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Author(s): Alex Koutsouris and Vasiliki Kanaki (AUA)

Contributor(s): ECAF, ICOEL, WIP, DELPHY, TEAGASC, LODR, IUNG, CONFAGRICOLTURA,

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Abstract

The aim of this document, i.e. Deliverable 1.4 of the AgroFossilFree project, is to provide examples of successful innovation processes and best practices in the field of FEFTS. In this realm, existing cases that comprise the whole innovation process starting with the felt need and the origins of the innovative idea until its implementation and finally steps of its diffusion have been identified and documented. The selected 9 innovation cases have been documented through written (stories presented here) and video-based material (links provided).

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1. Introduction

Thinking about innovation is evolving. Thus, many scholars are occupied with the identification of innovation generations, i.e. with the description of the phases of the process from idea to commercialized product. Among proposed taxonomies, the most well-known is that of Rothwell (1994) distinguishing five generations:

- first generation technology-push models (1950s first half of 1960s);
- second generation market-pull models (second half of 1960s early 1970s);
- third generation coupling model (early 1970s early 1980s);
- fourth generation integrated innovation process models (early 1980s early 1980s);
- fifth generation models integrated, interconnected, parallel and flexible innovation process models (since early 1990s).

Rothwell's analysis is considered almost universal given though that, based on Chesbrough (2003), a sixth model, that of open innovation, may be added to the list.

In line with such an argumentation, nowadays, in agriculture and rural development, the linear paradigm of innovation dissemination (Rogers 1983) is gradually abandoned (at least in theory) on behalf of Agricultural Knowledge & Innovation Systems/ Agricultural Innovation Systems (AKIS/ AIS) thinking embracing all the actors, and their interactions, involved in innovation generation, adoption, diffusion and use. Furthermore, AKIS/AIS thinking claims that the process of innovation is messy and complex with new ideas being developed and implemented by actors who engage in networks and make adjustments in order to achieve desired outcomes (see: Faure et al. 2011; Klerkx and Leeuwis 2008; Klerkx et al. 2010, 2012; Koutsouris 2018).

On the other hand, since the beginning of the 2010s strong concern about a number of issues/ bottlenecks pertaining the generation, dissemination and use of innovation in agriculture has been loudly voiced. For example, both the European Union (EU) and the World Bank (see, EU SCAR, 2012; 2014; World Bank, 2012) have stressed that: a) research is insufficiently related to practice and science-driven innovations remain on the shelf due to no/little dissemination activities; b) farmers' needs are not sufficiently addressed during innovation generation, and hence innovations are not relevant (enough); c) innovative ideas from practice are not captured and spread, i.e. local or practice generated innovations with strong potential for dissemination are not recognized or diffused, and d) a shift from science-driven to innovation-driven research has not yet taken place, the institutional, methodological and behavioural changes that are required for such a shift are not yet comprehensively explored and findings and experiences are not systematically documented and assessed.

Therefore, in the EU, through the reforms of its Common Agricultural Policy 2014-2020, two instruments were designed and gradually implemented since 2014 with the aim to more comprehensively and interactively tackle the complexity of innovation processes. The two instruments are: (i) the European Innovation Partnership 'agricultural productivity and sustainability' (EIP-AGRI) and, (ii) the multi-actor approach that has become a key component in a number of Horizon 2020 projects. In parallel, a high-level, multi-actor reflection group, the Strategic Working Group on 'Agricultural Knowledge and Innovation Systems' of the Standing Committee on Agricultural Research of the EU (SWG SCAR-AKIS) has been established since 2010. Not surprisingly, in all cases, specific focus is given to the interaction and cooperation of multiple actors in innovation networks and the key organisational or institutional arrangements and services which support actors to innovate.

Within such a context, the European Union Horizon 2020 project 'AgriSpin' (Space for Innovations in Agriculture; http://agrispin.eu/) run from March 2015 to August 2017. AgriSpin aimed to contribute to systems-oriented innovation research in agriculture based on the idea (shared with EIP-AGRI) that innovation emerges from interaction between stakeholders; thus, the focus of attention shifts from the diffusion of innovations to ways of creating space in which interactions may lead to innovation as a co-creative process. Focusing on innovation processes, 'AgriSpin' was designed to relate concepts to practice and to enrich theory from practice through the in-depth exploration of a series of innovations at farm level with special focus on what support service providers actually do to stimulate such innovations (see Wielinga et al., 2017).

Within AgriSpin the Innovation Spiral was particularly used. The Spiral was one of the tools developed by the action research pilot project 'Networks in Animal Husbandry' (2004 – 2007) which facilitated the establishment of 120 innovative networks in The Netherlands (Wielinga et al., 2008). During the project the monitoring team was looking for new ways to report on the progress of the networks as well as to orient facilitators. Being dissatisfied with the various versions of the classical, linear threephased innovation process (initiation, development and dissemination; see Godin, 2006; Crossan and Apaydin, 2010; Salerno et al., 2015) used in step-by-step planning to reach largely predetermined results, they looked for new ways to understand (and thus support), more or less, unpredictable processes involving multiple actors and concerning innovation co-creation in-the-making. They thus conceived of and applied the Spiral comprising seven stages (Fig. 1). Moreover, the Spiral explicitly allows for feedback mechanisms in case the process in one stage gets stuck; this implies the existence of backward loops as well as the understanding that stages may overlap. Therefore, following Leeuwis and van den Ban (2004) and Faure et al.'s (2014) line of thinking, it was possible to analyse the innovation process through the Spiral stages which, nevertheless, should not be understood in a linear fashion.

The Spiral identifies seven stages in an innovation process, from the initial idea until the embedding stage of the innovation (Wielinga et al., 2008; 2017). In each stage in Spiral of Innovations there are different key activities to be performed, actors to be involved and typical pitfalls to be avoided.

- 1. *Initial idea*: Someone has an idea in response to a problem or an opportunity.
- 2. *Inspiration*: Others become inspired and form a "warm network" around the initiative.
- 3. *Planning*: The network of initiators organises itself and negotiates space for experimentation.
- 4. *Development*: The initiators experiment to develop new practices and evidence of their effectiveness.
- 5. *Realisation*: The innovation is implemented in full scale.
- 6. *Dissemination*: Other people become interested and implement the innovation.
- 7. *Embedding*: The innovation becomes common practice/ is widely accepted and structures/ rules, etc. adapt to the new reality.

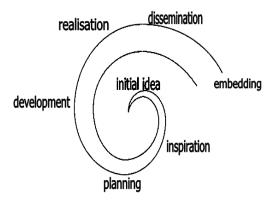


Figure: The Spiral of Innovations

Following, cases were elaborated into 'Learning Histories' (see Kleiner and Roth, 1997), i.e. the narrative, including all facts that mattered in each specific case.

2. Methodology

According to the AgroFossilFree project Grant Agreement, existing cases that comprise the whole innovation process, starting with the identified need and the origins of the innovative idea through to its implementation and finally its diffusion had to be identified and documented (Task 1.4).

Based on AgriSpin, initially the identification of the 16 innovation cases (2 cases per country-hub) through the proto-framework for a brief characterization of innovation cases (AgriSpin project - Annex 1) took place. REScoop contributed with 4 additional case study stories. Then the Task leader in collaboration with the project coordinator (CERTH) proposed the 9 cases (1 case per country hub and one additional case from REScoop) to be further explored so that the cases would cover a wide range of innovation processes and innovations.

Following, partners used the "case study questionnaire" (based on the Spiral of Innovations – AgriSpin project; Annex 2) to interview relevant to their case stakeholders as well as a guideline for the presentation of the (written) 'case history'.

To facilitate partners, the Task leader also provided instructions for the production of videos (Annex 3), examples of videos from other projects (INNOSETA project) along with an example of a case timeline and 'case histories' (cases from the INNOSETA project).

The (written) 9 case histories were reviewed by the Task leader (AUA) and partners (CERTH, AU and IUNG) in order to be finalized and included in the current Deliverable. Corresponding to the 9 innovation cases videos were uploaded to the AgroFossilFree YouTube channel.

3. Case Studies

3.1 Spain. Improvement of carbon stock in soils in Spain through conservation agriculture.

Contact Details

Name: Antonio Manuel Conde, farmer - agricultural engineer,

• Email: g42coloa@uco.es

Name: D. Pedro Maestre, farmer - agricultural engineer

• Email: <u>pmaestre@telefonica.net</u>

Case study author

Julio Román-Vázquez, ECAF, jroman@ecaf.org

Links

Case study video: https://www.youtube.com/watch?v=q7FciiwUH-s

3.1.1 Introduction

According to the European Environmental Agency, "Agriculture contributes to climate change and is also affected by climate change". The EU needs to reduce greenhouse gas emissions from agriculture and adapt the food production systems to adapt and mitigate crop production to climate change. In this sense, soil management techniques based on the three principles of Conservation Agriculture, i.e. minimum mechanical soil disturbance, permanent soil surface organic cover, and diversification of species through crop rotation, contribute to reducing fossil fuel use in agriculture, minimising greenhouse gas emissions, and therefore mitigate climate change.



Three principles of Conservation Agriculture.

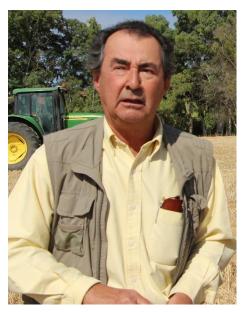
Source: FAO

Through this case study, it is shown how two farmers, located in the region of Andalusia (Spain) have implemented these techniques and the results they have obtained.

Mr Antonio Manuel Conde, a young farmer and agricultural engineer, manages 5 hectares of traditional olive groves farm located in Castillo de Locubin (Jaén). On the other hand, D. Pedro Maestre, farmer and agricultural engineer, manages a farm larger than 750 ha under Conservation Agriculture, cultivating mainly herbaceous crops.



Mr Antonio Manuel Conde



D. Pedro Maestre

In both cases, the implementation of these techniques was a response to the need to improve the soil structure, to reduce the great problems that appear associated with runoff and erosion.

