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Barriers, Driving Forces and Non-Energy Benefits for Battery Storage in Photovoltaic (PV) Systems in Modern Agriculture

Anna-Lena Lane [1,2,*], Magdalena Boork [2] and Patrik Thollander [1]

1 Department of Building, Energy and Environment Engineering, University of Gävle, SE-801 76 Gävle, Sweden; patrik.thollander@liu.se
2 RISE Research Institutes of Sweden, Box 857, SE-501 15 Borås, Sweden; Magdalena.Boork@stuns.se
* Correspondence: anna-lena.lane@ri.se; Tel.: +46-70-669-5871

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Abstract: Battery storage has been highlighted as one way to increase the share of renewables in energy systems. The use of local battery storage is also beneficial when reducing power variations in the grid, thereby contributing to more robust and cost-effective energy systems. The purpose of this paper is to investigate barriers, drivers and non-energy benefits (NEB) for investments in battery storage in photovoltaic systems (PV) in the context of farmers with PV systems in Sweden. The study is based on a questionnaire about barriers, driving forces and NEB for investment in battery storage connected to PV. The questionnaire was sent to farmers in Sweden who already have photovoltaics installed and about 100 persons answered, a response rate of 59%. The major barriers found are related to the technical and economic risks of investing in battery storage. One of the main conclusions is that the highest-ranked driver, i.e., to use a larger part of the produced electricity oneself, turns out to be the highest priority for the grid-owner seeking to reduce the need for extensive investments in the grid. The primary NEBs found were the possibility of becoming independent from grid electricity.

Keywords: barriers; drivers; photovoltaics (PV), agriculture; energy efficiency; battery storage; renewable energy

1. Introduction

In 2015 the United Nations set 17 global goals for sustainable development. To reduce the unsustainable impact of fossil fuels, target 7.2 states that the global share of renewable energy must increase, as part of the seventh goal of clean and affordable energy [1]. The United Nations further states that the unsustainable impact of reliance on fossil fuels must be changed into renewable production and awareness concerning usage of energy [1]. One way to approach this target is to increase the use of photovoltaic solar panels (PV). The installed PV capacity and energy produced by PV systems is still a minor share of the total global electricity production but is rapidly increasing. In 2015, 1% of the global power production came from PV systems [2], and in 2016 it had increased to 1.3% [3]. In Sweden the total share of installed electricity production capacity from PV systems has increased from 0.5% in 2016 to 0.7% in 2017.

However, challenges associated with PV power production include solar energy being an intermittent source of electricity, causing considerable variations in power supply. Annual average global horizontal radiation in the world varies between 800–2800 kWh/m^2/year. The variation in Sweden from north to south is between about 880 to 1050 [4], which is not so far from the data for north and central Europe, where it can reach up to 1200 kWh/m^2/year [5].

Additionally, periods of high PV production often do not coincide with periods of high electricity demand, especially in the Nordic countries. This in turn may affect the power grid in terms of overvoltage, limiting the hosting capacity, particularly in weak low-voltage grids in the countryside. At the same time, agriculture has a seemingly high potential for PV power generation due to different options to install PV on land or farm buildings. The theoretical annual PV potential in Sweden has been estimated to amount to about 162 TWh, including both roof-mounted and ground-mounted PV [6,7]. The potential is, however, substantially limited by the capacity of the power grid, as well as by current Swedish legislation and economic conditions. Extensive expansion of PV in the countryside could result in voltage rise and overload in the electricity grid, and thereby a demand for reinforcements of the power grid to increase the hosting capacity [7]. An alternative to costly grid reinforcements is to increase self-consumption of the locally generated PV power. However, it has been shown by Norberg et al. [6] that few energy-consuming activities are flexible in time in agriculture, in particular when it comes to ensuring animal welfare.

An alternative to demand response flexibility would be to store the PV power locally. A short-term energy storage system would thereby increase the self-consumption, contribute to peak shaving in the power exchange with the grid, and stabilize the local low-voltage grid [8]. There are different opportunities for storing solar power over time, such as pump storage, hydrogen, and battery storage. This study focuses on battery storage. Battery energy storage has the possibility to reduce the variation in access to electricity due to a lack of solar radiation. To make solar power available during the night, there is the need for energy storage. For short-term storage, e.g., 24 h, battery storage is an upcoming technology [9–11]. The development of battery storage technology was described thoroughly by Akinyele et al. [12], including prices for different types of battery storage at the time of the paper. The Swedish governmental energy commission states that increased storage capacity in the power grid is a prerequisite for enabling considerable expansion of PV power generation from 0.1 to 20 TWh [13]. Still, the development of battery storage is driven not only by the implementation of PV in the world, but even more so by the target of fossil-free transportation, e.g., electric cars and vehicles.

The use of local battery storage is also beneficial for the Transmission System Operator (TSO), since batteries will reduce the power variations in the grid and thereby contribute to a more robust and cost-effective energy system. This in turn will increase the hosting capacity without costly grid reinforcements [14,15]. Additionally, by increasing self-consumption, grid losses can be reduced for customers located in low-voltage grids in the countryside due to the reduced need for power transmission [15–19].

From a global perspective, reliable battery technology is crucial to achieving sustainability target 7.1, which requires universal access to modern energy [20]. Thus, PV also provides the possibility of supplying electricity in countries with unstable power grids, while battery storage increases the stability of the energy system even more and also makes energy accessible during the night. However, at the same time, battery storage may harm the environment and have negative environmental consequences [21].

Battery storage has not yet reached economic profitability, but rapidly falling market prices are expected to change the conditions for batteries [22–24]. When a product becomes economically profitable, it becomes increasingly important to understand the target group, its values and benefits to develop and design technical solutions, services and business models.

