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Prediction of the Spatial and Temporal Adoption of an Energy Management System in Automated Dairy Cattle Barns in Bavaria—"CowEnergySystem"

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Abstract: In view of rising global demand, energy is becoming a significant cost factor in industry and society. In addition to the global players China, India, and the USA, Africa will also become a driver of the world's primary energy demand in the future due to the rapidly growing developing countries. In addition to the armed conflicts in Ukraine and the Middle East, global energy markets are tense and volatile due to inflation and higher borrowing costs. Because of society's desire to phase out the use of fossil fuels, the use of renewable energies is increasingly taking center stage worldwide and especially in Germany. Rural areas and agriculture, especially energy-intensive livestock farms, are particularly affected by this development and are therefore faced with additional economic challenges. Additional energy can be generated by using photovoltaic systems on the roofs of farm buildings or by utilizing the liquid manure from livestock farming in biogas plants. For these farms, such alternative sources of energy could open previously untapped potential and additional synergies for using their own inexpensive energy on the farm or supplying surplus electricity directly to the public grid as a market participant. Agriculture could thus serve as an actor in a decentralized energy supply and thus build up regional energy networks. However, intelligent electricity storage concepts and a corresponding energy management system (EMS) are essential to be able to utilize the potential for renewable energy generation at all, to coordinate both internal production processes and the varying energy demand and supply on the electricity grid. As agricultural production processes differ greatly from farm to farm and region to region, the introduction of an energy management system is strongly dependent on user acceptance. The purpose of this study is to use the web-based software tool ADOPT (CSIRO 2018) to predict the level of acceptance and the duration of the market launch of an EMS based on the region of Bavaria. Individual important influencing factors for the subsequent regional marketing concept are also identified.

Keywords: decentralized energy supply; agricultural energy management systems; renewable energies; market launch; innovation

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1. Introduction

1.1. Background Global Climate Change

Due to the globally noticeable climate change and loss of biodiversity, this debate is not only of scientific importance but is now also very much on the political and social agendas [1]. In some cases the effects are reaching into the health sector [2]. The socio-political transformation from fossil and nuclear energy generation to renewable energy sources is increasingly bringing biomass, solar energy, geothermal energy, and wind energy into the focus of electricity generation in Germany [3]. The rapid rise in the cost of natural gas is leading to higher electricity prices, with a cost increase of +66.5% for all consumer groups (February 2021 to February 2022) [4]. According to estimates by the IEA (International

Energy Agency), the peak in the use of fossil fuels will be reached before 2030, before there is a downward trend in fossil fuels and an effective transition to renewable energy sources [5]. In 2020, the Federal Republic of Germany committed to increasing the share of renewables in "gross final energy consumption" to 30% by 2030 through the "National Energy and Climate Plan" (NECP) [6]. In addition, the European Union has decided to become the first climate-neutral continent by 2050 by establishing the "European Green Deal". This also means that the proportion of electricity generated from renewable sources is to increase to 42.5% by 2023 [7]. One consequence of this transformation is also a change from centrally controlled and permanent grid stability, e.g., through nuclear power, to decentralized regulation of electricity generation from photovoltaics and wind power in the future [8]. The differences in regionalized energy production are thus set against the electricity demand from industry and households, which will lead to a change in supply and demand on the electricity market, which will need to be balanced [9]. Recently, intelligent energy management systems (EMS) have increasingly come to the fore in discussions about dwindling fossil fuel resources, the goal of a sustainable energy transition [10], and the need for regional grid regulation [11]. This can be seen, for example, in the growing incentive to introduce EMS in accordance with DIN EN ISO 50001 in the German economy [12]. In practice, however, the legal requirements for the intended energy regulation are often lacking [13].

1.2. Background to the "Stable 4.0" Research Initiative

Since 2013, the "Stable 4.0" research initiative has been working on a practice-oriented development of system-specific principles for the implementation of an on-farm EMS for agricultural dairy barns [14]. In cooperation with partners from industry and with the support of the German Federal Ministry of Food and Agriculture (BMEL), an EMS was designed for the agricultural sector and has since been developed to market maturity. Parallel to the growing degree of automation in agricultural and horticultural field management in the form of autonomous agricultural machinery and field robots [15], research in indoor agricultural management is also developing in the direction of integrated dairy and energy production (Integrated Dairy Farming) with the highest degree of automation and sensor-controlled production management [16,17]. The existing buildings (stables and storage buildings) required for animal husbandry offer the possibility of independent energy generation on site [18]. The holistic system view shows a realistic opportunity for a more efficient utilization of existing resources in the field of renewable energies. The multi-stage "Stable 4.0" research program, with its defined project sections, has already provided meaningful insights into the necessary requirements for such an on-farm energy management system on a practical farm, analyzed in detail and implemented in a practical hardware and software solution [19]. Following this basic research, a demonstrator was installed in a newly built dairy barn on a second test farm. This demonstrator provides new scientific findings and foundations for the intelligent networking of relevant system elements. It provides a largely autonomous supply via the decentralized production of renewable energy and thus represents a further platform for possible synergy potential in practice. The multidimensional energy management system has a complex communication structure within all relevant system components due to the very specific requirements of human-animal-technology interaction and intelligent load management [20].