3.1.2 Initiation

In the mid 90's Mr Pedro Maestre was worried about the decline of soil fertility owing to runoff and erosion. According to Pedro Maestre, "we lost the wealth from the soil". Thanks to the knowledge he had got at the university and the close relationship with local input dealers who provided him with plant protection products (PPP) and fertilizers, Mr Pedro Maestre was introduced into the new techniques to conserve soil. These dealers were in touch with Monsanto, and got the opportunity to know more about Conservation Agriculture, which was introduced in the USA and South America many years ago and, therefore to disseminate these techniques among their customers.

During these years, Mr Pedro Maestre was raising his awareness and knowledge by reading some books and scientific articles from Latin American researchers.

In 1997 he attended a field day organised by Monsanto where he saw some demonstrations of no-till seeders and also got new knowledge from advisors who presented that machinery.

After such familiarization with Conservation Agriculture, in 2001, a group of twenty farmers and technicians, in which Mr Pedro Maestre took an active part, created the Andalusian Association of Conservation Agriculture, to share knowledge and exchange experiences so as to develop environmentally and economically sustainable agriculture. This association, together with other, similar regional associations in Spain, was activated under the umbrella of the Spanish Association of Conservation Agriculture (AEAC-SV), which was created in 1995 with the aim to promote among farmers, advisers and society, techniques that conserve the soil and encourage the research of any aspect related to Conservation Agriculture.

Regarding Mr Antonio Conde's farm, he started to approach the three principles of Conservation agriculture in 2015 when he started to study Agriculture at the University of Cordoba. As a farmer, he was aware of the huge loss of fertile soil by erosion because his olive grove is located in a field with high slopes and is managed based on tilling. He observed reduced soil productivity due to the decline of organic matter in soil, and consequently loss of biodiversity, which is very important in this region because of the cultivation of fruit trees for which the local fauna and flora are a great ally to fight against pests and diseases. During 2016, Mr Antonio Conde also started to approach Conservation Agriculture through the attendance of seminars organised, among others, by the AEAC-SV, and by visiting some farmers who were already using this management and reading books and articles about CA.

3.1.3 Implementation

In both cases, planning for the introduction of the principles of Conservation Agriculture had been carried out by the farmers on their own initiative. Both farmers planned the introduction of conservation agriculture gradually, in order to adapt the techniques to the soil and climatic characteristics of their fields. The planning process for the implementation of these techniques is complex. Farmers face the challenge to obtain good crop production and profit which depends on market fluctuations and weather conditions.

In 1998 Mr Pedro Maestre bought his first Marliss direct seeder, but he had to replace it two years later because the seeder was not adapted to the local conditions. In 2000 he bought a Solá direct seeder which is better adapted to the region. Also, thanks to the experience he gained, he was making constant modifications to the machinery and the cultivation system to adjust it to all crops, especially sunflowers.

During these early years of implementing Conservation Agriculture on his farm (2001), one of the first actions carried out by Mr Pedro Maestre, together with the farmers-members of the Andalusian Association of Conservation Agriculture, was the hiring of Mr Rodolfo Gil, Agricultural Engineer of the National Institute of Agricultural Technology of Argentina (INTIA)¹, the who had extensive knowledge on Conservation Agriculture. Mr Rodolfo Gil had a long experience in implementing CA, and for 2 years he was advising Mr Pedro Maestre among other members of the Andalusian Association of Conservation Agriculture. At the same time, the AEAC-SV was supporting Mr Pedro Maestre to develop the new system on his farm.

During the following years, the farmer was adapting the system to his needs and collaborated with the AEAC-SV in the development of some projects. In 2018 the farmer joined to the LIFE Agromitiga farm network, which promoted carbon sequestration in the soil through the implantation of smart agriculture based on Conservation Agriculture principles and precision agriculture. Thanks to that project the farmer obtained enough data to corroborate the benefits that the system offers in terms of carbon sequestration in soil. Moreover, Mr Pedro Maestre is in close touch with the technicians from de AEAC-SV and the European Conservation Agriculture Federation (ECAF) to improve the results of the system on his farm, due to the innovation plan must be upgraded continuously year after year.

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¹ From 1999 to 2002 there was an economic and political crisis in Argentina, and many people had to migrate to other countries to develop their activities.





Mr Antonio Conde introduced Conservation Agriculture on his farm in autumn 2017, once he had acquired the necessary knowledge for its implementation. Thanks to his proximity to the AEAC-SV and the University of Cordoba, he received advice and gradually improved the implementation of groundcover in his olive grove. Fortunately, the introduction of groundcover in perennial crops is a fairly well-developed technique and obtaining the necessary knowledge for its implementation had become easier.

In 2018 he also joined the LIFE Agromitiga farm network, and thanks to this collaboration, the farm was monitored with regard to the evolution of soil carbon content and GHG emissions. Therefore, he was able to adapt the farm operations to optimize the system.



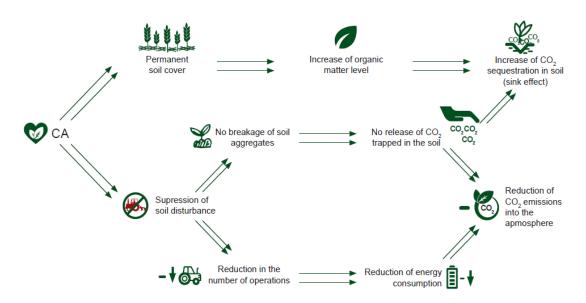
Regarding public support, the farmers claim that the subsidies for implementing these techniques in the field are practically non-existent, and they hope that thanks to the eco-schemes, public aid to farmers who adopt these techniques will be improved.

RESULTS

The results obtained in both farms, verify that the implementation of the principles of Conservation Agriculture provides proven benefits sustained over time, regarding the economic, social and environmental dimensions.

For both Mr Pedro Maestre and Mr Antonio Conde, the first benefit observed after the implementation of Conservation Agriculture is the drastic and immediate reduction in the loss of fertile soil due to, mainly, water erosion. Focusing on the environmental effects owing to gas emissions, one of the great environmental benefits that have been verified in the short term is the reduction in fossil fuel consumption. Both farmers corroborate that the reduction in fuel consumption is around 50% compared to conventional agriculture, and consequently, the emissions produced by their farms are significantly reduced.

Furthermore, regarding the medium and long term, Conservation Agriculture enhances the ability of the soil to sequester carbon, and therefore, partially offsets the negative effect of emissions caused by the use of machinery. In this sense, both farmers corroborate an increase in the soil organic carbon content of around 0.5 t ha⁻¹year⁻¹ (approx. 1.7 tonnes of CO₂ sequestered per ha and year) on Mr Pedro Maestre's farm, and 1.2 t ha⁻¹year⁻¹ (approx.5.4 tonnes of CO₂ sequestered per ha and year) in the farm managed by Mr Antonio Conde.



Climate change mitigation through Conservation Agriculture.

Source: ECAF

Thanks to the LIFE Agromitiga project farm network, these results are being monitored so as to verify that the introduction of Conservation Agriculture in the field is one of the most effective agricultural techniques for mitigating climate change.

Finally, many other benefits indirectly help the agricultural land to adapt and mitigate climate change, such as the improvement of soil health, the increased soil biodiversity and the more efficient use of inputs due to an improvement in the environmental conditions of the farms. That makes a significant reduction of carbon footprint in agriculture.

3.1.4 Dissemination/Diffusion

Spreading Conservation Agriculture is a complex task. According to the farmers' opinion, the main problem that exists with the implementation of this innovation is the lack of training and also the lack of technicians who would offer appropriate advice. Fortunately, farmers know of Conservation Agriculture, but depending on the crops and the involvement of knowledgeable technicians, the implementation of this technique varies enormously.

Regarding the spread of Conservation Agriculture, Mr Pedro Maestre has diffused these techniques among his close circle of peers, but the result has not been as positive as he would expect. Some of his neighbours are reluctant to implement notill techniques due to the adaptations and the new knowledge that it requires. Other farmers have incorrect perceptions about the yields and the inputs needed to establish this type of soil management. Anyway, he continues disseminating Conservation Agriculture among farmers from all over the country and, as he said, many of them start to apply these techniques.

Mr Antonio Conde disseminates the implantation of groundcovers among farmers of the region and indeed all over Spain thanks to being active in the social nets. He claims that most of these farmers are starting to establish groundcover in their groves. Of course "there are few who are reluctant who in many cases are farmers who have already tried to implement this system of soil management, but did not had adequate advice to do it properly."

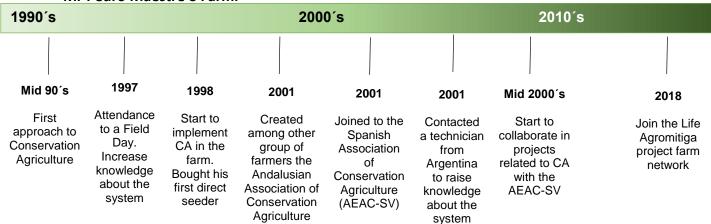
Moreover, and concerning the dissemination, activities carried out by the Conservation Agriculture associations through the different projects in which they are involved are important. Thanks to this, D. Pedro Maestre's farm has been shown (farm demonstrations/ open field days) as an example of a sustainable farm that mitigates climate change to technicians, policymakers and the civil society.



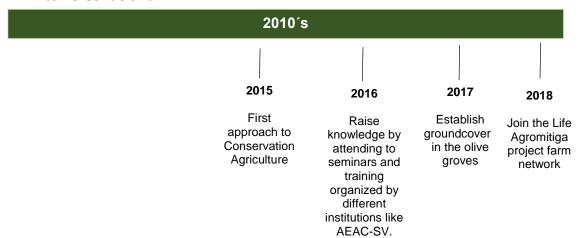
Figure: Field day at Pedro Maestre farm: Dissemination of Conservation Agriculture to policy makers

TIMELINE

Mr Pedro Maestre'S Farm.



Mr Antonio Conde's Farm.



3.2 Denmark. Development of Green protein refineryclover grass to replace soya in feed to monogastric animals.

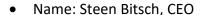






Contact Details

- Name: Kristian Lundgaard-Karlshøj, Owner
- Organization / Company: Ausumgaard (Manor House, Organic farm)
- Email: kirsten@lundgaard-karlshoej.dk
- Website: https://ausumgaard.dk/



- Organization/Company: Vestjyllands Andel (Feed production)
- Name: Erik Fog, Senior advisor
- Organization / Company: Innovation Centre for Organic Farming (ICOEL)*
 - *(Until October 2021: SEGES Organic)







Case study author

Linda Rosager Duve, Innovation Centre for Organic Farming, ldue@icoel.dk
Arne Grønkjær Hansen, Innovation Centre for Organic Farming, Arne@icoel.dk

Links

Case study video: https://www.youtube.com/watch?v=8UBzvuSFIBI

3.2.1 Introduction

The aim of this document is to provide an example of successful innovation process starting with the felt need and the origin of the innovative idea until its implementation and finally steps of its diffusion.