In Australia the implementation of PV and battery storage is progressing faster than in other parts of the world [9]. High electricity network prices, policy regulations and favorable access to solar radiation are supporting interacting factors for the transition. Moreover, in a recent European study [5], it was shown that investments in battery storage in Spain and Germany can be profitable due to high electricity prices.

In Sweden, a political intention is to support technology by regulatory and economic conditions to enable short-term storage in the grid. The Government supports development, inter alia, through investment support for grid-connected batteries with the aim of increasing the use of locally produced electricity [25]. Therefore, there is a set of policy support systems targeting different actors.

In 2018, when this study was performed, there was state financial support for investments in PV systems including storage for private persons, municipalities and companies [26]. There was also specific economic support for battery storage in private homes connected to local production of renewable power [27]. It is common practice that agricultural properties in Sweden have buildings intended for business, e.g., agriculture, and at least one private residence. Investment support, as well as taxes related to energy production and consumption, differ depending on in which of these buildings the PV systems are installed. [28].

An economic question connected to PV and battery storage is whether self-consumption is profitable compared to selling surplus. The electricity price per kWh in Sweden consists of a fee to the electricity company, a fee to the electricity network company, energy tax and VAT. Power from the PV system that is sold can be paid for by the electricity company. Net debit for local energy production is not applied in Sweden. Instead there is a tax reduction on the incomes from the energy production up to a certain level, depending on the amount of electricity purchased from the grid.

For renewable energy production, electric certificates can be obtained and sold on a market to producers who must reach a certain level of renewable energy in their production [29]. This provides extra income per sold kilowatt-hour, even for self-consumption if one installs an electric certificate meter. To overcome the investment cost for the electric meter, self-consumption has to be relatively high.

All users of electric power have to pay energy tax in Sweden. For some companies, farmers included, there could be a reduction or repayment of the energy tax [28]. Apart from actual cost savings, research has shown that several other additional benefits may such as increased productivity, reduced maintenance, etc. [30].

The aim of this paper is to investigate barriers, drivers and non energy benefits (NEB) investment in battery storage in photovoltaic systems (PV) for end-users or prosumers in the context of farmers with PV systems in Sweden. The study presented is based on the following research questions:

- What are the major barriers to battery storage investment in PV systems?
- What are the major drivers to battery storage investment in PV systems?
- What are the major non-energy benefits (NEBs) of battery storage investment in PV systems?

It should be noted that the use of the term non-energy benefits, derived from the energy efficiency literature, in this case is applied to battery storage in PV systems. The paper is unique since, to the authors' knowledge, no previous study on barriers, drivers, and non-energy benefits has been undertaken regarding battery storage of PV systems among Swedish farmers or farmers in other countries.

2. Theory, Methods and Data

To identify the driving forces, barriers and benefits of installing battery storage among Swedish farmers, a questionnaire [31] was designed (Appendix A). The content of the questions was based on barrier theory [32], and was also inspired by Brudermann et al. [33], focusing mainly on factors that can affect whether battery technology becomes an attractive investment or not for a farmer. The focus of the survey was on battery storage, the reasons for installing solar power in terms of PV systems, and attitudes to sustainability.

The study was limited to farmers who had already installed solar power plants, and thus provides an end-user prosumer perspective on battery storage in PV systems. Notably, the perspective of grid-owners and their perspectives on battery storage and PV are not within the scope of this paper. Most barriers and driver studies are related to current technologies that are perceived to be cost-effective. Battery storage is still in an early phase in terms of market adoption. We have therefore extended the system boundary and assumed that the technology will be cost-effective in the future. Furthermore, we have chosen to include several questions related to the current policy mix, in order to draw conclusions regarding potential policy implications of our paper. The questions were in the form of multiple-choice questions, estimates and free text responses.

To get in touch with farmers within the target group, four different lists of postal addresses were used: one list of farmers who had shown interest in participating as a demonstration of farming for a feasibility study, a list of members of the farmers' federal union who purchased PV system solution offers, and two address lists of farmers who received government investment support for PV installations in two different Swedish counties, one in the north, and one in the south of Sweden.

The questionnaire was sent out in paper format along with a cover letter that also contained a web link to enable the recipients to respond electronically. Telephone interviews were also carried out with fourteen of the farmers in the final address list in order to open up for further comments on the topics. The interviews were based on the same (form as the) questionnaire and the answers were entered in the same way as the questionnaire responses. The purpose of the interviews was to provide scope for an extended reasoning about the issues, which is difficult to capture in questionnaires. All responses were entered into the computer tool SurveyMonkey for data processing. Both qualitative and quantitative data were considered in the compilation of the results.

The data collection was carried out in the summer of 2018. In total, 192 farmers were contacted to answer the questions, of which 14 telephone interviews were conducted and a questionnaire was sent out to 178. Out of the 178 questionnaires, 99 replies were received, of which 88 were in paper format and 11 were submitted via the web link that was sent with the paper questionnaire. Thus, the final proportion of respondents amounted to 59 percent. All answers, both from the questionnaire and the telephone interviews, are included in the results presented in this paper. The results were normalized on a scale ranging from zero to one.

The study was inspired by the energy efficiency gap and studies on barriers to and drivers for energy efficiency [7]. Barrier theory [32,34] tries to describe the difference between potential cost-effective energy efficiency measures and measures that are implemented. Barriers are related to the economy, organization and behavior. This method has previously been used in studies in industry in Sweden [35] and in Europe [32]. The barriers were categorized into risk, access to capital, hidden costs, and imperfect information, while the drivers were categorized into financial, environmental and other driving forces, see Table 1.

Table 1. Categorization of barriers [34].