1.3. Objectives and Problem Description in the "CowEnergySystem" Research Project

As a result of falling revenues due to inflation and the situation on the electricity market described above, the pressure on farmers to further reduce their production costs is also increasing. In such an environment, tensions between producers, retailers, and consumers will inevitably increase further [21]. As a result, the EMS presented could generate significant added value not only for farms, but also for society and local authorities. Compared to the test farms presented, agricultural production processes are very different both in terms of their operational equipment and their geographical location [22]. The energy management system presented herein is a newly developed innovation and is the only one of its kind in the world. As part of a scientific study in 2020, an initial survey was carried out for the Free State of Bavaria in the form of a survey on the acceptance and market potential of an energy management system among dairy farmers [23]. The introduction of corresponding energy concepts is associated with extensive changes for farms and their management. Innovation research has shown that the success or failure of innovations is determined by their acceptance by the market [24]. In many cases, subsequent problems arise in this context, such as internal barriers to innovation or even general rejection [25], which have a decisive influence on the spatial and temporal spread of an innovation (diffusion speed). A survey conducted to date on the use of an energy management system in Bavarian agriculture shows a positive basic acceptance, but no more precise estimate can be derived about market adoption. The necessary marketing strategies and targeted advertising measures associated with the introduction of the prototype on the market are difficult to design with only the data provided by the survey.

This raises a question for those responsible for the "CowEnergySystem" research project as to the extent to which the industrial prototype can be introduced and marketed within the agricultural sector and which features of the EMS (innovation) will influence the responses of the farmers (users). In the present work, therefore, a more precise temporal and spatial forecast of the market adoption to the innovative concept of the developed EMS is offered, initially for the region of Bavaria and later nationwide. With the help of the web-based software tool CSIRO ADOPT 2018 (Adoption and Diffusion Outcome Prediction Tool), the probable degree of adoption and diffusion of these agricultural innovations for the geographical region of Bavaria and the specific target group of Bavarian dairy farmers can be modeled and the result analyzed.

2. Materials and Methods

With the help of the web-based software tool ADOPT), which was developed in cooperation with the University of South Australia, the probable degree of adoption and diffusion of innovations through the target group of Bavarian dairy farmers can be predicted and evaluated [26,27]. In addition to predicting a possible adoption rate and the maximum diffusion in practice, ADOPT provides a weighting of various factors that influence innovation diffusion. The model is flexible for the agricultural sector and uses a conceptual framework that incorporates a few variables, including questions about profitability, risk, environmental outcomes, farmer networks, farm and farmer characteristics, and the ease and convenience of using new technologies in practice. A consistent environment is assumed, while changes in prices or legal aspects, for example, cannot be considered. In practical comparisons, good correlations have already been found between the ADOPT forecast results and the practical figures for automatic steering systems and no-till farming, for example [26]. Although ADOPT was originally designed purely for the agricultural sector, it is already being used for analyses outside of agriculture [28,29]. For example, the ADOPT tool is also used to evaluate factors influencing the introduction of photovoltaic systems for water extraction in Australian sugar cane irrigation [30].

ADOPT is structured to look at four categories of influence (Figure 1). The ability to learn about the relative benefits of the process, which depend on the characteristics of both the management system and the potential users (farmers), plays a central role. ADOPT users responded to 22 questions on the following characteristics

(a) the application practice that influences its relative advantage,
(b) the user population and its environment, which influence the perception of the relative advantage in practice,
(c) the ease and speed of learning, which influence the willingness to use it in practice,
(d) the potential user's ability to put the application into practice.