The selected Danish Case is presented here as well as 3 central stakeholders who took part in the innovation process all the way. A video that also describes the process and each of the partners role is developed and available at www.Agrofossilfree.eu and www.agrofossilfree.eu

The main idea and need of the case is to produce a high value protein that can be used to feed for monogastric animals like poultry and pigs. A result of soy production and import is the occupation and deforestation of more and more land and use of fossil energy for transport. To develop alternatives to soy was therefore a need that was identified many years ago and it was an idea that could only be developed if several actors in the Agricultural Knowledge and innovation Systems interacted and were involved in the project at the same time thereby increasing the chance for both a scientific breakthrough that could lead to high output and to the adoption and use of the technology and the end product.

The extraction of protein from clover grass is a process that in the first place uses energy; nevertheless, in the end, it delivers more energy because the side streams from the process can be used as substrate in anaerobic digestion for methane. The biogas industry and the feed industry were therefore the most important actors. The biogas industry was and is still growing rapidly in Denmark and all plant managers are looking for new biomasses in order to increase production. Some biogas plants were already experimenting with fresh grass as a direct substrate for gas production and for import of N to the system (for the use of slurry for fertilization). But it seemed to be a waste of good protein to put it into the biogas plant.

This case story focuses on presenting the innovation process which has led to the establishment of the first facility at a Danish organic Farm, Ausumgaard. Before this, many researchers and feed experts had been involved in experimentation. To identify and credit everyone involved in the Innovation processes and place them in the 7 steps that is described in the spiral of innovations is complicated. Therefore, we have tried to mention the organizations involved in the process leading to the building of two large demo plants in Denmark.

WHAT IS GREEN PROTEIN?

Green protein is a protein extracted from clover grass by biorefining with the purpose to use it as feed ingredient - and possibly for human consumption in the future as well. The green protein has an amino acid composition that makes it particularly suitable for monogastric animals and it can therefore be used instead of soy. The idea is to avoid the import of organic soya from China and South America.

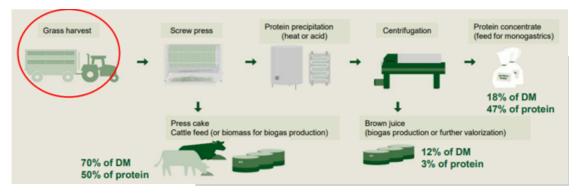


Figure: The process of extracting green protein from clover grass and the side streams of residues.

From idea to factory

During the past 14 years, an innovation process has been ongoing in Denmark to investigate and develop the biorefining process as well as sales opportunities. Figure 1 shows how the protein is extracted from the clover grass and how the products can be used to feed monogastric animals. The side stream "press cake" can be used for cattle feed or biogas and the second side stream called "brown juice" can be used as substrate for biogas production.

In 2020, the first commercial plant to produce green protein was established at Ausumgaard. The second plant was established in 2021 by another consortium led by the Danish Coop Feed company DLG in 2021 called BIOREFINE. Thus, the innovation process has been very successful and has been extremely open, which has allowed more players to develop protein refineries based on clover grass from organic farms in Denmark.

3.2.2 Initiation

In Europe there is a strong desire to become self-sufficient in protein for livestock, while until now, large quantities of feed have been imported from countries outside Europe and over great distances. There is thus a growing demand to find locally produced sustainable alternatives to reduce energy consumption, land use and climate impact related to the production of protein feed. Through the years, the entire livestock industry has become aware of the need for a more sustainable alternative to

soy. A large part of the imported protein feed consists of soy, the majority of which is produced in areas where natural forest and habitats are cleared for cultivation. It gives soy a negative reputation – not least in a climate context. As climate challenges within livestock production became more apparent, the incentive to reduce the use of soy increased.

The import of soy cake in DK is 1.5 mio. tons every year. Researchers at Aarhus University have calculated that it would require 500.000 ha clover grass in total to replace soy in the supply the livestock sector. At the same time, organic production in Denmark expanded, and within this production system, it is particularly difficult to obtain enough protein feed with an optimal amino acid composition.

In Denmark, innovation within green protein began in 2009. Initially, Aalborg University, Copenhagen University and two private knowledge enterprises, Biotest Aps and Solum A/S, investigated the possibilities to make the production of green protein profitable. In 2012, Aarhus University and SEGES joined this innovation process, and in 2014, the feed producing company, Vestjylland's Andel, was involved.

A key focus area has been to produce green protein for organic production, as the price of organic protein feed is higher than that of non-organic. In addition, it is attractive for organic farmers to grow large amounts of clover grass to benefit crop rotation. Thus, clover grass can become a sales crop for organic poultry growers, pig producers and plant breeders, who usually do not have large areas of clover grass in their crop rotation.

The project "Super Grass Pork" was initiated in 2017 by SEGES and Aarhus University. The purpose was to improve the biorefinery processes and evaluate the feed value of grass protein for pigs but also to evaluate the possibilities for the commercialization of the production. (SuperGrassPork (icrofs.dk). The role for SEGES has mainly been as project manager and leader of dissemination.

In 2019 Aarhus University built a demo plant based on the research results of the first projects. This approach has been essential for the innovation process and the plant has been central in several green grass protein projects since then because the results could be used in relation to upscaling and commercialization.

SEGES / Innovation Center for Organic Agriculture represented by Erik Fog has been involved in the innovation process since the beginning in 2012. The initial idea is much older since research about green protein extraction has been going on for decades but only on academic level. Since the beginning Erik has been the project manager for several projects which have contributed to the innovation process and in collaboration with various universities participated in optimizing all stages of the extraction process which by 2020 made it possible to build the first commercial plant

for the extraction of grass protein at Ausumgaard This was based on technology that had been tested in smaller scale at Aarhus University.

3.2.3 Implementation

The company Vestjyllands Andel - Denmark's largest producer of organic pig feed has collaborated with the farm "Ausumgaard" in building the first full-scale plant for green protein production.

Vestjyllands Andel strives to reduce the imports of soy. In addition, they perceived an opportunity to combine three different industries, each of which is challenged to be profitable by itself, but which interact very well together. These three industries are:

- 1. Green protein
- 2. Biogas production including biomethane certificates
- 3. Starfish meal

The residual products from green protein can be used in the production of biogas, the degassed manure from the biogas plants can be used as fertilizer for new fields with clover grass and the drying plant used to dry the grass protein in the summer can be used to dry starfish meal in the winter, when grass protein is not in production.

Ausumgaard was the first commercial farm who implemented the technology and

Benefits of combining production of green protein and biogas

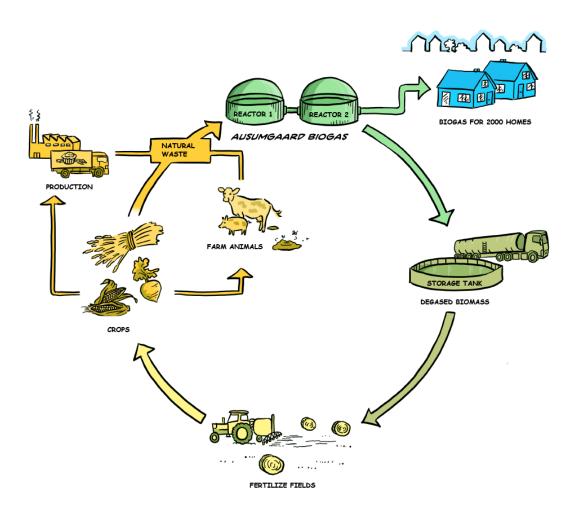
- Both the brown juice and the pulp from the production of green protein can be used as biomass in biogas plants which means that residues are utilized
- The pulp is utilized more effectively in the biogas plant than in grass silage, because
 it is more finely chopped, and the waste generated in a silage process is avoided in
 the biogas plant
- The brown juice ensures extra liquid for biogas production in the summer
- The residual products are thus converted to biogas and fertilizer for the fields.

used the energy from refinery residues to produce biomethane to the grid. The farm is a large family-owned farm with 700 ha of organic plant production. Part of the farm buildings are rented out for chicken and pig production. The biogas plant produces energy and organic fertilizer based on manure and residues from green grass protein production as input. Its location in Jutland near Aarhus University (AU) made Vestjyllands Andel and Ausumgaard a good match for the innovation process and a perfect place for grass production when scaling up from first prototype at AU.

At Ausumgaard, sustainability is a major focus area, and around 2010, Kristian Lundsgaard-Karlshøj became interested in producing protein feed which is sustainable and locally sourced. Initially, Ausumgaard joined another project focusing on insect

protein, but as the general attention increasingly turned to grass protein, and the combination of green protein production and a biogas plant has many benefits in relation to sustainability, and therefore this area became of greater interest at the farm.

Ausumgaard was a first mover in using clover grass silage as a substrate for methane production, and therefore they could see an advantage in putting the clover grass into the grass protein plant and then using the residual products (press cake and brown juice) in the biogas plant. The biorefinery is a great improvement because it generates a high-value product from clover grass and, at the same time, the residual products, which are much better substrates for biogas production than the clover grass silage, can be used. Ausumgaard has had sustainable production as its strategy for many years starting with organic farming, wind turbines and biogas and now finally protein production and extra biogas.





Pig feed with different proportions of grass protein. The darker the feed, the more grass protein.

Photo: Erik Fog, Innovation Center for Organic Agriculture

Expected effects of the innovation process

- 1. Developing the techniques for extracting grass protein, facilitating the possibility to produce green protein large scale
- 2. Ensuring a profitable business and a sustainable production of green protein
- 3. Demonstrating that green protein is a suitable protein feed

Vestjyllands Andel has participated in the innovation process since 2014 and was responsible for developing feeding plans containing green protein as well as conducting feeding experiments. Ausumgaard joined the innovation process in 2018. In 2020 Vestjyllands Andel and Ausumgaard built the first commercial green protein plant in Denmark.