Type of Barrier.	Barrier
Market failure/ market imperfection	Imperfect information Adverse selection Principal Agent relationship Split Incentives
Non-market failures	Hidden costs Access to capital Risk Heterogeneity
Behavioral	Credibility and trust Bounded rationality Values
Organizational	Power Culture

It should be noted that the term 'energy efficiency gap' is connected in this case to battery storage in PV systems, while in principle it is more related to renewable energy sources (RES). The study carried out a literature review inspired by Yin [36]. In the literature study, the search terms "battery storage", "photovoltaics" and "barriers" were used, leading to five papers being found in the Web of Science database. From these five papers, only one was considered to be relevant for this paper [37]. Furthermore, using the search terms "battery storage", "photovoltaics" and "driver" resulted in six papers being found in the Web of Science database. From these six papers, only two were considered to be relevant for this paper [14,38]. Furthermore, using the search terms "battery storage", "photovoltaics" and "agriculture" only led to one paper being found in the Web of Science database [39].

When changing to using the search terms "battery storage", "photovoltaics" and "farm", seven papers were found in the Web of Science database, of which two were considered useful [40,41].

Finally, when using the search terms "battery stock" and "photovoltaics", six papers were found, among which three were initially selected [9,42,43].

The part concerning NEBs (Non-Energy Benefits) in this study was inspired by Nehler [30]. Notably, there could also be several drawbacks, such as noise from the battery cooling, increased maintenance cost (for batteries) and also increased waste when battery lifetime is reached. However, these were not included in the actual study, because they may vary depending on the specific battery technology, such as potential noise from battery cooling, increased maintenance cost (for batteries) and increased waste when battery lifetime is reached.

3. Results and Analysis

This section shows the weighted results of the interviews and surveys. First, the respondents' general energy and environmental interest are described, then the barriers, and lastly the driving forces for Swedish farmers with PV to invest in battery storage.

The respondent group as a whole is aware of energy and environmental issues. Above all, energy and environmental issues are seen as a social issue where politicians have a great responsibility. However, they think that companies and individuals also have a responsibility and that they, in their own company, take a little more responsibility compared to what one requires of others.

As is also noted by Rogers [44], many see themselves as early adopters when it comes to energy and environmental issues. For example, one farmer stated that:

"*We are probably the only grain-oriented company in Sweden that is climate-positive*".

Of those who answered the questionnaire, 38% have some form of labeling with eco-requirements (KRAV, Swedish seal, etc.) for their agricultural production.

In one part of the questionnaire, an array of general energy-related questions related to PV and battery storage were asked regarding the respondents' perception of this system solution in general, as well as farm electricity production. The results of these general questions are shown in Figure 1. Questions related to some of the barriers in Table 1 are also included in Figure 1 and will be discussed later on in the paper.

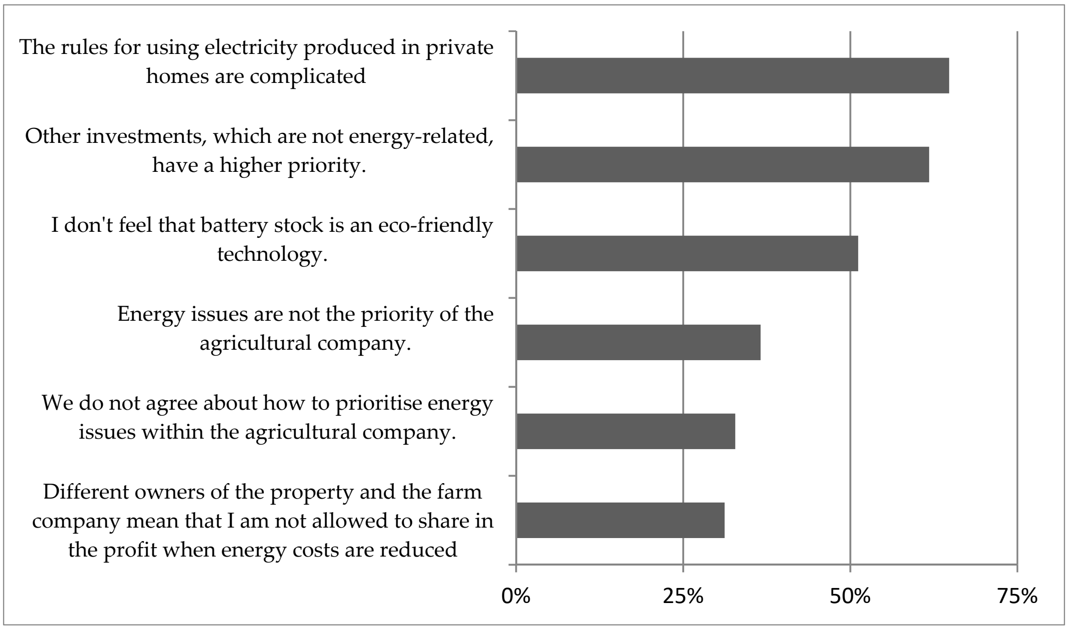

Figure 1. Some general energy-related questions regarding modern agriculture. The x-axis is graded from "takes full distance" (0) to "fully agree" (1) with the statement.

