a challenge taken on during the EU-PLF project.

European PLF is driving the development and implementation of PLF technology across the world. To keep this leading position in an emerging market, the EU has invested heavily by supporting several research projects like EU-PLF. During EU-PLF, it was acknowledged that new technology is necessary to ensure that farm animals are reared and killed humanely with minimal environmental impact and that food from animals is safe for consumers (EU-PLF, 2016). However, it was also recognized that the experts in this field must support farmers and give them the best chances to deploy PLF solutions in an optimal way. Therefore, a primary aim of the project was to develop a blueprint for PLF application by farmers across the world.

Overview of the Work Done during the EU-PLF Project

The EU-PLF project took on the challenge of translating the PLF systems that have already been developed at the laboratory scale into commercial products with significant social and economic value creation for farmers and companies alike. The project dealt with three specific subjects: (1) the definition and measurement of key indicators, (2) the creation of social and economic value, and (3) the development and validation of a blueprint for PLF innovation in the livestock sector. The general approach taken in EU-PLF is outlined in the following sections.

Defining and Measuring Key Indicators

Within EU-PLF, we defined a key indicator (**KI**) as a variable that quantifies the state or level of the animal health and welfare, environmental load, or productivity of a farm. Similarly, a gold standard (**GS**) was defined as a reference value or the best truth to check whether the KI is a good measure of health and welfare. In November 2012, the project began by defining a set of important existing and new PLF-measureable

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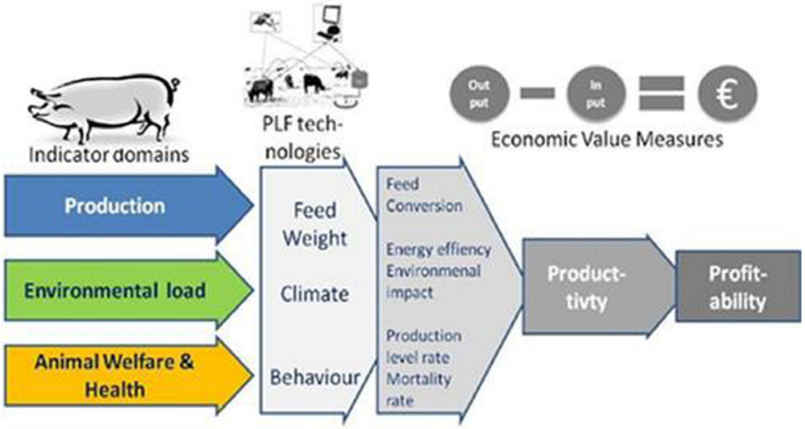

Figure 2. Scheme relating key indicators on a livestock farm to the profitability potential for the farmer.

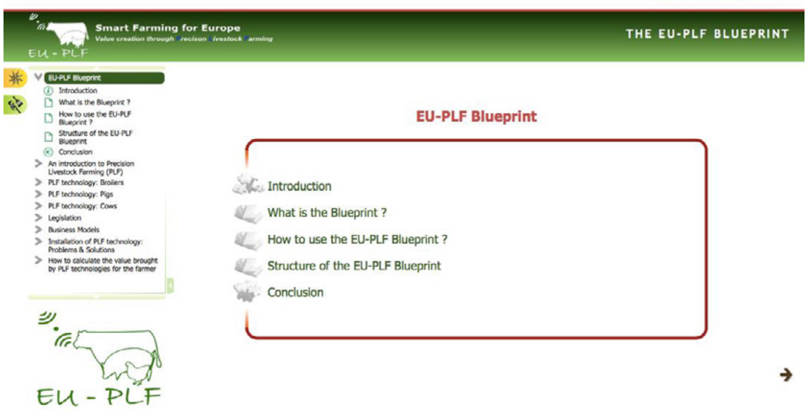

Figure 3. A screen shot of the blueprint structure.