The various steps of the innovation process are outlined below.

Initial Idea

When 2009-2013

Who Biotest/ Aalborg University

Role Private laboratory and public university. Development and test of efficiency

How Test of fermenting techniques for protein extraction from Alfalfa juice

Storytelling The increasing focus on climatic and environmental challenges in agriculture and the large amount of imported soya for animal feed. Farmers fearing restrictions on soya import in the future and a wish to be proactive in finding solutions for local supply with protein feed.

Inspiration phase

When 2013-2014

Who SEGES-Organic Innovation/ Aalborg University/ Aarhus University/ Fermentation Experts/ Biotest/ Copenhagen University/ IFAU Institute for Food Studies & Agro Industrial Development/ Danish Technological Institute

Role SEGES/Organic Innovation is representing the organic farmers and their advisors. Universities and DTI: Research and laboratory analysis. Private companies – Market analysis and possible collaboration /financing options.

How The stakeholders form a R&D project consortiums called OrganoFinery og Multiplant. Both targeting the challenge to extract green protein from grass for use in monogastric animals. The substrate is clover grass and alfalfa.

Storytelling Researchers and farmers' representatives see the challenge and need for new protein and the possibilities for new business and need for test and demonstration. Parallel talks between research and the government. The researchers call for more support for development of new biotech solutions in agriculture and feed industry.

Planning

When 2014-2019

Who SEGES-Organic Innovation/ Aalborg University/ Aarhus University/ Fermentation Experts/ Biotest/ Copenhagen University/ IFAU Institute for Food Studies & Agro Industrial Development/ Danish Technological Institute.

Role SEGES/Organic Innovation is representing the organic farmers and their advisors. Universities and DTI: Research and laboratory analysis. Private companies — Market analysis and possible collaboration /financing options.

How The consortia receive grants for the projects. As soon as the first results are found the consortia both agree to apply for more funding with new goals.

Storytelling The first projects "OrganoFinery" and "Multiplant" are planned for testing several solutions for improvement of protein yield, different plant species and mix. Also the optimal use of side stream in biogas and for cattle feed is evaluated. Evaluation of the economic potential of the total concept when using all parts of the plant. Feed value of different plants used. Evaluation of the positive side-effects on wild bees, etc.

Development

When 2015-2020

Who SEGES-Organic Innovation/ Aalborg University/ Aarhus University/ Fermentation Experts/ Vestjyllands Andel/ Biotest/ Copenhagen University/ IFAU Institute for Food Studies & Agro Industrial Development/ Danish Technological Institute

Role SEGES/Organic Innovation is representing the organic farmers and their advisors. Universities and DTI: Research and laboratory analysis. Private companies – Market analysis and possible collaboration /financing options.

How The first projects are conducted at several locations: in universities, test facilities and through field tests. All experiments are disseminated in articles addressing farmers, farm advisors and other feed experts via SEGES/organic innovation.

Storytelling The first projects showed that protein concentrate can be extracted from grass juice both on a laboratory scale and on a larger scale with 400 tones of grass. The poultry experiments showed that the animals like to eat the protein and that the yolks take on a strong yellow color. A follow-up feeding experiment at Aarhus University with dairy cows shows that the cows like to eat ensiled fiber cake from the protein extraction and even give more milk compared to the traditional feeding with grass silage. These results impressed the large fodder production (private) companies, which in turn started to get involved in the projects, including West Jutland's Share. The promising results in terms of extraction and feed value were triggering a positive economic potential, showing that there is a positive business model for organic grass protein, while price relationships were not yet favorable for conventional feed. Organic production in Denmark reached more than 10% of the country's agricultural production and the commercial actors saw a business opportunity in an organic grass protein market. This also affected the Ministry of Agriculture, which set up a Danish bioeconomy panel to assess new development paths for Danish bioresources. Interest in the ministry's development agency Green Development and Demonstration Program (GUDP) was increasing to support grass protein projects. The grants amount to around DKK 120 million DKK in this period. Among others, funds to establish a demonstration and development facility at Aarhus University's experimental station for agricultural research in Foulum were made available. At the same time, there was a growing interest in developing plant-based foods with a view to limiting animal production, which is often harmful to the environment. Grants were therefore also given to projects that started developing grass protein for food and projects that upgraded side streams from protein extraction to food and other high-value products.

Realization

When 2020-2022

Who DLG/ Danish Agro/ DLF - BioRefine Vestjyllands Andel/ Ausumgaard - "TailorGrass project"

Role These stakeholders represent the largest feed companies in DK and a large organic farm. DLF is the largest grass seed company. They collaborated to form two grass protein factories targeting the organic feed market in the beginning

How The Ministry of Agriculture offers a project call of 14 mio. DKK for the construction of the fist 2 full scale demo plants. Vestjyllands Andel and AUSUMGAARD build a plant with a capacity for 20 tons of grass per hour. DLG, Danish Agro og DLF, builds a similar plant and forms a new company called "BioRefine". The plant is established at a former grass pellet plant.

Storytelling The good experiences from the established and completed development projects as well as the recommendations from the national bioeconomy panel led to increasing positive expectations in the Ministry of Agriculture for the potential, for

Danish agriculture, of the establishment and the development of an industry for the production of feed with locally produced grass protein. They therefore offered two subsidy pools of DKK 14 million DKK for the establishment of two full-scale demo plants, which should serve to gain experience with full-scale production and to create interest in the fact that more actors would become interested in grass protein and would start commercial production.

Dissemination

When 2022-2023

Who Actors involved in Demo plants ICOEL/ SEGES Farmers or Private companies from DK and abroad.

Role The demonstration plants offer information and experience for further development. ICOEL and SEGES demonstrate the technology and result at demo/open days for all interested Farmers and Private companies from DK and other countries.

How Demo-arrangements and farm/factory visits.

Storytelling An increasing volume of information is available in the agricultural media about the experiences gained from the development projects, while industry representatives and politicians mention grass protein as an interesting new possibility that can help fulfill the targets of the Danish agriculture regarding both the environment and climate change.

Farmers, consultants, agronomy students, suppliers and purchasers, private companies in agriculture and food industry are seeking knowledge about the area and are increasingly participating in the completed demo arrangements or arranging visits to the demo facilities.

Embedding

When 2023-

Who Ministry of Food - Danish Agricultural Agency/ Farmers and Private companies (Biogas plants) from DK

Role Danish Agricultural Agency announced a new grant. Different stakeholders including Farmers and Private companies who manage biogas plants form consortia to apply for funding for new plants under construction or planed.

How Danish Agricultural Agency launched grants (open calls by the end of 2022) offering 100 % of the expenses concerning the improvement of the existing plants and for the planning of a new green biorefining plant in full scale. The maximum grant is 15 mio. DKK. A second call gives 65 % subsidy for the establishment of new plants. The budget is 245 mio. DKK.

Storytelling As a conclusion of the many development projects and their promising results, and in response to the ever-increasing need to be able to replace imported protein feed - especially soy, it was decided by the government to allocate funds for

new facilities to receive support, so that the uptake of the new technology can have speed on.

Actors from research, industry organizations within agriculture and biogas production as well as advisors contribute prior to the launch of the subsidy scheme with advice on how the subsidy scheme can best be made attractive to the target group. Not least, the interaction between biorefining and biogas production is expected to play a prominent role, because it is a simple and effective way of utilizing the side streams from protein production while, in parallel, the demand for biogas to replace natural gas is growing strongly, especially after war has been declared in Ukraine and the supply of gas from Russia is expected to stop. Great interest is therefore expected in the Danish Agricultural Agency's first information meeting on 25 October 2022, which will take place at one of the two full-scale demo plants at Ausumgaard, and where representatives of the players who have been involved in the development work will contribute their experiences and recommendations.

Financing

The innovation process has largely been driven by public innovation support. Financing has been crucial until 2020. The Danish state has spent more than DKK 120 million on innovation within the area of the production of green protein. In 2019, it became possible to apply for DKK 14 million in grants for a full-scale demonstration facility, and the support obtained by the facility established at Ausumgaard was obtained. The other 16 million, which has been spent on establishing the facility, has been paid jointly by Vestjyllands Andel and Ausumgaard. At the same time, Vestjyllands Andel ensures that the protein can be sold. It is crucial that sales are ensured, so that we do not face that uncertainty, says Kristian Lundgaard-Karlshøj, Ausumgaard.

Challenges and solutions

In the course of the projects there have been many technical challenges.



Kristian Lundgaard-Karlshøj, Ausumgaard Owner Photo: Linda Rosager Duve, Innovation Center for Organic Agriculture

- The equipment we used proved several times not to perform well enough, and we have had to optimize; the first season at Ausumgaard, the grass was harvested at full length, and it was necessary to subsequently crush the grass to squeeze out the juice; the system with the hammer mill did not work, and the grass is now cut in the field instead, mentions Erik Fog from the Innovation Center for Organic Agriculture.
- When we harvest grass at full length, we can harvest 20 tons per hour, whereas when use the forage harvester, we can harvest 80 tons per hour. In addition, it is possible to transport larger loads of the cut grass to the plant, approximately 18 tons against the previous 8 tons per read. Another challenge is the drying process, which is expensive and undesirable in relation to energy consumption and climate impact. Therefore, a part of the innovation process has focused on the possibility of feeding pasta (green protein that has not been dried). This proved to be challenging, primarily since shelf life of the pasta compared to the dried green protein is very low. Consequently, protein is currently dried explains Kristian Lundgaard-Karlshøj, Ausumgaard.

3.2.4 Dissemination/Diffusion





Currently, the production of green protein at Ausumgaard is based on grass from approximately 400 ha which are cultivated by Ausumgaard and two neighbors. Within one to two years, the goal is to increase production to 700 ha, and within approximately five years to 1000-1200 ha. Accordingly, Ausumgaard plans to produce even more clover grass, and a dialog has been initiated to establish whether several neighbors are willing to grow clover grass for the plant. The clover grass should preferably not be transported more than approximately 15 km.