3.1. Barriers to Battery Storage Investment in PV Systems

The results from the questionnaire regarding barriers are presented in Figure 2. Each type of risk is discussed separately below and is related to the barriers in Table 1

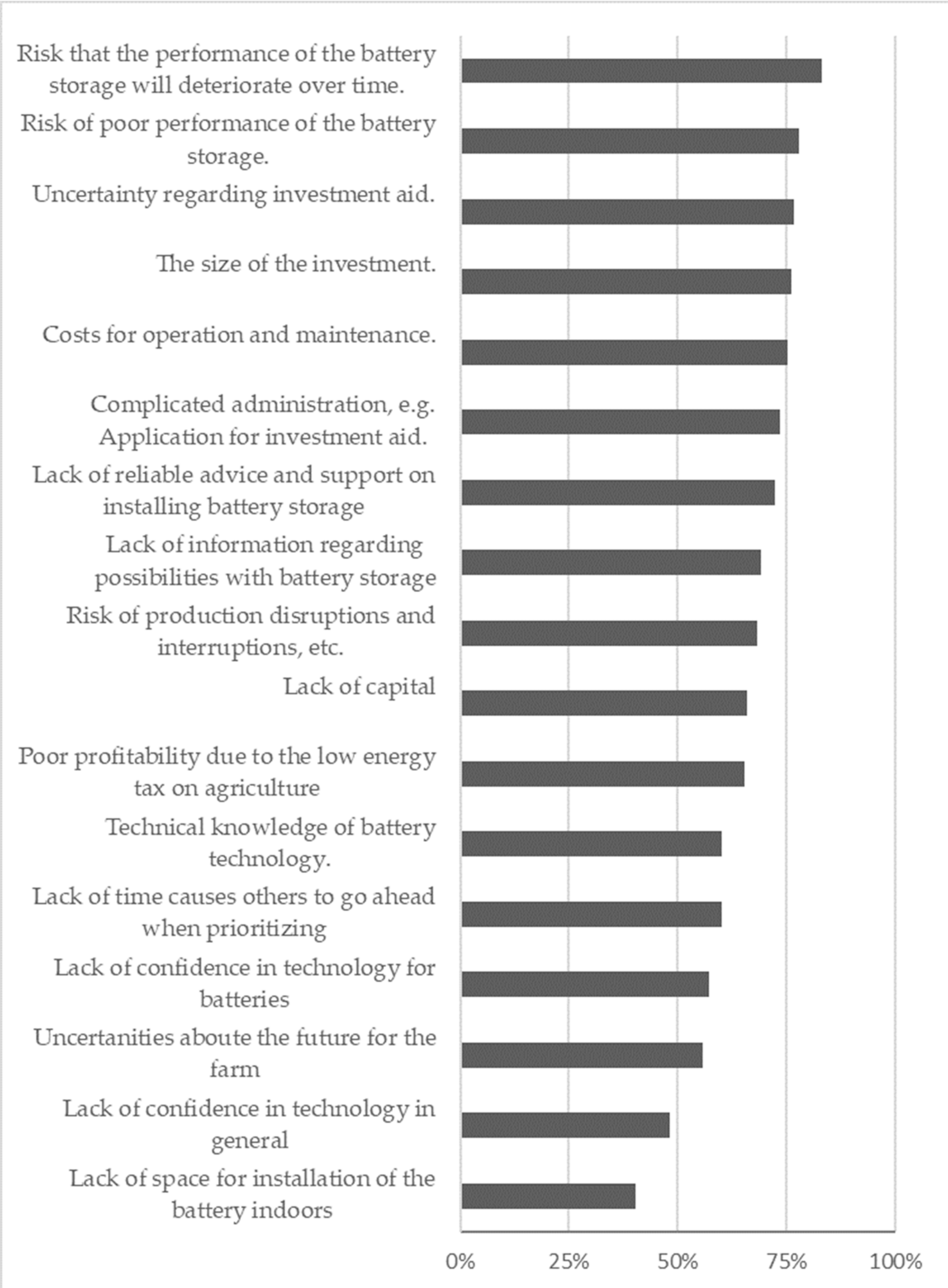

Figure 2. Major barriers to battery storage in PV systems, where 0% corresponds to very low barrier and 100% to very high barrier.

3.1.1. Risk

Notably, the four major barriers to battery storage in PV systems in modern agriculture are related to technical and financial risks, i.e., "*The risk that the performance of the battery storage will deteriorate over time, Risk of poor performance of the battery storage, Uncertainty regarding investment aid, and The size of the investment*".

This is most likely due to the fact that the technology is still in its early phase of adoption, and also that the respondents are not so willing to take on their own risk in relation to these specific types of investment.

Mid-ranked among the risk-related barriers were "*Risk of production disruptions and interruptions, etc. Barriers of lower importance included Lack of confidence in technology in general, and Uncertainties about the future for the farm*". One of these last two barriers is notably related to the fact that the respondents have great confidence in technology in general but perceive the specific technology as uncertain. Furthermore, the last barrier regarding uncertainty of farm survival shows that this is not a large barrier for PV and battery investments. Rather, the fact that some of these farmers have shut down normal farm activities, they still see PV investments as a possibility to continue to have a positive revenue stream from the farm after the shutdown of common farm activities. An elderly retired farmer says that he "*lives on one of the agricultural properties. Owns only the dwelling but has access rights to the solar panel until my death*".

Investing by using own or borrowed capital is seen as a risk, which may be due to the uncertainty surrounding function and performance. Therefore, investment support is preferred, but requires long-term regulations to dare to invest in the technology. With better reliability and function of battery storage, especially regarding uninterruptible power supply (UPS), it is possible that the desire to invest in equity would increase.

3.1.2. Lack of Access to Capital

One barrier related to *Lack of access to capital* was found to be ranked low. Relating this to the other responses shown under the heading risk, it is not the actual lack of capital per se that is the issue, but rather the size or magnitude of the investment.

3.1.3. Hidden Costs

Two barriers related to hidden costs found were "*Complicated administration, e.g., application for investment aid, and Costs for operation and maintenance*". Notably, the barrier "*Complicated administration, e.g., application for investment aid*" was ranked high. This barrier is very closely related to the violation of the principles of a well-functioning market. In the present case, there is an investment subsidy in place, i.e., a policy has been put in place to overcome market failures in the first place, but as this subsidy is perceived to be complicated to apply for, the subsidy itself gives rise to considerable transaction costs related to the investment. This is not desirable and may even be a violation of a well-functioning market in itself.