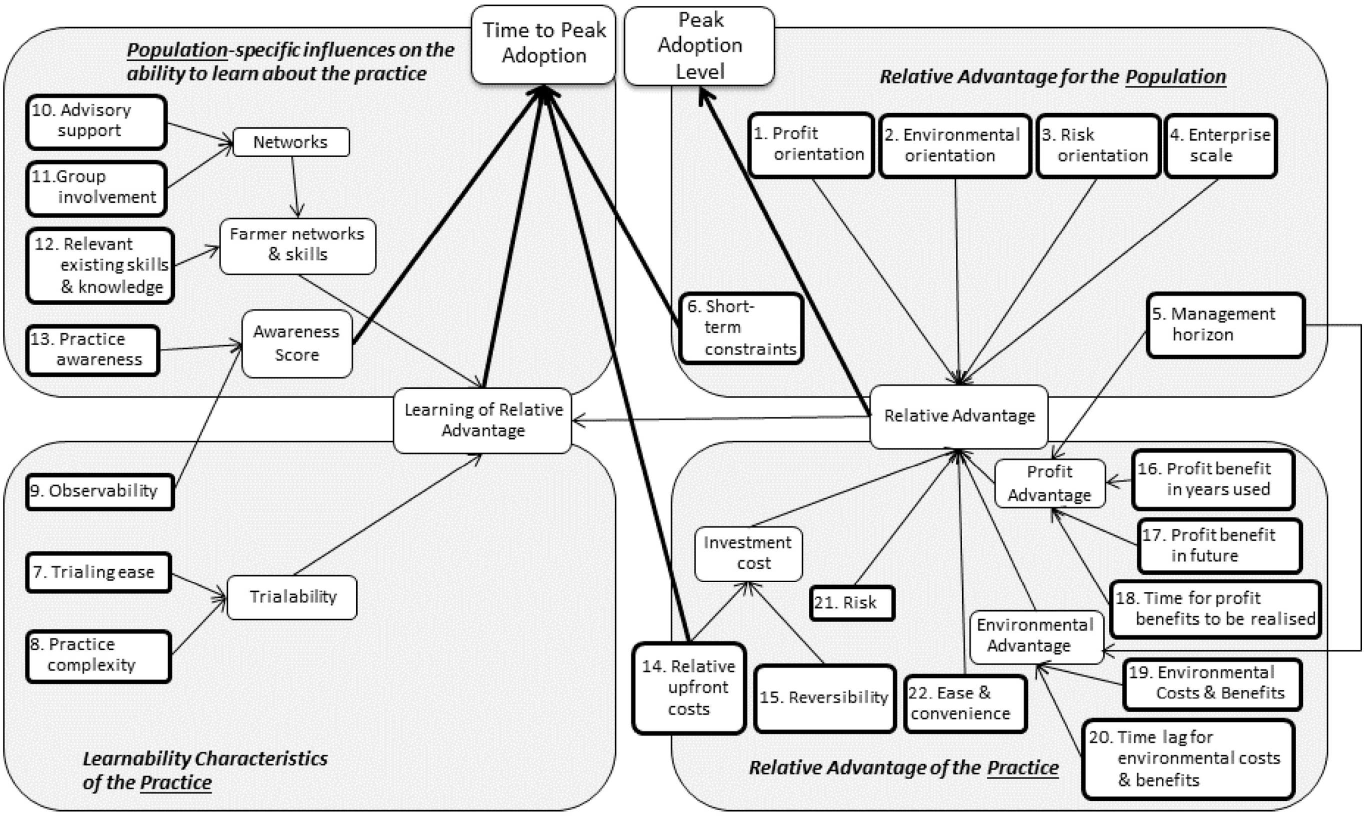

Figure 1. How CSIRO Adoption and Diffusion Outcome Prediction Tool works.

The user has the option of weighting the respective variables within various specific scales, e.g., from 1 to 5, 1 to 6, or 1 to 8, when answering. In addition to predicting the duration of dissemination in practice, the ADOPT tool also provides the option of sensitivity analyses about the factors that influence the speed and maximum of dissemination [31].

The 2018 version of the ADOPT standard model from CSIRO was used to analyze the adoption of the EMS. The innovation under investigation was defined for "Bavaria" and the target population was defined as "farmers with dairy cattle". The scaling and weighting of the 22 variables (Table 1) was based on extensive literature research and the corresponding arguments from the previous survey results [23]. In addition to a SWOT analysis, individual value drivers and the scale of potential EMS users within the industry were also queried. In the following, the analysis of variable occupancy is presented using the example of question 4, as this also deals with the target size of potential users/buyers.

Question 4: Enterprise scale—On what proportion of the target farms is there a major enterprise that could benefit from the innovation?

Due to the steady decline in the number of farms, there has been a significant structural change in the agricultural sector. However, this differs from region to region and in terms of socio-economic farm types [32]. Almost half of all dairy farmers in Germany (59,925 farms in 2019) are based in Bavaria (27,588 farms in 2019), regardless of whether they are conventional or organic. At the same time, the number of farms with an automatic milking system (AMS) continues to grow steadily [33]. In 2021, the "Landeskuratorium der Erzeugerringe für tierische Veredelung in Bayern e.V." (LKV) registered around 2900 member farms with one or more milking boxes [34]. This in turn corresponds with the survey results of the project study at the Weihenstephan-Triesdorf University of Applied Sciences [23]. In the study, 48.9% of participants were already equipped with an AMS. A further 8.1% are planning to invest in an AMS in the foreseeable future (in the next 5 years). In terms of farm size, measured by livestock numbers, around 50% of the farms have livestock on the order of between 50 and 125 livestock units per farm. It can therefore be assumed that, based on livestock numbers, around half of the participants run a medium to large farm that could be considered for the use of an EMS, especially as around 57% will work with an AMS in the medium term. This indicates a positive correlation with the use of further innovations in the field of automation [23].