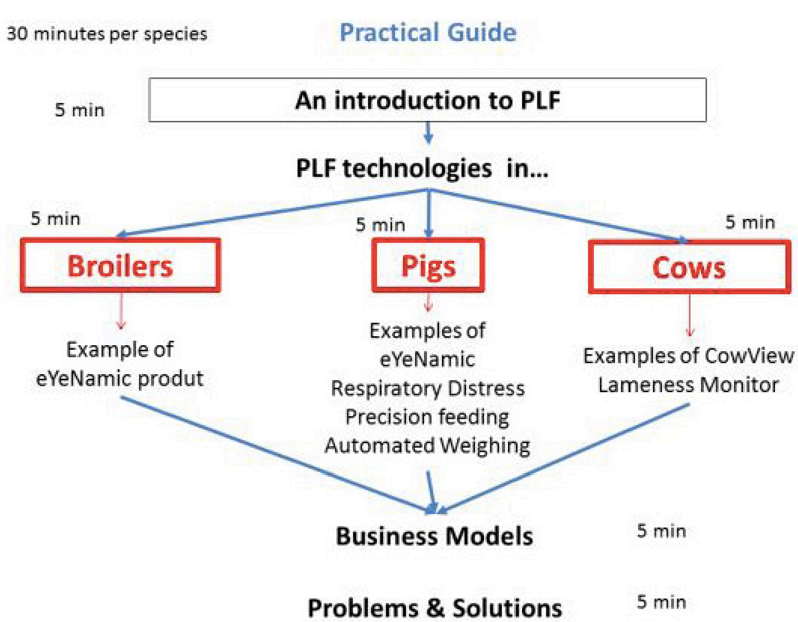

Figure 4. Blueprint logic line.

KIs, along with associated GS's based on the experience of a multi-disciplinary group of scientists and technology providers, and combining outputs of related EU projects such as Welfare Quality. Lists of these key indicators are available in the first EU-PLF deliverable (Nielsen et al., 2013). On each of the 20 farms, some KIs were selected for monitoring with PLF technology in at least one of the domains of welfare and health, environmental load, and productivity.

Creation of Social and Economic Value

Along with the task of monitoring important KIs, PLF solutions should also exploit the relationship between monitored KIs (for welfare, health, environment, and productivity) and value measures to actively control process inputs (feed supply, climate control, medication, etc.). An important objective of the project was to analyze the social and economic value creation potential of exchanging collected data and information along the feed–animal–food supply chain. Economic value creation was collected from farm data that included feed conversion, growth rate, mortality, medical costs and chain data like meat quality in the slaughtering house. Later in the project, the selected individual farmers testified about their experience to many more farmers and participated in open discussions about the value of PLF for the farmer and other stakeholders along the feed–animal–food chain. The realization of economic value creation with PLF is given in Figure 2.

Validated Blueprint for Innovation in the European Livestock Sector

The EU-PLF Blueprint is a manual for farmers, their surrounding industry including high-tech small- and middle-sized enterprises, and other stakeholders.

It is a reference tool offering pragmatic guidance on how PLF systems can be implemented at the farm level to create value for the farmer and other stakeholders. To analyze how PLF technologies can create value at farm level by improving animal welfare, health, environmental load, and productivity, extensive field tests are performed by scientific and industrial partners in collaboration with high-tech small and middle-size enterprises. Moreover, 20 farmers, spread over Europe, have used and experienced the technology and actively given feedback to help us develop this blueprint. Highly experienced European teams from different disciplines with a proven track record in animal and PLF-related fields—animal scientists, veterinarians, ethologists, bio-engineers, engineers, social scientists and economists, leading industrial market players in the livestock industry, and high-tech small- and middle-sized enterprises—have joined a consortium together with 20 farmers to deliver the EU-PLF Blueprint, a useful practical guide. The blueprint is made for all stakeholders related to PLF and representatives of the stakeholders (mainly stockpersons and related industry).

The aim of the blueprint is that all the PLF stakeholders can use it; for example, a company can use it to transfer its developed prototype into an implementable system, make it operational on farm, and prove that value is created at least on farm level. The

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blueprint highlights the business opportunities that result from EU-PLF. It leverages the economic and organizational research activities conducted during the course of EU-PLF and is complemented by an in-depth market analysis that goes beyond the common knowledge of the state-of-the-art. The blueprint is available to all consortium members and supports the confidential exploitation activities of individual stockpersons, industrial partners, and small-to-medium-sized enterprises (SMEs). The blueprint will soon be available through a website and can be used in an interactive way to support the PLF industry in Europe.

How to Use the Blueprint

Website access and structure

To access the blueprint, farmers and industry professionals must log on to the e-course website, which is currently hosted by Agrocampus-Ouest in France. The URL of the e-course and blueprint website is: https://tice.agrocampus-ouest.fr/enrol/index.php?id=917. There you can request log-in credentials. Upon entering the blueprint portal, the reader is first introduced to the structure of the blueprint, which is shown in Figure 3.