3.1.4. Imperfect Information

Two moderately high-ranked barriers related to imperfect information found were Lack of "*information regarding possibilities with battery storage, and Lack of reliable advice and support on installing battery storage*". Notably, there seems to be a need for further marketing of the technology and advice, so that it is perceived as credible.

3.1.5. Values

Questions regarding the environmental friendliness of today's battery technology exist and are considered to be important to solve. One respondent states that "*One should not talk about solar and battery storage and then in 5 years say that it was not good. If you have batteries that are a bit ugly, but turn out to be very ugly, then you have to remove them*".

In the questionnaire, the respondents partly agreed with the statement: "*I think battery storage is an environmentally friendly and sustainable way to use more self-produced electricity*", while they were neutral or took a partial distance from the "*claim I do not feel that battery storage is an environmentally friendly technology*". There is thus an expectation about the function that battery storage can offer, but it is important that the technology be perceived as sustainable from an environmental perspective in order for the technology to become widespread. Otherwise, values could be major barriers.

3.1.6. Low-Ranked Barriers

As can be seen in Figure 1, farms have authority over their decisions, and do not seem to be in conflict with other owners (they are single or family owners), and further, they seem to prioritize energy issues, as this was a low-ranked barrier. It should be noted, however, that none of the farmers in this study was running the farms on lease. Thus, when generalizing the results from this paper, the type of ownership is important to take into consideration.

3.2. *Drivers to Battery Storage Investment in PV Systems*

In another part of the questionnaire, an array of questions related to driving forces in regard to PV and battery storage was asked. The results regarding drivers are presented in Figure 3.

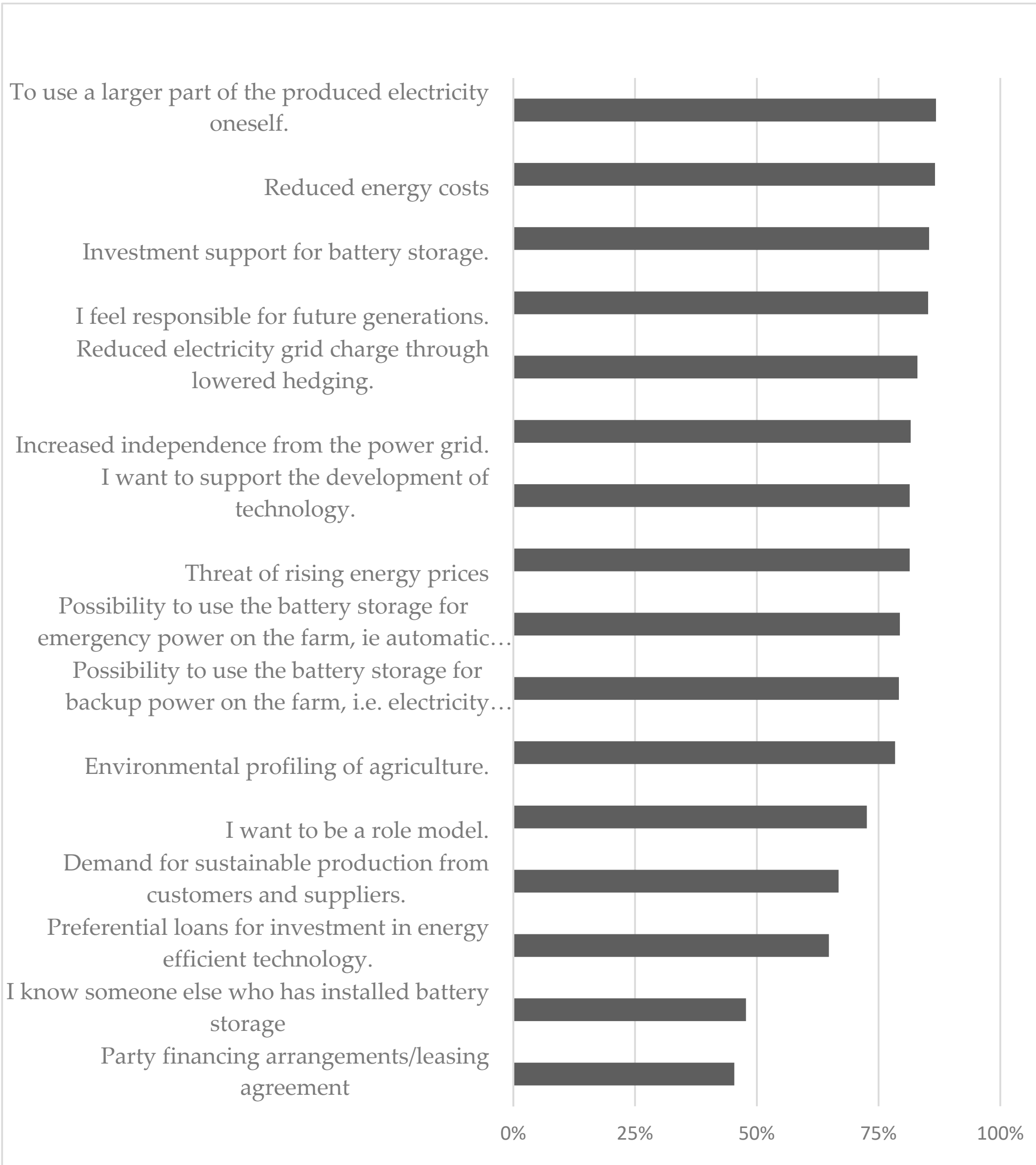

Figure 3. Major drivers to battery storage in PV systems, where 0% corresponds to a very low-ranked driver and 100% to a very high-ranked driver.