Table 1. Overview of the selected responses and associated scaling of the ADOPT analysis.

Question	Response	Scaling
Relative Advantage for the Population		
1. Profit orientation	Almost all have maximising profit as a strong motivation	**5**-(1-5)
2. Enviromental orientation	About half have protection of the environment as a strong motivation	**3**-(1-5)
3. Risk orientation	A majority have risk minimisation as a strong motivation	**4**-(1-5)
4. Enterprise scale	About half of the target farms have a major enterprise that could benefit	**3**-(1-5)
5. Management horizon	A majority have a longterm management horizon	**4**-(1-5)
6. Short term constraints	About half currently have a severe short-term financial constraint	**3**-(1-5)
Learnability Characteristics of the Innovation		
7. Trialable	Easily trialable	**4**-(1-5)
8. Innovation complexity	Not at all difficult to evaluate effects of use due to complexity	**5**-(1-5)
9. Observability	Not observable at all	**1**-(1-5)
Learnability of Population		
10. Advisory support	About half use a relevant advisor	**3**-(1-5)
11. Group involvement	A majority are involved with a group that discusses farming	**4**-(1-5)
12. Relevant existing skills & knowledge	About half will need new skills and knowledge	**3**-(1-5)
13. Innovation awareness	A minority are aware that it has been used or trialed in their district	**2**-(1-5)
Relative Advantage of the Innovation		
14. Relative upfront cost of the project	Moderate initial investment	**3**-(1-5)
15. Reversibility of the innovation	Difficult to reverse	**2**-(1-5)
16. Profit benefit in yearsthat it is used	Moderate profit advantage in years that it is used	**6**-(1-8)
17. Future profit benefit	Moderate profit advantage in the future	**6**-(1-8)
18. Time until any future profit benefits are likely to be realised	Immediately	**5**-(1-6)
19. Environmental costs & benefits	Very Large environmental advantage	**8**-(1-8)
20. Time to environmental benefit	Immediately	**5**-(1-6)
21. Risk exposure	Large reduction in risk	**7**-(1-8)
22. Ease and convenience	Large increase in ease and convenience	**7**-(1-8)

ADOPT assessment:
"About half of the target farms have a major enterprise that could benefit"
Definition of scaling:

3—(for selection options 1 to 5)

All scaling of the 22 variables to be evaluated is shown below (Table 1).

3. Results

3.1. Main Results

Under the defined starting situation and the associated variable assignment, the peak of market introduction among Bavarian dairy farmers is expected after 8 years. Market penetration is expected at a maximum adoption rate of 98% (Figure 2).

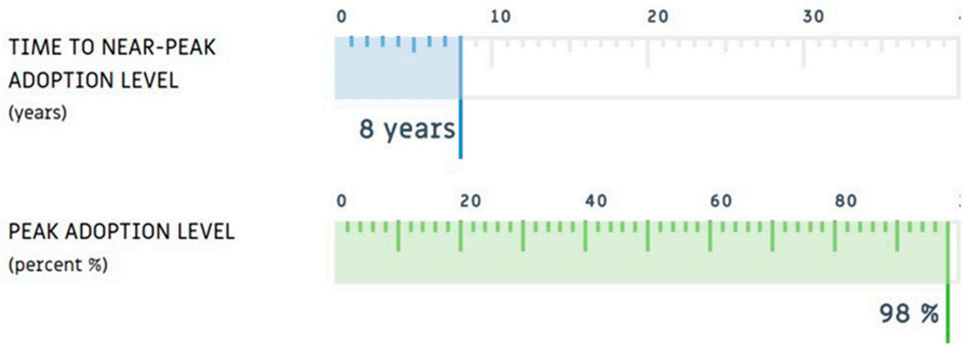

Figure 2. Result of the forecast of the ADOPT tool for the introduction of an EMS in Bavarian dairy farms.

Figure 3 shows the adoption prediction in more detail over time until the maximum spread is reached.

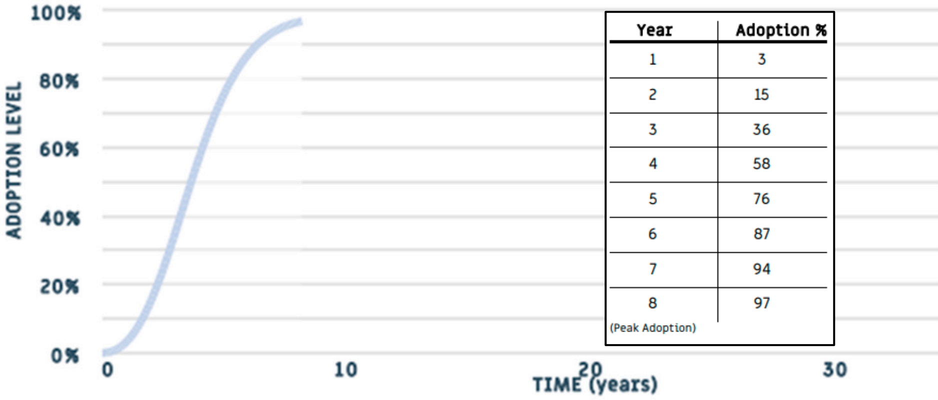

Figure 3. Prediction of the time course of the adoption rate of an EMS in Bavarian dairy cattle farms (I).