In the introductory section, the reader learns how to navigate the blueprint in an effective way. Figure 4 shows the individual paths that farmers/technology providers interested in dairy, pig, and broiler can take when navigating the blueprint. Since farmers and professionals have limited time to study this information, we designed the blueprint to be read completely from start to finish in approximately 30 min. The typical division of this time across the different sections is shown in Figure 4. Of course, we acknowledge that some people would like further depth of understanding than what is available in the blueprint. For those, this section includes a link to the PLF e-course, which is an 8-h course that covers PLF technology development and application more thoroughly.

Introduction to precision livestock farming

Here the reader is introduced to the core arguments driving the development and application of PLF technologies. Most of these are already given in the text above, but in the blueprint, they are presented in a far more visually appealing way, as the key aim is to deliver a high-impact message as quickly as possible. The key of this section is that the tools for PLF can only be developed through multidisciplinary collaborations and that currently systems are creating values for the farmers at the moment. The section finishes with a brief pictorial overview of examples in PLF systems.

Details on specific precision livestock farming technologies

The following three sections discuss the details on the specific technologies in the field currently. For broiler production, the eYeNamic systems are presented, and its implementation is demonstrated schematically and through a commercial video. Figure 5 gives an overview of the eYeNamic discussion in the blueprint. The subsections include briefing on technology, applications of the product, and value it creates for the farmer. The ambition is not only to present the product in a commercial sense, but to highlight

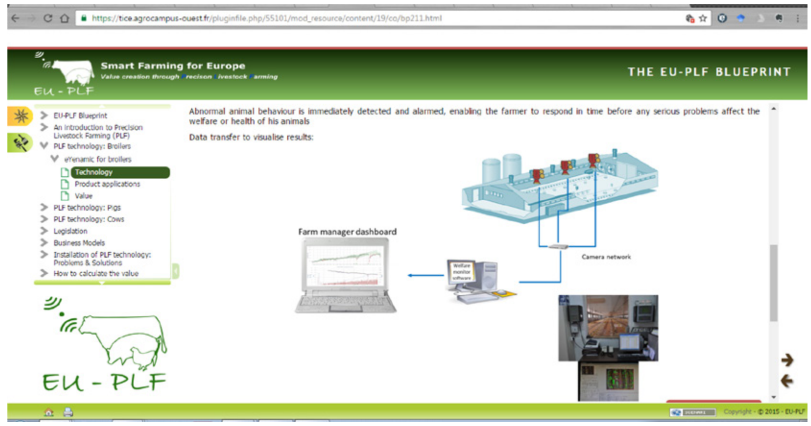

Figure 5. eYeNamic presentation.

Business Models for Precision Livestock Farming as a Service

In this section, an overview of how PLF can be practically realized as a service tool for farmers is introduced. Of course, PLF is more than just a service tool for farmers, PLF can also be used in closed loop processes, such as precision feeding. However, this type of model was not under consideration during EU-PLF, and therefore not described in the blueprint. Four different models are presented and discussed in enough detail to deliver the concept. These include:

- **Model 1: PLF as a sensor.** An economic description of how such a business model would work is given for the case where a farmer uses standard environmental measurements with PLF (biometric) sensors.
- **Model 2: Early warning with PLF technology.** An economic description of how such a business model would work for a case where a farmer installs PLF sensor systems, and an early warning tool is used as part monitoring the production process.
- **Model 3: Process optimization with PLF technology.** An economic description of how such a business model would work is given for the case where all PLF sensor techniques will be installed and the early warning tools will be used to monitor the production process, with flock or herd reports being made and used for on-farm process optimization. These farm reports are based on references set by the genetic breeding potential of the animals and the current market prices in the sector. These reports can be used to compare different flocks/herds within 1 yr or different houses within one round.
- **Model 4: Continuous consultancy and benchmarking of PLF data.** An economic description of how such a business model would work is given for the case where all PLF sensor techniques will be installed and the early warning tools will be used to monitor the production process, with flock or herd reports being made and used for on-farm process optimization. In addition, meta-data analysis will be applied. Meta-data analysis implies that the flock/herd data are analyzed on a daily level, and the process settings are updated on a daily level. Previously, process settings were updated after each flock/herd report, whereas in this business model, the process is updated during the production process. This gives the farmer more process control to compensate the volatile feed and meat prices.