3.2.1. Financial Drivers

The highest ranked driver for installing battery storage in PV systems in the study was "*To use a larger part of the produced electricity oneself*". This also related to the sixth highest ranked driver, "*Increased independency from the power grid*". These drivers are both related to a desire to be more self-sufficient in terms of energy supply, as well as "*Reducing costs*", which is the second-highest ranked driver. Furthermore, even the third highest-ranked driving force, "*Investment support for battery storage*", is related to finance and reducing investment risk. Also, in fifth place in the ranking, a financial-related driver, "*Reduced electricity grid charge through lowered hedging*", is found.

Other semi-high ranked driving forces related to financial issues were, "*Threat of rising energy prices, Possibility to use the battery storage for backup power on the farm, i.e., electricity supply during longer blackouts, Possibility to use the battery layer for emergency power on the farm, i.e., automatic short-term electricity supply of the main functions while waiting for other backup power to be connected*".

3.2.2. Environmental Driving Forces

In fourth place among the highest ranked drivers was "*I feel responsible for future generations*". Notably, even though the other top-ranked drivers are related to financial issues, even environmental values as a driver seem to be of importance. Also, the seventh ranked driver, "*Supporting the development of technology*", is related to values among the decision-makers. "*Environmental profiling of agriculture*" as a driver was ranked as the eleventh most important driver, "*The desire to be a role model*", in 12th place.

However, environmental values as a driver are ambiguous, as in other parts of the questionnaire, and battery storage as an eco-adapted technology was questioned. Two respondents stated that:

"*Not to rush the first time when it comes to battery technology, batteries are today an environmental problem that will avalanche if you do not follow up on recycling*"; and

"*Will probably install more solar cells, doubtful about batteries ...*".

Notably, this may also be related to whether the respondents are so-called early adopters or not.

3.3. Non-Energy Benefits from Battery Storage Investment in PV Systems

Related to the concept of non-energy benefits (NEBs), the study revealed several such benefits, as well as drawbacks. The primary NEBs found were the possibility to become more independent of grid electricity.

Furthermore, another important NEB is that battery storage is in fact an environmentally and climate-adapted solution, and that the respondents are acting for sustainability by investing in these technologies. Moreover, it was now also possible to run an electric car, for farmers who own such, on the electricity from PV as well as from the battery. This was also considered an important NEB. Furthermore, decades of farming shutdowns among Swedish farmers, as a consequence of increased competition from outside of Sweden, have led to many of the studied farms now being inactive. Installation of battery storage and PV is seen as an alternative form of business activity for the farm.

Yet another NEB found was that it is perceived as enjoyable to make one's own electricity.

4. Conclusions

The aim of this paper was to investigate the barriers, drivers and non-energy benefits (NEB) for investments in battery storages in photovoltaic systems (PV) in the context farmers in Sweden with PV systems.

The major barriers to battery storage investments in PV systems were found to be related to technical and financial risks, i.e.,:

- *Risk that the performance of the battery storage will deteriorate over time;*
- *Risk of poor performance of the battery storage;*
- *Uncertainty regarding investment aid;*
- *The size of the investment.*

The major drivers to battery storage investments in PV systems were related to financial, policy and environmental drivers:

- *To use a larger part of the produced electricity by oneself;*
- *Reducing costs;*
- *Investment support for battery storage;*
- *I feel responsible for future generations.*

The major non-energy benefits mentioned in battery storage investment in PV systems were the possibility of being independent of grid electricity, that the installation of battery storage and PV are seen as an alternative form of business activity when farming is shut down, the possibility to running an electric car, and that it is perceived as enjoyable to make one's own electricity.

The reasons for installing energy storage in agriculture with PV systems thus seem to be motivated by increased self-consumption. At least with the higher implementation of PV in the grid, especially in the weak low-voltage grids in the countryside, problems such as voltages that are too high on the grid, etc., will force costly grid reinforcements that could be avoided through the use of battery storage [9,18,19]. The results of this study show that higher self-consumption is also the highest ranked driver among the end prosumers for the installation of battery storage in PV systems. Even if the drivers perceived by prosumers and the needs of the grid coincide, there are barriers of great importance to a greater degree of implementation that need to be overcome. These are related to technical and economic risks.

Notably, the driving force concept and the NEB concept were found to partly overlap. For example. The possibility of using the battery storage for backup power on the farm, i.e., electricity supply during longer blackouts, and the possibility of using the battery storage for emergency power on the farm, i.e., automatic short-term electricity supply of the main functions while waiting for another source of backup power to be connected. In the questionnaire, these were intended to be drivers, but the study shows that a driver could also be a NEB. We suggest that the concepts of driving forces and NEBs need to be further explored in future research.

Based on the fact that the annual solar radiation for our studied farmers is similar to the rest of north and middle Europe's, our study may have further implications, and our results may be generalizable to other European countries with similar conditions to those of the studied Swedish farmers.

In the study, it was found that policy implications related to investment support are important for the implementation of battery storage. Investing by using own or borrowed capital is seen as a risk, which may be due to the uncertainty surrounding function and performance. Therefore, investment support is preferred, but requires long-term regulation before people are willing to dare to invest in the technology. With improved reliability and functionality of battery storage, especially regarding the reserve back-up power function, it is possible that the desire to invest will equally increase.

In Australia, PV has had a greater breakthrough than in Sweden. The local circumstances, which include high and even solar radiation, contribute to this. Battery storage also has a higher rate of implementation, even if the economics of combined PV and battery storage is still marginal. However, other benefits, like peak shaving and avoided losses can, in combination with a policy of more rapid adoption, promote a higher degree of implementation in Australia [9].

To enhance deployment of batteries in PV installations, this study found that end-users want to see policies that reduce the technical risks associated with the technology, as well as for support for battery storage. Such policies could range from direct investment subsidies to demonstration plants and information campaigns regarding the technical performance of battery storage.