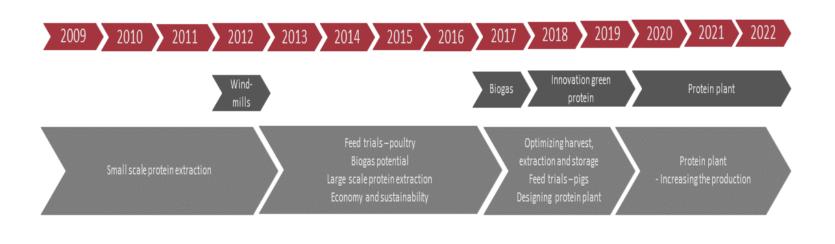
- However, it depends on the future harvesting methods and harvest logistics; if in the future the grass can be compacted more so that we can have more on each load, we will be able to receive grass that has been harvested further away; In 2021 and 2022, several adjustments have been made to the plant to increase productivity, but from 2023, it will be possible to implement the model by others who want to establish a plant, argues Kristian Lundgaard-Karlshøj.

The farmers who will benefit from the innovation process are producers who supply clover grass to the plant; livestock producers who can buy locally produced and sustainable protein feed; and farmers establishing a green protein plant. In favor of even more farmers delivering to the plant and using the feed is that the need for locally produced protein has become even greater in recent years due to both the challenges of securing the feed supply and the climate impact of soy production. At the same time, the production and use of green protein match the organic mindset. It has also been confirmed that green protein is a very suitable feed with high digestibility and in the long run, further refinement for human consumption may be possible, ensuring organic producers an even higher price for their clover grass.

Virtually everyone is very positive about the production and use of green protein - both farmers, politicians, and the Danish population in general.

- Often there is "a flip side to the coin" when new innovative initiatives are set in motion, but not in this case, says Kristian Lundgaard-Karlshøj.

TIMELINE



Ausumgaard

Green protein

3.3 Germany. New Holland Methane tractor T6

Contact details

Name: Gilles Mayer

Email: gilles.mayer@newholland.com
 Organisation / Company: New Holland

Website: https://agriculture.newholland.com/eu/en-uk/equipment/products/agricultural-tractors/t6-methane-power

Case study author

Chuan Ma, WIP, chuan.ma@wip-munich.de
Dominik Rutz, WIP, dominik.rutz@wip-munich.de

Links

Case study video: https://www.youtube.com/watch?v=e4ULmnr0SOk

Other links: https://youtu.be/xgn5Iqze-9M
https://youtu.be/rZ9Y25ydo E

3.3.1 Introduction

Farmers are about to make a significant shift toward self-produced bio methane, which has a much better environmental impact than fossil methane while also being more appealing economically because it is less expensive than fossil methane and received government subsidies for the production infrastructure. In 2011, the beginning of the R&D project within CNH Industrials was made feasible by the interaction of these two elements. CNH Industrials N.V. is an Italian-American multinational corporation with global headquarters in Basildon, United Kingdom. CNH Industrials products are marketed globally through several brands, such as New Holland Agriculture.

3.3.2 Initiation

Farmers stay on the front edge of new technology. It was already acknowledged that methanization, which creates electricity from trash, was a source of energy, but its financial viability was unproven. Nevertheless, New Holland studied ethanol and hydrogen before concluding that biomethane fuel is the most environmentally

friendly option for the next years. The incorporation of light duty on-road vans into the off-road environment will be facilitated by their internal technologies.

Since 2006, New Holland has been communicating to the agriculture world its willingness to lead the sector into clean energy. The EU regulations were clearly showing a path into NO_x and particular matter reduction, but CNH Industrials, through New Holland, was already looking for alternative solutions to diesel. In 2007, they were the first to support 100% biodiesel on their tractors. In 2009 the NH_2 hydrogen concept was unveiled by them and they presented the 'Energy Independent Farm' concept. The work on the NH_2 project made it very clear that the technology was far from being financially viable. Their customers, on the other hand, wanted a solution in the short term; they didn't want to wait for the hydrogen technology to mature. The NH_2 project also considered the use of methane from biogas, and the customers liked the idea of using bio-methane to power tractors.

On top of the environmental benefits related to the reduction of pollutant emission and GHG emission, there is an economic benefit due to the lower price for the farmer with respect the fossil methane. Municipalities and councils would have less carbon emissions. By implementing methane fuel stations, the distance between country and city could be merged.

3.3.3 Implementation

On a farm there are many renewable energy sources one could use, such as solar panels, wind turbines, and biogas. Prior to the development of the methane tractor, in 2011 New Holland first showed a tractor that used hydrogen as a fuel alternative. During the show of this tractor, the participants and New Holland came up with the idea of developing a carbon-neutral tractor that uses biogas as fuel.

During the "planning" phase of the methane tractor, the company and farmers were together to discuss and understand the benefits and challenges associated with it and to collect the initial requirements needed for a good methane tractor. At the initial stage, biogas producers across the EU, predominantly German farmers, were involved.

The missing legislation for a methane tractor was the first challenge encountered, since it is the first one in production and, of course, due to the fact that this product is a pioneer in this field, having this tractor in production is always a challenge since there is no reference point to compare with. In entering an unexplored area, a clear target does not exist while the technical solution(s) needs to be explored, so it is all based on assumptions, which is normally what is happening at the R&D department. Most of the assumptions are based on mathematics and calculations but they are all preliminary; so there is a high risk behind them that makes the planning of the

activities to be undertaken challenging. As the first to market in agriculture, homologation requirements were not present, so agreements had to be made with governing bodies.

Following the planning phase, the company conducted an internal exploration of the technology to understand the real feasibility and challenges in practice. This is a rather fast internal phase without external stakeholders. Potential performance and benefits for customers were identified. It was decided to have the fastest way for a mule to start working, which is called the "concept phase". The mule was developed between 2011 and 2013. During this period, the development was driven and deployed by the company without any support from other actors, apart from engineering companies to support the design activities, and the suppliers of components like methane feeding line and engines to provide them for prototyping.

This mule is suitable only for internal development and controlled activities with the goal of having more robust information for future development—the "Innovation" phase. The goal of this phase was to go from a mule to a working prototype in the field. This development took place from 2013 till 2017. The company kept working on the development and assembly while research centers were involved for the initial test bench activities (mainly PTO dyno tests to check engine performance) and, once the bench activities were completed, the development did move into the field thanks to the support of farmers that made available their fields to test the tractor under different working conditions.

A huge number of field tests were carried out on the performance and safety. Those tests were done by two units under different scenarios. It was tested in not only in Europe, but also in America, Japan and Brazil - especially in Brazil, because of the dust, temperature, and more tillage than in the EU. Additional units were added in this process so they could commercially show this tractor around the world to reach its maximum market potential. From these field tests, farmers and other stakeholders provided feedback, especially on the tractor's performances. During the years 2014 and 2015, the first live demo of a methane tractor was made. Then it was presented during Milan EXPO 2015, where it received positive and valuable feedback. Afterwards, the company decided to continue this development in a more serious direction with the development team receiving a major amount of money from the company.

After the realization of the demo, other actors entered into the discussion, such as suppliers of components for the vehicle itself and the farm infrastructure; national funded projects and authorities, especially those concerned with methane, together with company representatives; the national authorities to discuss incentives and rules to regulate all the aspects related to this new product that, being first in the market, triggered a lot of discussions.

Following the "innovation phase", came the development stage. The purpose of this stage was to get the designed tractor tested and proven on the production line before full production commences. Dairy farmers with lots of liquid waste were involved in this stage. As their waste could be turned into a natural and financial resource — methane, they could use the least expensive raw materials on site and transform them into fuel they could use for a powerful tractor.

During the development of the tractor, there were problems and difficulties. The packaging of a completely new fuel feeding system, which is very different to diesel, must respect safety standards in such harsh environments as off-road equipment. From the packaging point of view, they had at least 3 iterations to get to an optimal solution with the best performance, such as running time, thermal, and heat protection. The overall vehicle tuning, starting from the engine to the driveline, since the target is to have a tractor that behaves like a diesel one in terms of performance, required extensive calibration activities on the bench and in the field to secure acceptable performances. For the overall vehicle tuning, they struggled a bit more because they had to review some key components to secure proper controllability and provide the expected performance. The availability of CNG (Compressed natural gas) infrastructure in the UK agriculture was another challenge since gas from AD (Anaerobic digestion) was not a viable fuel option for vehicle use; AD plants turn organic materials into biogas which is a highly versatile renewable fuel. Furthermore, the covid pandemic delayed the project, so they had to redesign it to reduce costs. Otherwise, the normal process was followed to resolve issues found in the validation process. Due to COVID measures, they had to find new ways of working together as a cross-functional team located in different countries. Some delays are due to the inability to integrate with field test customers.

One of the biggest challenges is autonomy, i.e. to ensure enough fuel to complete the missions required by the tractor. Even at the beginning of the production phase, they development team investigated new technologies that could help in this because the architecture of the tractor doesn't work with normal shape tanks. But in the end, they found other technologies were either too expensive or not performing well, so they used the same technology (structure) as the demonstrator. More time and effort were put on tuning and driving ability work to tune the fuel consumption. Now they have reached the point at which with basically the same consumption the tractor has the same performance as with diesel.

Part of the UK government's founding supported the development phase and field tests. The central role was played by the Advanced Aropulsion Center (APC), which provided the foundation for CNH Industrials' continued development. This center also introduced CNH Industrials to companies that have rich experience in engine exhaust management, and they also provided the materials to the tractor developer that were

needed to overcome the hot engine exhaust issue (the engine could be over 200 degrees). Without the center's introduction, the developers of the tractor would have never come across these companies.

In the development validation stage, many departments were involved, i.e., field testing, rig testing, software validation, and engine validation with the engine supplier. The development of the tractor was completed in 2021. The first prototype was very different from the current tractor; changes concern the engine, the CNG bottle been removed, the tanks modified, the larger converter for cleaner exhaust, the software update, and the completely different control architecture. Rage-extending fuel cylinders were relocated from the cab to the front of the vehicle. Key aspects of the tractors were patented, such as the extra fuel capacity and safety aspects to ensure the possibility of maintenance for farmers. Despite the patent technology of this tractor, the background of the company helps greatly with the development of the tractor.

3.3.4 Dissemination/Diffusion

The predominant users are intended to be dairy farmers. The product has been delivered to the first customers starting at the end of 2021. This innovation is successfully delivered among the early adopters. Besides, New Holland also joined agricultural-related associations such as the European Biogas Association and European Agricultural Machinery Industry Association.