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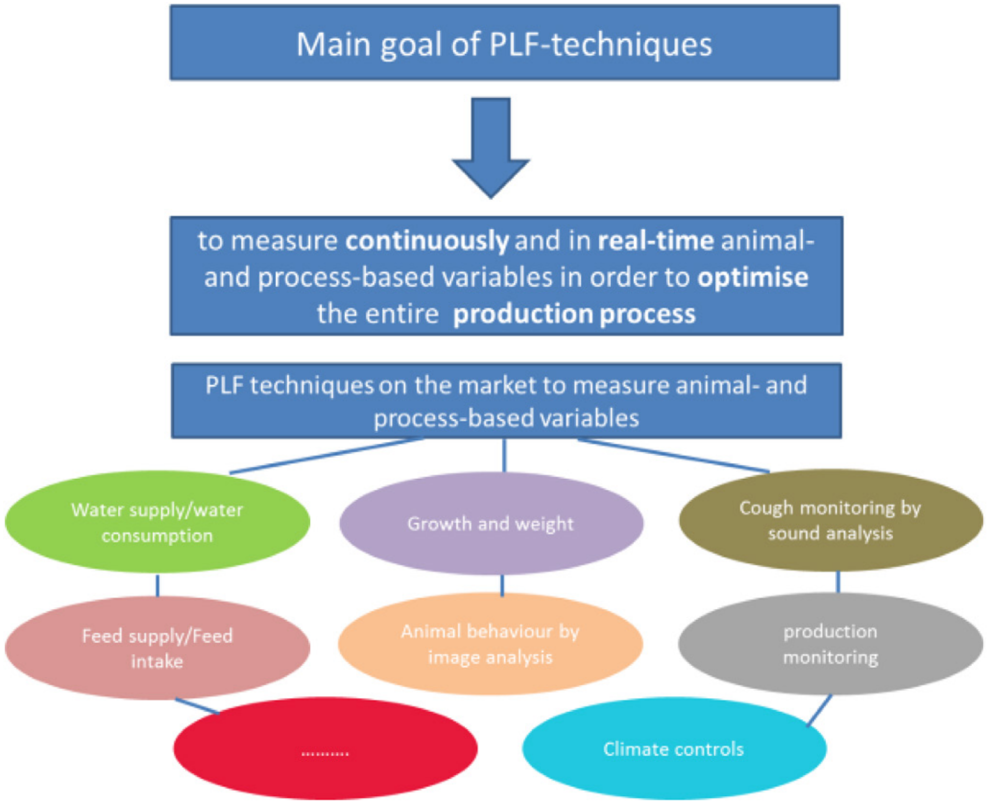

Figure 6. Schematic showing the integration of PLF products.

the scientific principles on which it is based and how the product can be used in an appropriate way to generate value for the farmer.

Legislation

In this section, the new Animal Health Law (European Commission, 2016) that has been recently released in the EU is briefly discussed. This law brings together more than 40 legal acts enforced in Europe to safeguard the health and welfare of livestock during the production process. A key aspect of this law that has not previously been considered is the need to link animal health and welfare and increase efforts in animal health and welfare surveillance. This is where precision livestock farming can greatly assist the producers and veterinarians of the future.

As shown in Figure 6, the main future target of the service package is the linking of the different PLF solutions to create value for the farmer. This integration is done by the consultant.

Installation of PLF technology: Problems and solutions

In this part, practical problems and solutions during installation of PLF technologies within EU-PLF are presented. During the project, it was considered important to log all the key challenges faced and problems that occurred during installation and system follow-up. Below the key issues that we encountered are outlined for future developers to consider that have been highlighted in the blueprint.

Power–battery life of sensors. The battery life of PLF equipment requiring sensors to be worn by an animal (e.g., accelerometers) is a worry for farmers. It is essential in such sensors that the battery life does not incur a heavy workload on the farmer for recharging/replacing. Low-power systems are therefore essential, and significant considerations must be made for the transfer of data, i.e., the amount of data, frequency, and range of transfer. To get around the problem, PLF systems (typically for dairy) transfer small amounts of filtered data only once or twice a day to save on costs and power efficiency.

Power–stability on the farm. Power outages are regularly encountered on farms. The loss of power to a farm can affect the running of the equipment such as climate control and feeding or cooling equipment and can result in significant economic losses on livestock farms. Precision livestock farming systems should act as a line of defense in detecting abnormalities on the farm, and therefore, must be robust to these outages. During EU-PLF, the main advice emerged was that when in doubt about the stability of the on-farm power install an Uninterruptible Power Supply (**UPS**) to detect a power failure and quickly switch over to run your equipment on its battery.