Apart from the unique results of barriers, drivers and NEBs, this paper has made a methodological contribution in which the developed methodology could be adopted and further developed in studies in other countries. This methodological contribution was enabled by adapting studies on improved energy efficiency in industry to this research field. This interdisciplinary approach shows the utility of embracing scientific knowledge from beyond the respective research field. This is, of course, not always possible, but shows that interdisciplinary research can sometimes speed up the creation of new scientific knowledge, which in turn may contribute to a faster transition towards a sustainable society.

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Appendix A

Questionnaire: Solar power and battery storage

The questions in this survey are about solar power and battery storage in the Swedish agriculture. Your answers are very valuable for us to understand what barriers and driving forces there are to invest in a battery storage to a photovoltaic system. The survey is conducted by RISE within a research study, see also the attached letter. The questions are answered with a cross (X) unless otherwise stated. The questionnaire takes about 15–20 min to answer and can also be answered at web-link.

Background questions

1. Do you own a farm? □ Yes, I am the only owner □ Yes, I own a part □ No
2. Do you live on a farm? □ Yes, I live on the farm that I own □ Yes, I am leasing the farm □ No □ Other [Comment]
3. Is there a PV plant on your farm? □ Yes, I have invested within the farming company □ Yes, I have invested for private use, not within the farming □ No □ No, but we are planning to invest in PV

If the answer is Yes on question 1 and/or 2 and 3 you belong to the target group for this survey. Please answer the rest of the questions. If you do not belong to the target group, we are grateful if you send the questionnaire back in the enclosed reply envelope.

Your farm

4. Is agricultural activity carried out on the farm property that you own and/or live on? □ Yes, as main economic activity □ Yes, as a secondary occupation □ No
5. What type of business do you conduct in your business? (You can set multiple options.)

□ Milk production	□ Goats/Sheep	□ Feed production
□ Poultry Production	□ Production Garden	□ Grain production
□ Pig production	□ Processing food	□ Contract operations
□ Nut production	□ Forestry	□ Energy
□ Horses	□ Crop production	□ Tourism

□ Other, namely . . . [COMMENT FIELDS]

6. How many employees are in the agricultural company (including yourself)? [. . . . . . .] persons
7. What is the turnover of your agricultural company? □ Less than250,000 SEK □ 250,000–500,000 SEK □ 500,000–1 miljon SEK □ 1–2 miljoner SEK □ 2–5 miljoner SEK □ 5–10 miljoner SEK □ över 10 miljoner SEK
8. Does agriculture have any type of ecolabelling (KRAV, Swedish Sealetc.) □ Yes □ No Please comment [COMMENT FIELDS]

Your PV-plant

9. What year was the farm photovoltaic plant in operation? [COMMENT FIELDS]
10. Roughly how large the plant is? [. . .] m^2 and/or [. . .] kW [. . .] □ Do not know
11. In what main direction is the plant located?□ East □ Southeast □ South □ Southwest □ West
12. How much electricity does your plant generate in relation to electricity consumption on an **annual basis**? Disregard that the plant occasionally produces a surplus. □ It generates significantly less electricity than the total consumption□ It generates roughly the same amount of electricity as the total consumption□ It generates significantly more electricity than the total consumption □ Other, namely
13. What motivated your farm to acquire a photovoltaic plant? [COMMENT FIELDS]
14. Did you experience any difficulties linked to the construction of the photovoltaic plant? [COMMENT FIELDS]
15. Do you consider that the photovoltaic plant is a profitable investment? □ Yes □ No □ Partly
16. Please comment on profitability calculations[COMMENT FIELDS]
17. What is an acceptable depreciation period for an investment in renewable energy production for your agricultural company? [COMMENT BOX] Year
18. Is the acceptable depreciation period different to other types of investment? □ Yes □ NO
19. Please comment in what way [COMMENT FIELDS]

Driving forces to invest in a battery storage to the photovoltaic system on your farm

A battery storage can store electricity for short periods of time, such as day to night or between days. This means that self-produced solar electricity can be used throughout the day and that the battery storage can reduce the power to the mains. At present, battery storages are relatively costly, but the development of technology is fast, which can make battery storages profitable in the future. Let's say that battery storage is already a profitable investment. What would make you invest in a battery storage to the photovoltaic system on your farm?

	Type of Driving Force	**Un-Important**	**Less Important**	**Neither or**	**Important**	**Very Important**	**Do not Know**
19	Investment support for battery storage.	□	□	□	□	□	□
20	I know someone else who has installed battery storage	□	□	□	□	□	□
21	Party financing arrangements/leasing agreement	□	□	□	□	□	□
22	Reduced energy costs.	□	□	□	□	□	□
23	Reduced electricity grid charge through lowered hedging.	□	□	□	□	□	□
24	Threat of rising energy prices.	□	□	□	□	□	□
25	To use a larger part of the produced electricity oneself.	□	□	□	□	□	□
26	Increased independency from the power grid.	□	□	□	□	□	□
27	Possibility to use the battery storage for backup power on the farm, i.e., electricity supply during longer blackouts.	□	□	□	□	□	□
28	Possibility to use the battery storage for emergency power on the farm, ie automatic short-term electricity supply	□	□	□	□	□	□
29	I want to support the development of technology.	□	□	□	□	□	□
30	I want to be a role model.	□	□	□	□	□	□
31	I feel responsible for future generations.	□	□	□	□	□	□
32	Environmental profiling of agriculture.	□	□	□	□	□	□

	Type of Driving Force	Un-Important	Less Important	Neither or	Important	Very Important	Do not Know
33	Demand for sustainable production from customers and suppliers.	□	□	□	□	□	□
34	I know someone else who has installed battery storage	□	□	□	□	□	□

How well do you agree with the following statements about your agricultural company?