The greatest increase in diffusion is predicted between the third and fourth year after the introduction of the innovation (Figure 4). After 5 years, 76% of companies have already achieved widespread use.

In addition to the conclusions about the introduction of innovation, the ADOPT program analyzed the main influencing factor within 22 occupancy variables from the four categories mentioned. Factors that have an impact on the adoption rate or the adoption time are described and evaluated in more detail using a sensitivity analysis.

3.2. Analysis of the Influence on the Acceptance Level

The sensitivity analysis on the level of maximum acceptance clearly shows that company size (question 4—In what proportion of the target companies is there a larger company that could benefit from the innovation?) has the greatest influence on the acceptance of the innovative EMS technology (Figure 5). Other factors are linked to short- and long-term profit expectations (questions 16 and 17). Their value is in the order of −0.2% (scale −1) and +0.15% (scale +1) respectively.

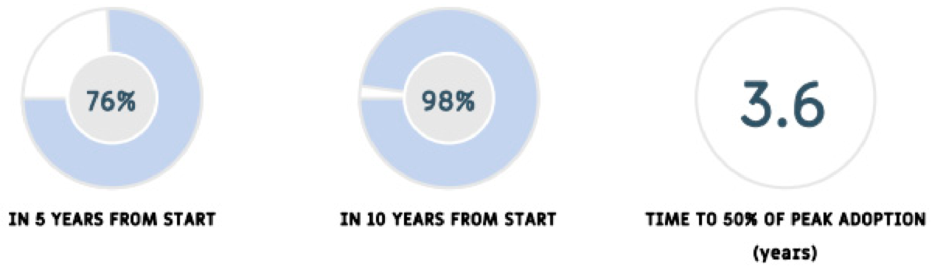

Figure 4. Prediction of the time course of the adoption rate of an EMS in Bavarian dairy cattle farms (II).

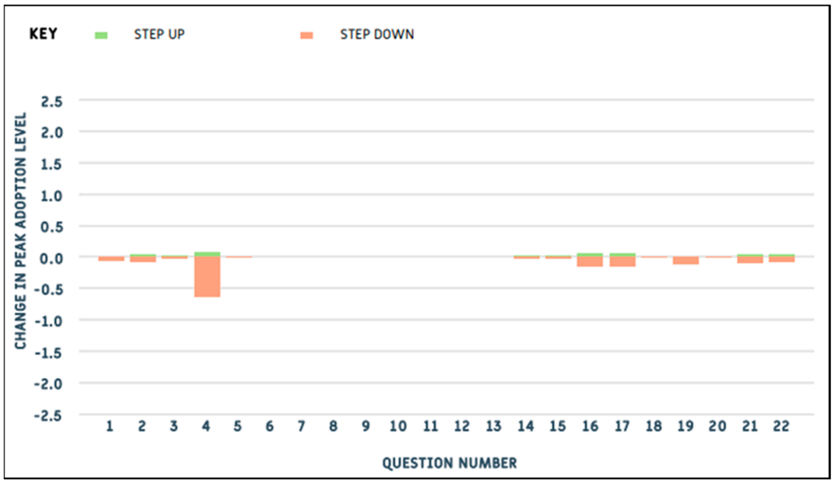

Figure 5. Effects of individual variables on the maximum acceptance level.

In summary, it should be noted that company size has a threefold higher effect on acceptance than all subsequent variables (Figure 6). Overall, 9 of the 22 variables considered (or 41%) have a notable influence. However, the variation on overall acceptance is less than 1%.

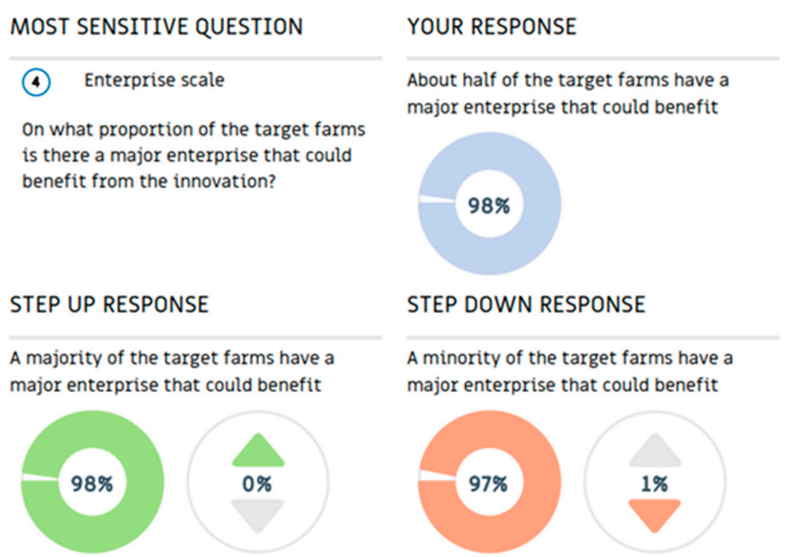

Figure 6. Main variable influencing the prediction of the maximum adoption level of an EMS by Bavarian dairy farms.