Internet access on the farm. The instability of internet connections proved to be a significant problem for the installation and operation of PLF systems during the project. Farms are typically in less populated rural areas of a country, and therefore, the 3G network coverage is oftentimes poor. Moreover, the lack of broadband connections means that PLF solutions cannot rely completely on cloud-based data analysis at the moment.

Physical robustness of the systems. Livestock buildings need to be regularly cleaned by power washing. Therefore, any sensor systems within a building need to be able to withstand high-pressure water jets. Technology providers must completely test their equipment and physical bracketing, so failure doesn't occur. Moreover, the placement of the systems themselves or any associated wiring should not be within reach of the animals and be pest resistant; otherwise, they can become damaged or eaten.

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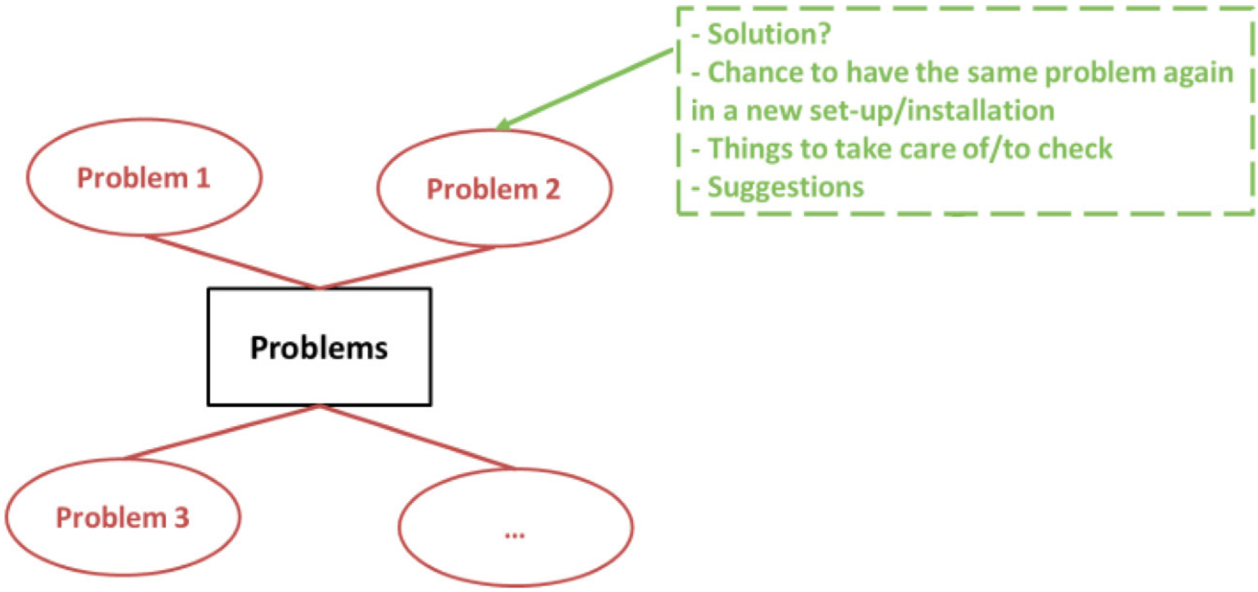

Figure 7. Schematic showing the problems and solutions when installing PLF products.

Solutions. The main objective is not to point out the problems but to offer solutions to the farmers and technology providers. The blueprint presents these solutions in a very accessible way so that producers and technologies can link to generic problems that are encountered, as seen in Figure 7.

How to calculate the value brought by PLF technologies for the farmer

In this section, the benefits provided to the farmers are discussed, and videos of testimonials contributed by the farmers and researchers are presented. The running message is that PLF is one piece of the puzzle that will enable a more sustainable animal production. Here it is highlighted that consumers and the society will benefit from the use of PLF technology as it will allow them to have access to information on the welfare and health of the animals. And that PLF technology will allow a reduction in the use of medicine, particularly of antibiotics, and will contribute in reducing the impact of animal production on the planet.

Finally, the tangible, semi-tangible, and intangible benefits of PLF systems are calculated using a simulation tool developed by Wageningen University, who was a partner during the EU-PLF project. For the tangible benefits, a simulation tool is provided for free download by the reader, with instructions on how to use it. An example is worked out for an automated heat detection system for dairy cows.

Acknowledgements

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