The financial benefits of a methane tractor were acknowledged by farmers during fairs. Education of the farmers is important so they will know the difference between a traditional diesel tractor and a methane tractor. It is not only circular farming and energy independence, but also how farmers could pay off the tractor and make a profit over the lifetime of the machine. Therefore, the necessary education and training on the machine are also supported through the company's dealerships and sales force. The commercial life of the new tractor has only started.

TIMELINE

2006 Clean Energy Leader strategy® launched

2007 All New Holland engines are 100% biodiesel compatible

2009 1st NH^{2™} Hydrogen Tractor and Energy Independent FarmSM concept presented

2011 First phase "concept" and start of "innovation"

2013 1st generation T6 Methane Power Tractor

2014-2015 First live demonstration on Agricultural version

2015 2nd generation T6 Methane Power Tractor launched at Milan EXPO

2015-2016 Intensive field test world-widely

2017-2019 Further Extensive field test with different engines

2019 Won "Sustainable tractor of the year"

2019-2021 Production Development

2021 Won "Sustainable tractor of the year" again

2022 Launching in Brazil, USA, Canada and EU



Figure 1: T6 METHANE POWER TRACTOR



Figure 2: METHANE POWER TRACTOR with handle



Figure 3: METHANE POWER TRACTOR in the field



Figure 4: METHANE POWER TRACTOR on duty

3.4 Greece. Brite Solar: Semi-transparent photovoltaics for agricultural applications.





Contact Details

• Name: Nick Kanopoulos Ph.D, CEO Brite Solar

• **Email**: info@britesolar.com, nkanopoulos@britesolar.com

• Organization / Company: Brite Hellas SA

Address - Headquarters:

Thermi Building no.2, 9th klm. Thessaloniki – Thermi P.O. Box D8129, Post Code: 57001 Thessaloniki, Greece

Tel: +30 2310 321342

Website: https://www.britesolar.com/

Case study author

Vasiliki Kanaki, AUA, <u>vskanaki@gmail.com</u> Alex Koutsouris, AUA, <u>koutsouris@aua.gr</u>

Links

Case study video: https://www.youtube.com/watch?v=agxrNrUnomw

3.4.1 Introduction

Brite Solar is a nanotechnology company, developing nanomaterials for solar glass applications in agriculture to facilitate sustainable food supply. Brite Solar consists of a team of 20 highly educated people, who are all company shareholders. The company is headquartered in Thessaloniki, Greece with R&D development offices in Patras, Marketing and Sales Development in the U.S and Project Development in the Netherlands.

Brite's technology allows the dual use of land for both agricultural production and solar energy production at the same time, either in greenhouse or in crop protective structures for open field farming (Agri-PV).

3.4.2 Initiation

Greenhouses are an important technology for agricultural production worldwide. However, depending on the type of greenhouse structure and crops' needs, they can be very energy demanding. Currently they rely mostly on fossil fuels to cover their energy needs, e.g. for cooling or heating. Energy cost is considered to be one the most important costs of the greenhouse, reaching up to 28% of the operating costs. Brite tried to develop a sustainable technological solution that solves the problem of energy cost in the greenhouse and has small or zero carbon footprint, being aligned with EU's goals (re: Green Deal) of climate neutrality by 2050.

Brite Solar was founded in 2010 when the company's founder and CEO Dr. Nick Kanopoulos, came back to Greece, after almost 30 years of studies and professional experience in the US.

Dr. Kanopoulos, an electrical engineer, worked for many years in the semiconductor industry. The last 2 years of his career in the US he worked for Applied Materials, a major technology supplier for turn-key factory equipment for the manufacturing of conventional solar panels.

When working in solar industry, he came up with the idea that a greenhouse is an excellent construction to produce energy, as long as the roof and/or the glass panes around it were photovoltaic panels (PVs).

On the downside, conventional panels lacked in transparency for use in the greenhouse because the plants under the glass need to photosynthesize. There had been trials with the use of conventional PVs sparsely placed on the greenhouse roof, but in several cases they impacted negatively on plant growth, and were therefore not a universally applicable solution. In cases of open field horticulture, PVs compete for

land use. PV panels needed to be transparent enough in order to allow plant photosynthesis and avoid yield losses or negative effects in plant growth.

The idea development started in 2010 when Dr. Kanopoulos started discussions with Elias Stathatos, Professor in the Electrical and Computer Engineering Department at the University of Peloponnese and Head of the Nanotechnology and Advanced Materials Laboratory (N&AML). His research interests were focused on third-generation solar cells and the use of nano-structured materials. They had to answer to the question: «Can we create a PV panel, transparent enough in order to allow plant photosynthesis, without negative effects on crop yield?"

3.4.3 Implementation

Early years

2010 - 2013

Brite Brite was founded in 2010 by Dr Kanopoulos with Dr. Stathatos being in the core team. The aim was to develop the idea of semi - transparent PVs for greenhouse use and to turn such an idea into a marketable product.

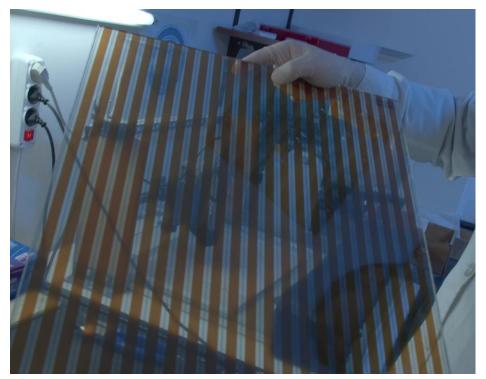
At the beginning, the company was entirely funded by Dr. Kanopoulos (seed investor) and funds from Greek and European Innovation Programs followed (Green Deal, H2020 and National Programs). In those years, the company faced several financial difficulties. At that time, Greece was experiencing an unprecedented economic crisis, with severe implications in attracting foreign investors (high country risk). This factor slowed down the company's development significantly, which was a common problem for all start-ups. In addition, the absence of down payments in many projects resulted in cash flow management to be a significant problem (required the existence of own capital).

Coping with Greek bureaucracy that is involved in the management of National and European projects was another great challenge. Hundreds of working days and hours were devoted to loads of paperwork and bureaucratic procedures.

But the most important challenge was to produce a validated prototype based on a technology that was not in the market and devise the means of mass production for this technology.

In the early years, Brite started the semi- transparent third generation solar panels development by using Dye Sensitized Solar Cells (DSSC) technology, which they believed would yield a viable product. Brite was the first company to develop a scheme that was manufacturable for that technology (standardized materials, ability to be developed in big surfaces and potential industrial production). But after 5 years of laboratory development, when they did the pilot test in a greenhouse, they found that the glass transparency affected the crop yield negatively by 20%.

Figure 1: Semi - transparent third generation PV panel (Dye Sensitized Solar Cells)



Pilot test 2013 - 2015

During 2013-2015, Brite did a pilot test in a greenhouse cultivating tomatoes. They collaborated with ELGO-Dimitra, the Greek Organization for agricultural research and promotion of innovations. These experiments were done in the context of a national funded project called "COOPERATION". Two identical greenhouses were compared, the first one using conventional glass and the second one using Brite's solar glass. Brite provided the innovative solar greenhouse and ELGO tested the crop development. Results showed that the solar greenhouse had a negative impact on the tomato yield in the order of 20%.

These results contradicted the agronomist assurances to Brite stating that the panel transparency was suitable for the light requirements of crops like tomatoes and other salad vegetables. When developing the prototype panel, they were giving emphasis

on the average transparency of the panel. However, the transparency was not linear over the visible spectrum and more specifically over the first photosynthetic area for plant development of 400 to 459 nanometers. In fact, the panel was 35% transparent in that region, which reduced the tomato yield by 20%. Most importantly, this solar glass transparency was fixed and couldn't vary at the manufacturing stage, which made the product applicable only to crops that could be unaffected by the light transparency of the glass. This limited the market for this product.

Brite had developed a technology that would have negative effects on some crops, and therefore couldn't be applied universally, because no farmer would accept a yield loss just to produce energy. So, they decided to do a pivot, and change the technology completely.

New technology development 2015 – 2019

The new panel (Brite Solar Glass Panel), was based on silicon-based solar cells, and the transparency of the panel was fixed to be linear over the visible spectrum, in all the important stages of plant photosynthesis. Most importantly Brite adapted the glass transparency to the light requirements of crops under the glass, thus making a product with universal applicability.

• Custom made panel transparency and size.

Brite developed the ability to adapt the panel transparency to the light requirements of the crops under the panel. And because there is no standard dimension in greenhouses, they are able to change panel size depending on the greenhouse construction (roof size). So, they do not have one product, but one design with different levels of transparency and panel size.

That is a Brite's distinctive comparative advantage.

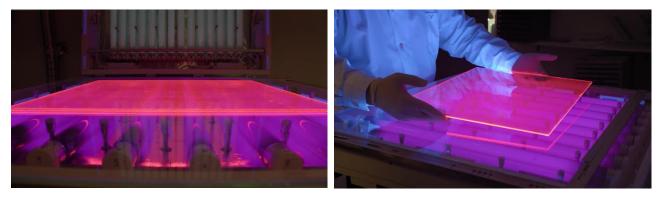


Figure 2: Different size and transparency configurations of Brite Solar Glass Panel

Nano-coating materials for photosynthesis optimization (Luminescent Solar Coatings)

Another technological advantage is the optimization of the transparency of the solar glass in the wavelengths critical to photosynthesis.

Brite has developed nanostructured coatings which convert UV light into strong visible light. These coatings absorb light in the ultraviolet spectrum, which is useless for both plants and solar cells and retransmits it into the red (600-650nm) or blue (400-450 nm) region of the spectrum which is useful for both plants and solar cells. This provides an increase in the primary photosynthetic regions when compared to standard greenhouse glass, i.e. the amount of light energy the plants receive in order to photosynthesize, is increased. The nanocoating can also be used in conventional glass to increase the plant's photosynthetic activity.



Figures 3,4: Glass covered with Brite's nanostructured coatings, illuminated with low-power UV light.



Figure 5: Demonstration of the nanocoating effect when two cubes of coated and uncoated glass are illuminated by UV light.