3.3. Analysis on the Influence on Adoption Duration

Analogous to the acceptance analysis, the influence of individual variables on the diffusion period of the innovation was also calculated by using the tool to determine the variation in results for a change in scale by one unit in each case. The individual effects are summarized in Figure 7. The highest rate of change in terms of duration is ±1.2 years. Looking at the individual effects, the variation of 21 variables (or 95.5%) has an impact on the length of initial adoption period (Figure 7).

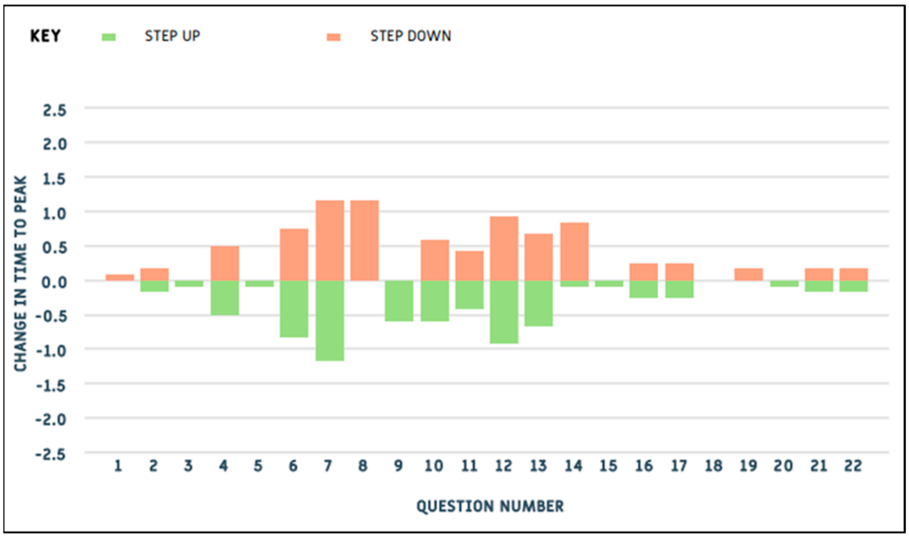

Figure 7. Influence of individual variables on the time to reach the highest acceptance level.

The most effective single effect is triggered by the scaling of question 7 (Testing—How easy is it to test the innovation on a limited scale before it is adopted on a larger scale?) with ±1.2 years in each case (Figure 8). This is followed by the effects in the scale assignment from questions 8 and 12. While the available knowledge and skills (question 12) cause a two-sided change of ±0.9 years for the farm manager, the changes in question 8—complexity (scale value +1 or higher) cause an extension of the adoption time by 1.2 years to a total duration of around 9.2 years. For the other variables, there is a range of 0 to 0.75 years, whereby it is noticeable that the individual scattering has the same effect both positively (shorter time) and negatively (longer time).

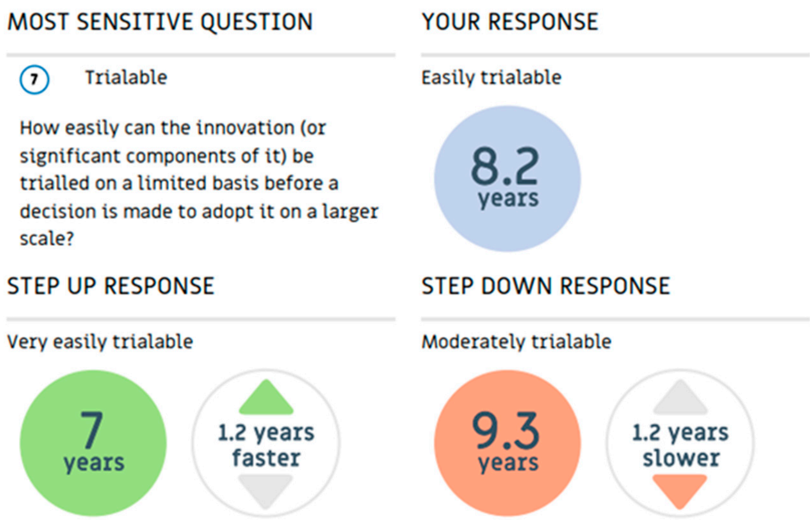

Figure 8. Main variable influencing the prediction of the adoption period of an EMS by Bavarian dairy farms.

Overall, with an average adoption period of 8 years, a fluctuation range of 15% must be expected.