	Statement	Takes Full Distance	Takes a Partial Distance	Neither or	Partly Agree	Fully Agree	Do Not Know
35	My agriculture has a long-term energy and environmental strategy.	□	□	□	□	□	□
36	Renewable energy is important in my agriculture.	□	□	□	□	□	□
37	I think that battery storage seems to be a safe investment.	□	□	□	□	□	□
38	I think battery storage is an interesting technology solution.	□	□	□	□	□	□
39	I think battery storage is an environmentally friendly and sustainable way to use more self-produced electricity.	□	□	□	□	□	□
40	I or someone else in agriculture is interested in new technology solutions.	□	□	□	□	□	□
41	Investment in a package solution combining solar cells and battery storage is more attractive than two separate investments.	□	□	□	□	□	□

Barriers to investing in a battery storage to the photovoltaic system on your farm

What would prevent you from investing in battery storage to the photovoltaic plant on your farm?

	Type of Barrier	Un-Important	Less Importantt	Neither or	Important	Very Important	Do Not Know
42	Lack of capital	□	□	□	□	□	□
43	The size of the investment.	□	□	□	□	□	□
44	Poor profitability due to the low energy tax on agriculture.	□	□	□	□	□	□
45	Costs for operation and maintenance.	□	□	□	□	□	□
46	Lack of time causes others to go ahead in prioritization.	□	□	□	□	□	□
47	Uncertainty regarding investment aid..	□	□	□	□	□	□
48	Complicated administration, e.g., Application for investment aid.	□	□	□	□	□	□
49	Lack of confidence in technology in general	□	□	□	□	□	□
50	Lack of confidence in technology for batteries	□	□	□	□	□	□
51	Lack of technical knowledge of battery technology.	□	□	□	□	□	□
52	Risk of poor performance of the battery storage	□	□	□	□	□	□
53	Risk that the performance of the battery storage will deteriorate over time.	□	□	□	□	□	□

	Type of Barrier	Un-Important	Less Importantt	Neither or	Important	Very Important	Do Not Know
54	Risk of production disruptions and interruptions, etc	□	□	□	□	□	□
55	Lack of space for installation of the battery indoors	□	□	□	□	□	□
56	Uncertanities aboute the future for the farm	□	□	□	□	□	□
57	Risk of production disruptions and interruptions, etc.	□	□	□	□	□	□
58	Lack of reliable advice and support on installing battery stock.	□	□	□	□	□	□

How well do you agree with the following statements about your agricultural company?

	Statement	Takes Full Distance	Takes a Partial Distance	Neither or	Partly Agree	Fully Agree	Vet ej
59	Other investments, which are not energy-related, are higher priority.	□	□	□	□	□	□
60	Different owners of the property and the farm company mean that I am not allowed to share in the profit when reduced energy costs.	□	□	□	□	□	□
61	Energy issues are not the priority of the agricultural company.	□	□	□	□	□	□
62	We do not agree on how to prioritise energy issues within the agricultural company.	□	□	□	□	□	□
63	The rules for the use of electricity produced in the farm in the private dwelling are complicated.	□	□	□	□	□	□
64	I don't think that battery storage is an eco-friendly technology.	□	□	□	□	□	□

Information about battery storage and PV

65. Did you know the ability to install battery storage earlier? [Yes] [No]
66. If yes, where did you get information about battery storage? Please comment how useful the information has been. [COMMENT FIELDS]
67. Where did you get information about solar electricity for the installation of the farm's photovoltaic plant? Please comment how useful the information was for your decision to install solar electricity. [COMMENT FIELDS]

Energy and sustainability issues

How important do you think energy and sustainability are? Please answer the questions below.

	Statement	Not at all	Some	Neither or	Very	Very Much	Do Not Know
68	How prioritized do you think energy and sustainability issues should be in society?	□	□	□	□	□	□
69	How much responsibility do you think politicians have for energy and sustainability issues?	□	□	□	□	□	□
70	How much responsibility do you think companies have for energy and sustainability issues.	□	□	□	□	□	□
71	How much responsibility do you think individuals have for energy and sustainability issues.	□	□	□	□	□	□
72	How much responsibility do you think agricultural companies generally have for energy and sustainability issues?	□	□	□	□	□	□

	Statement	Not at all	Some	Neither or	Very	Very Much	Do Not Know
73	How much responsibility do you think your own company is taking for energy and sustainability issues?	□	□	□	□	□	□
74	How interested is your agricultural company investing in renewable energies?	□	□	□	□	□	□

Based on the above, please comment on the following in a few words:

75. How do you think and act on energy and sustainability issues in your agricultural company? [COMMENT FIELDS]
76. Besides a technical conversion, what do you think is required for sustainable development? [COMMENT FIELDS]
77. How do you think different actors (e.g., politicians, companies, individuals) should act on energy and sustainability issues? [COMMENT FIELDS]

Concluding questions

About You who have responded to the questionnaire

78. Born year [COMMENT FIELDS]
79. Gender □ Woman □ Man □ Other

The information you provide in this questionnaire will only be used within RISE research and the results for individual farms will never be disclosed to another party. The results will only be presented at group level, including in a report to the Swedish Energy Agency. Once we have received your questionnaire and checked it out in our mailing list, all links between survey responses and individual farming will be erased.

80. Do you approve that RISE saves the information you give us in this survey as described above? □ Yes □ No
81. Do you have anything further to add regarding barriers and driving forces for investments in solar electricity and/or battery storage? [COMMENT FIELDS]

Many thanks for your participation!

Please use the enclosed reply envelope to send your answers to us. Postage is paid by the recipient (RISE Research Institutes of Sweden).

Contact

If you have any questions about the study or survey, please contact NAME, PHONE, E-MAIL

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