At the same time, Brite Solar Glass Panel transmits uniformly all wavelengths of the visible light spectrum.

The efficiency of solar cells is also increased which allows for increased power in Brite Solar Glass. By combining this coating with silicon based solar cells, Brite has developed the worlds' most transparent solar glass (80%) with the highest solar cell efficiency.

Panepower Panel Description

A Brite Solar Glass Panel consists of a glass coated with Brite's nanostructured materials and on this glass, solar cells are placed. The arrangement of solar cells depends on the transparency required for the crop under the glass.



Figures 6,7: Brite Solar Glass Panel designed for vineyard greenhouse cultivation.

Interconnect

A. Net metering

The greenhouse can be connected to the grid and use net-metering to avoid the cost of storage and offset all electricity costs needed for its operation.

B. Use of batteries in cases of no available grid connection

Coupled with energy storage technologies such as batteries, a greenhouse can store the excess power produced during the day to be used at night or on cloudy days.

Pilot tests of Brite Solar Glass Panel

Brite Solar Glass Panel was finalized as a product in 2019 and has been used for a great number of pilot applications in greenhouses but also in open field cultivation (agrivoltaics) with excellent results and without any negative effect on crop yield.

Greenhouses

2019: Vineyard in greenhouse with Brite's solar glass – Evangelos Tsantalis Vineyards & Wineries, Thessaloniki, Greece

A study facilitated at Evangelos Tsantalis vineyards, one of the largest wine producers in Greece, cultivating almost 200 hectares of private owned vineyards. A 0.1-hectare greenhouse was experimentally installed in 2019, over a 10-year-old vineyard, by using Brite's Brite Solar Glass Panel on the roof. This allowed the measurement of the actual carbon footprint wine grape cultivation, which, until now, was only theoretically estimated. The energy produced by the Brite Solar Glass Panel installed on the rooftop exceeds the energy needed to operate the greenhouse.





Figures 8,9: Vineyard cultivation in greenhouse, Tsantali vineyards, Thessaloniki, Greece.

♣ 2022-2025: Tomato greenhouse, Ptolemaida, Greece



Figure 10: Tomato greenhouse in Ptolemaida, Greece.

2022-2023: Demonstration greenhouse, ornamental plants, World Horti Centre, the Netherlands

Brite's initiative to create a demonstration greenhouse with ornamental plants, in collaboration with Vertify research center, an independent private foundation in Netherlands which conducts applied research on a variety of crops and tests newly developed innovations. (https://www.vertify.nl/en/)





Figures 11,12: Ornamental plants demonstration greenhouse in the Netherlands. **Agrivoltaics**

4 2021-2022: Agrivoltaics over blueberries, the Netherlands

Agrivoltaics application with Brite's solar glass over blueberries and pear orchard, in collaboration with Wageningen University, Netherlands. Wageningen is responsible for the assessment of crop development. Both projects are partly funded by the Dutch Government.





Figures 13,14: Agri-PV over blueberries in the Netherlands.

4 2021-2024: Agrivoltaics over pears, the Netherlands

Agrivoltaics application with Brite's solar glass over pear orchard, in collaboration with Wageningen University, Netherlands. Wageningen is responsible for the assessment of crop development. Both projects are partly funded by the Dutch Government.





Figures 15,16: Agri-PV over pears in the Netherlands.

2023: Agrivoltaics in avocado trees, Crete, Greece (Project in development)

Patents and Excellence

The prototype product was finalized in 2020. Brite's technology is protected by patents in the Netherlands and EU, China and the US (15 patents granted and pending). Brite has won numerous national and international innovation awards.

Raising funds

The company has won a number of very competitive EU and Greek research and development projects raising the funds needed to develop its products. In 2020 the European Innovation Council Fund made an equity investment in the company.

3.4.4 Dissemination/Diffusion

Currently there are 10 end users, all of them giving positive feedback.

Strategy

Brite is building its own factory and production line in Patras, Western Greece aiming at the development of an international sales network for its products. Funds were raised by private venture capital and the European Innovation Council Fund, which is EU's flagship innovation program to support breakthrough technologies and gamechanging innovations, managed by the European Investment Bank.

Difficulties

Temporary difficulties are due to current supply chain circumstances, and they include high shipping costs and the long production cycle.

Installation cost

Brite's solar glass panels cost on the average 40-70 EUR per square meter. This cost depends on panel transparency and volume. The panel transparency depends on the light requirements of the crops under the canopy.

Solar glass panels have a life cycle of 25 years. So, after break-even point, the investor will have energy for free. The average break-even point is 5-7 years.

In addition, Brite has developed a Total Cost of Ownership model which allows one to input the greenhouse specifics (location, size, construction, plants to be grown, energy source) and then calculate the energy production and savings from Brite's installation.

Benefits

Brite's technology provides a practical approach for dual use land, either in greenhouse or in open field crops (AgriPV). PVs can be placed in highly productive land and have energy and agricultural production at the same time.

♣ Greenhouse

Energy autonomy: In the greenhouse the electricity generated by Brite's solar glass can almost eliminate energy costs, without affecting the yield of the crops. Excess of solar energy is fed into the grid.

Open field (Agri-PV)

- 1. **Crop protection**: AgriPV is used as a crop protection canopy to reduce damage caused by adverse weather conditions, such as frost , snow, hail, excessive heat.
- 2. **Rainwater management:** Brite provides a support structure for collecting and re-using rainwater for optimized irrigation.
- 3. **Energy production:** The energy generated can be sold to the power utility or used to replace traditional fossil fuel equipment with clean electric ones.

Who benefits

Brite's technology is suitable for any type of glass greenhouse or open field crops. All sizes of farms benefit from such an investment.

The investment can be made by:

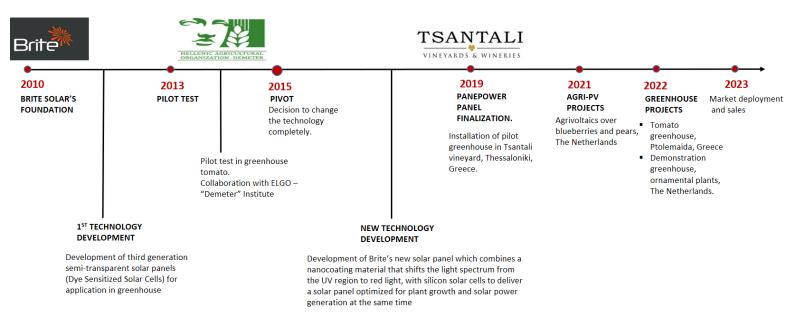
1. The farmer

The farmer/farm owner makes the investment, to offset the electricity costs by using the generated solar energy.

2. An energy investor

An energy investor rents the land or the space over the land from the farmer/land owner. The farmer will benefit from the crop protection canopy construction (protection from weather extremes and rainwater collection) while the energy investor benefits from selling clean energy to the grid.

TIMELINE



3.5 The Netherlands. 'Bewaarschuur van de Toekomst'

Contact details

Name: Tonnie van Peperstraten, CEO Van Peperstraten Group

• Email: tonnie@vanpeperstraten.nl

• Organisation / Company: Van Peperstraten Group

Website: http://www.vanpeperstraten.nl/
 Location: https://goo.gl/maps/DQ5J9n4ZLaPfHJTY7

• Name: Frank Hoeckx, Business manager Altez Group

Email: info@frankhoeckx.nl

Organisation / Company: Altez Group

Name: Luuk Salomons, CEO Omnivent

• Email: luuk.salomons@omnivent.nl

Organisation / Company: Omnivent

Case study author

Joris Tielen, Delphy, joris.tielen@delphy.nl

Links

Case study video: https://www.youtube.com/watch?v=Is C6VKJIPE

3.5.1 Initiation

In 2014, Tonnie van Peperstraten from the Van Peperstraten Group had the idea of creating and building an innovative storage barn on his arable farm with the ambition to become independent of fossil fuels in his agricultural operations. He created a cooperation together with Frank Hoeckx of Altez Construction Group and Luuk Salomons of Omnivent. Altez is a company specialised in agricultural and industrial construction works and Omnivent is specialized in industrial cooling/heating and ventilation systems.

Van Peperstraten Group is a family farm, currently ran by two different generations, namely Tonnie himself and his son Thomas. The farm has 250 hectares of arable land, on which potatoes, unions, wheat, sugar beets, carrots and peats are cultivated in a conventional way. For Dutch standards, Van Peperstraten Group is a large scale arable farming operation. The idea for the innovative storage barn of the future was to

remain a leading company in arable farming in the Netherlands and realize selfsufficiency and sustainability in their needs for energy to run their agricultural operations.

In the Netherlands, this is a pioneer project. There are no other concepts/designs in which the features of this storage barn have been tested, nor have the construction ideas implemented in this project been used/built on other sites before. The partners hoped to create new pathways for Dutch agriculture to become independent of fossil fuels in various operations and satisfy future demands such as track and trace systems of food and the production and sale of generated electricity and hydrogen.

For these reasons, Altez Construction Group was involved. This construction group is specialized in agricultural and industrial construction works and therefore is the ideal partner to design new, innovative concepts based on prefab constructions procedures. The new elements in the design aim to create a concept which completely relied on its own generated energy and other resources demanded extensive experience in large industrial construction project, which Altez Construction Group could provide.

Additionally, Omnivent is a leading company in the Netherlands in industrial cooling/heating and ventilation systems for arable farming. They also provided the expertise and experience needed to realize reliable new integrated innovative solutions in the design of the "Bewaarschuur van de Toekomst". This company also has extensive experience in the relationship between the cultivation of the crops and their quality maintenance after harvest.

The concept of the 'Bewaarschuur van de Toekomst' is based on eliminating fossil fuels from arable farming in the Netherlands. Energy is generated with solar panels, rainfall water is harvested and stored for use in the cooling systems, as cleaning water or for the production of hydrogen. Produced energy is either used for own purposes or for sales to the common energy grid, just as hydrogen at a nearby gas station. The ventilation and climate installations in the facility are designed to achieve the highest energy use efficiency as possible.

In this initiation phase, lasting from approximately from 2014 to 2018, hurdles had to be taken in terms of acquiring enough subsidy from the 'Groensubsidie' ABN AMRO bank, provided in the Netherlands. This is a subsidy scheme with the goal to subsidize and speed up sustainable construction concepts in the Netherlands, but is generally applied for in housing projects. Adjustments for application of this subsidy policy for the agricultural sector had to be made.