4. Discussion

4.1. Discussion of the Main Results

The primary purpose of this work was to predict how the described energy management system will spread on the potential market based on the variables of adoption rate and associated adoption speed. A market penetration rate of 98% was forecast for the selected group of Bavarian dairy farms, which should lead to maximum dissemination within 8 years from the time of market launch. In contrast to pure surveys, the ADOPT tool thus helps to make a quantified statement on the spatial and temporal spread of the EMS innovation. In principle, the number of 22 variables considered does justice to the complexity of the question. However, it must be acknowledged that although reference relationships between the variables are shown graphically (Figure 1), no concrete information on the calculation methodology (e.g., about variable weighting etc.) is provided either in the input mask or in the digital explanations [31]. A further weakness lies in the specified grid of the variable scaling, which was carried out for 15 variables (i.e., around 68%) in a range of 1–5, which may represent an (overly) coarse classification of the respective assessment criteria and thus only inadequately reflects the influence of potentially critical variables. Another point of criticism lies in the assessment of the economic benefits of innovation, which would be fundamentally necessary for realistic variable scaling. This relates less to the tool and the corresponding scaling itself than to the background data required for scaling, especially as the innovation is currently still in the pilot phase and therefore the actual company-specific benefit cannot be stated with certainty. A penetration rate of almost 100% seems very optimistic overall. In this context, it is assumed that all of the technically necessary elements (e.g., AMS, ice water cooling, e-vehicles, PV or biogas system) are already available, excepting only the EMS and additional required energy storage systems. However, liquidity assessments and economics change as the amount of additional technology to be purchased increases. A decrease in the benefit expectation, e.g., due to higher investment costs, would certainly lead to a lower spread and/or a correspondingly longer adoption time. This is also underlined by an economic evaluation of the Bavarian State Ministry of Food, Agriculture and Forestry, in which around 40% of Bavarian main commercial farms are attested a medium to high risk to their liquidity status [35].

4.2. Discussion of the Learning Properties Category

The ADOPT program groups 22 restrictions (questions) to be evaluated into four categories, which can be subdivided into "learning characteristics" and "advantage/relative advantage". The tool differentiates between the innovation (the on-farm EMS) and the so-called target population (farm/dairy farmer) during the evaluation. In this context, the effects of the variables within the categories can be compared using sensitivity analysis. This involves predicting how the variation of the category through the corresponding variable scaling affects the adoption rate and the adoption time. The analysis of the "learning characteristics" category shows that, despite variation of the associated variables (in both positive and negative directions), the level of acceptance did not change either for the innovation itself or when considering the target population; instead, effects were only found for the duration of the initial adoption phase in each case. This calculation result appears plausible. It can be deduced that if a corresponding variable variation, for example the ease of testing the innovation or the level of existing knowledge and skills in the population, does not result in any changes to the basic acceptance of the EMS, no real change in the adoption rate can be expected. In the case of a longer time required for testing or a greater need for farmers' knowledge, the assumed delay only affects the adoption time. In the examples given, this would mean a delay of 1.2 years in the case of the "testing" variable and a delay of 0.9 years in the case of longer knowledge transfer.

Based on the results of the influence of the "learning characteristics" category, it can generally be said that, depending on the initial disposition of the individual farmer, an acceleration or delay in learning is possible and, as a result, the adoption time is shortened or extended without the acceptance of the on-farm EMS necessarily changing. From this, targeted education and knowledge transfer measures can be recommended for the planned market launch of the EMS to help shorten the time to reach the peak of adoption. In concrete terms, faster testing during future research projects means faster adoption and effective marketing and information measures within the target group, such as articles in specialist journals or trade fair presentations, contribute to accelerated adoption. The results of Beinert's survey [23] regarding the sources of information used by respondents support the finding that there is an increased exchange and better transfer of knowledge within the sector from trade journals, the Internet, and agricultural trade fairs.

4.3. Discussion Category Advantageousness

When looking at the second main category "Advantages or relative advantage", the possibility of influence by the various variables is greater. However, it is important to mention here that the level of the respective individual influence (determined here by 15 scalable factors) is relatively low, overall at an average of $\pm$ 0.18% on the adoption rate and $\pm$ 0.29 years on the adoption time. Around 60% of the possible variables influence adoption time and rate, in contrast to the main category "learning characteristics", where only 42% have an exclusive influence on adoption time. Furthermore, the variables within the main category "Advantageousness" have a more varied effect and in most cases have a simultaneous effect on both adoption indicators (Figures 5 and 7). However, it must be emphasized that some variables stand out from the pool of questions involved, e.g., the size of the company (variable 4) and the investment-related, short-term financial restrictions (variable 6). It is also evident—and understandable—that the expected monetary success (variables 16 and 17) has a decisive influence on the spread of the innovation.

This means that a corresponding marketing concept, which has yet to be drawn up, must specifically address these points. Both smaller and larger farms (in terms of livestock numbers and volume of energy production) must be addressed directly. An investment or financing-oriented entry scenario must be developed as an aid for the innovation decision and as a basis for consultation. The economic advantages must be placed on a more stable data basis using reliable practical results and communicated accordingly using sample calculations. It is precisely when the ecological idea of using an EMS to generate renewable energy in combination with food production and animal welfare can also achieve a positive operating result from an economic perspective that the decision-making process of potential customers shifts toward investing in this innovative technology [36]. In addition to economic aspects, risk minimization (variable 21) and the facilitation of management (variable 22) also have a decisive, if only indirect, influence on the economic added value. This finding from the ADOPT evaluation further substantiates the results of the survey [23], which are thus scientifically underpinned.

5. Conclusions

This study investigated the question of how the central element of an EMS developed by Bernhardt and Stumpenhausen (2013–2021) as part of the "Barn 4.0" concept can be established among Bavarian dairy farmers. The basic idea of the overall concept is to combine the energy consumers of a dairy barn (e.g., milk production and cooling, chilling, ventilation) with energy generation and storage (photovoltaics, biogas, hydrogen) in such a way to provide not only extensive energy self-sufficiency for individual farms, but also an energy network in rural areas (e.g., in the form of a regional network). Such a network could then be integrated into and build a supply relationship with local energy supply companies.

Project managers and developers are interested in the extent to which the industrial prototype can be introduced within the user group and region. So far, attempts have been made to determine interest in this innovation with the help of traditional surveys and user interviews. Despite the positive response, it has not yet been possible to assess the potential actual adoption statistics with enough accuracy based on key figures. By using the ADOPT tool from CSIRO, the temporal and spatial market adoption of technical innovations can be predicted using 22 scaled questions. This modeling can be used to supplement the previous study. The result can be summarized as follows.

(1) For the EMS in question, a market acceptance rate of 98% was calculated within the pre-defined user group and the diffusion period until maximum market penetration was estimated at 8 years. This is the first time that valid figures on the diffusion of this innovation have been presented.
(2) However, when using ADOPT, it must be critically noted that in some cases the calculation algorithms and the variable weighting in the tool are not described in a sufficiently comprehensible manner. This puts the (comparatively very positive) overall result in a somewhat critical light.
(3) In the in-depth impact analysis of the (2 $\times$ 2) variable categories used in the tool, individual main influencing factors such as "company size", and "current and future benefit expectation", were found to be significant for the intensity of adoption, indicating a need for further investigation. This finding is in line with the value drivers mentioned in the survey, which can directly and extensively influence a purchase decision. It will therefore be necessary for the project team to develop economic principles and the necessary framework conditions, especially for the economic added value, to provide farmers with reliable economic information about the EMS used, which can have a positive influence on the purchase decision.
(4) The other references to the detailed results of individual factors, which provide an interesting statement on the spread of new technology, are also very useful. The analysis of the influencing factors and the measures derived from them is particularly important for developing a future marketing concept. The focus here is on both target-group-oriented and region-adapted advertising of the on-farm energy management system and the appropriate variable assignment in the tool.
(5) Although ADOPT was originally designed purely for the agricultural sector, it is already being used for analyses outside the agricultural sector [28,29]. In comparisons, good correlations have already been established between the forecast results of ADOPT and practical figures, for example for automatic steering systems and direct sowing [26]. For example, factors influencing the introduction of photovoltaic systems for water pumping in Australian sugar cane irrigation systems have also been evaluated by the ADOPT tool [30].

Outlook

In the "CowEnergySystem" project, which is to be continued, investigations are to be carried out to test the functionality of the management system developed to aid the optimization of power flows in dairy farms. Supported by the planned pre-series test on ten further farms, this should confirm that the EMS can be used permanently and reliably. Furthermore, the installation of this pilot series is intended to test whether functionality can be guaranteed even with different technical equipment in the barns, both in a new building situation and in existing facilities. In addition to the technical and application-related investigations, an important part of the further research project is the early creation of a marketing concept based on the ADOPT evaluations to be able to start with an information and participant acquisition campaign that is as target-group-oriented as possible. To do this, however, it is essential to extend the prediction of the time of adoption and the duration of adoption to the entire territory of the Federal Republic of Germany. At the same time, further analyses must be carried out in the ADOPT tool to provide statistically-reliable evidence of the influencing factors and their interactions. It can be assumed that the internal drivers or the main category "learning characteristics of the population" described in the ADOPT tool vary significantly depending on the geographical location of the farms. In addition, there will also be differences in the category "Advantage for the population", as the operational equipment and production branches of a northern German farm differ significantly from those of a southern German farm. Consequently, it is likely that both the scope and duration of adoption may differ significantly in northern Germany from those observed in Bavaria. As the customer base of the project partners in the research network is also located outside Bavaria, this would be an important finding and a necessary basis for a nationwide marketing strategy.

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