Additionally, this concept of the "Bewaarschuur van de Toekomst" also implied some consequences with regard to its environmental integration, such as the size of the building and the infrastructure needed to deliver energy and hydrogen to the energy grid and nearby gas station respectively. Local authorities, such as the province of

Zeeland and local municipalities, had to adapt current regulations for construction and land use purposes for this unique building concept.



Figure 1: Layout of the 'Bewaarschuur van de Toekomst' with Dutch explanation of some key features.

3.5.2 Implementation

The implementation phase started from 2019 onwards, when the construction of the storage barn started with laying a complex foundation for the rest of the building. In that year, some 1460 piles were dug in the soil to lay the basis of the rest of the building. Thereafter, the construction of the building was continued that year. In the timeline presented below, the different phases of the construction, implementation and moment of becoming operational are presented.

In this process, Altez was in charge of the building operations and took charge of this phase. Because of the pioneering nature of this construction project, the concept has been adapted several times for requirements in the future on traceability of the agricultural produce and an automated transportation system in the storage barn itself. These requirements were implemented in the building concept later than the initiation phase. Because of the large and wide lay-out of the storage barn, there was still 'room' available to meet these additional requirements in the implementation phase.

Besides that, there were several difficulties in terms of the fire safety of the building, because almost all the ventilation and climate control systems were incorporated in the concrete design of the building. These installations had to be accessible according

to security regulations; otherwise they were not accessible for maintenance and in case of fire, in order to extinguish the fire.



Figure 2: Construction of the foundation piles and ground floor of the "Bewaarschuur van de Toekomst" in 2019.

The 'Bewaarschuur van de Toekomst' includes 5000 solar panels which produce around 1.8 MW per year. Underground, there is a water storage unit of 6000 cubic meters for rainfall water harvesting. This water is used to moisturize the agricultural produce, produce hydrogen, wash agricultural machinery, for spraying operations and as drinking water or demi-water. An energy management system determines whether the produced energy is used in the facility itself or sold to the common energy grid. Additionally, in combination with the isolation concepts described later, the energy management system is also programmed to use the least number of hours to maintain good storage conditions for the agricultural produce.

In total, there were five units for bulk storage of 800 ton, three units for bulk storage of 1600 ton and three units of box storage of 650 ton in operation in 2021. The first five units for bulk storage were already available for use in 2020. On and transshipment of unions, both for Van Peperstraten Group themselves and other farmers in the area, is outsourced to another company called SEPA, a company specialized in sales in the union market. They also have an office in the 'Bewaarschuur van de Toekomst".

Besides these main features of the storage barn, the construction includes some other key innovative elements. Altez Construction Group introduced prefab- built concrete walls and rooftops to start the construction in 2019. This makes construction onsite much easier, as the building is composed of several elements that only need to be installed on the building site. The building is designed to keep the warmth outside during summer and the warmth inside during winter by double isolation walls and by using only concrete as building material. Additionally, a wide crossing of the rooftops has been created to create more shade on the walls from the outside of the building, forming a sort of hat on the building.



Figure 3: Front view of the "Bewaarschuur van de Toekomst" with wide crossing of the rooftop, creating a lot of shadow on the walls and around the building.

Another innovation introduced by Altez Construction Group on the concept of the 'Bewaarschuur van de Toekomst' are the so called 'flexifloors' in the storage barns. This are plastic shapes that can be placed in the concrete ground floors on the outlets of the ventilation installation. The shapes vary in size, creating the possibility to store different products in the same storage units, from shapes such as potatoes and unions to grass seed and grains. The shapes can be replaced by hand.

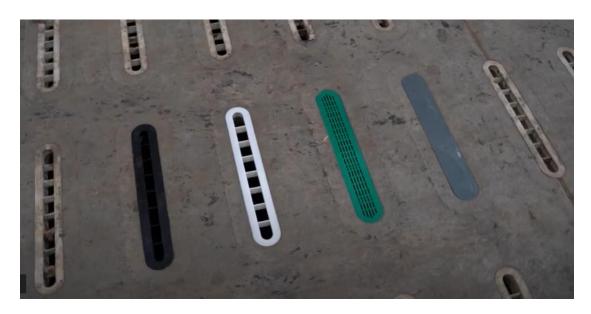


Figure 4: Different types of flexifloors for ventilation in the storage units of the "Bewaarschuur van de Toekomst".

Omnivent introduced a new innovative concept for ventilation and cooling systems in the storage barns as well. These installations are normally place outside the main construction building, but at the 'Bewaarschuur van de Toekomst they are installed inside the concrete walls and roofs. This has the advantage of more space been available in the storage units.

These innovations were implemented in the building simultaneously with the finalization of the storage units respectively. During 2022, the last technical aspects of the building were finalized over the year. In 2023, the installation of the facilities to start producing hydrogen by electrolysis is planned.

Furthermore, other innovations that are planned for 2023 in the 'Bewaarschuur van de Toekomst' are an intern transportation system in the storage barn between the climate units and the in- and outlets of the facility. A sorting area will be created as well to cater for differentiations in sizes and the quality of the harvested produce and installations to follow 24 concepts of traceability of agricultural produce.

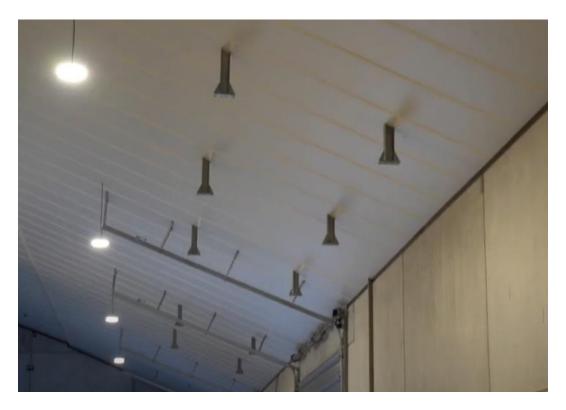


Figure 5: Preparations to realize an intern transportation system in the "Bewaarschuur van de toekomst" to realize traceability of agricultural produce.

3.5.3 Dissemination/Diffusion

Until now, there are no other plans to construct other storage barns with a similar sustainable building concept as the 'Bewaarschuur van de Toekomst'. However, all three stakeholders involved in this project, namely Van Peperstraten Group, Altez Construction Group and Omnivent, all pointed out that they are open to and interested to assist other farmers with similar ideas with the knowledge developed in this construction project.

Persuasion of other farmers to invest in projects like the 'Bewaarschuur van de Toekomst' may also be stimulated in the future when certain concepts incorporated in this design will become more attractive in terms of making money instead of achieving a reduction in production costs. For example, the energy produced in the facility now is mostly used on the farm itself with the goal to achieve self-sufficiency, but it may become even more attractive when the delivery of energy to other customers via the energy grid would result in a good income. Different concepts incorporated in the design of this project can also be implemented and copied on other locations separately to reduce the costs of construction.

The same accounts for the production of hydrogen. This technology is rather new and the number of local customers of hydrogen on the local gas station is limited.

Additionally, Tonnie van Peperstraten pointed out that he is far from making money with the sales of hydrogen now, but he is convinced that this will become part of his company in the future.



Figure 6: Greenpoint gas station nearby the "Bewaarschuur van de Toekomst" which is used as point of sale for the produced hydrogen to other customers from 2023 onwards.

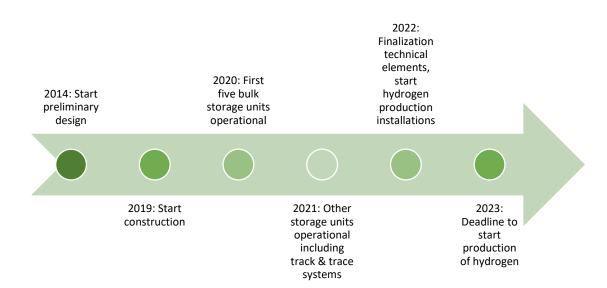
The concepts incorporated in the 'Bewaarschuur van de Toekomst' are also applicable to other arable farming and open field vegetable farming enterprises in the Netherlands, but also abroad. To make this possible in the future, other customers can also make use of the technical support of Altez Construction Group and Omnivent and the experience of this pioneer project at Van Peperstraten Group.

To make implementation possible in other sites, interested entrepreneurs should keep in mind that there were also difficulties in this project regarding the environmental integration of the storage barn. Local authorities and municipalities might not always have regulations that are relevant to these new concepts of building. In the Netherlands, this are often the so-called "Bestemmingsplannen", which determines what type of constructions, with what maximal dimensions, and for which purposes are eligible to be constructed on a piece of land. In this project, the size of the building was initially constrained by these regulations.

Additionally, connecting infrastructure between private companies and common infrastructure, such as the facilities to make redelivery of electricity or hydrogen to local gas stations possible was problematic at first. This infrastructure is still developing all over the Netherlands and regulations and laws to allow and permit construction of pipelines between private companies and gas stations, for example in this project, are not designed so to facilitate new citizen initiatives. Still, this infrastructure has to be built on property of municipalities and/or provinces.

Additionally, financing was only possible due to special regulations and adaptations in subsidy policies of ABN AMRO bank, as mentioned before. All partners also point out that for this type of pioneer project, a lot of personal trust and confidence between the parties involved is also necessary to take on all the multidisciplinary construction challenges, but also to make a better stand regarding government bodies that need to adapt policies and regulations to facilitate the project.

TIMELINE



3.6 Ireland. Waste to Energy Company BHSL

Contact details

• Name: Jack O'Connor, founder BHSL Waste Solutions

• Email: sales@bhsl.com

Organisation / Company: BHSL Waste Solutions

• Website: https://www.bhsl.com

Case study author

Tom Houlihan, Teagasc, Tom.Houlihan@teagasc.ie

Links

Case study video: https://www.youtube.com/watch?v=gbLuYkYTkak

3.6.1 Introduction

BHSL is a highly successful Irish agri-tech company that has developed a unique, patented system, incorporating fluidised bed combustion (FBC). One of the many residues that the technology can efficiently accommodate is manure from poultry production converting it into energy for heating, cooling and electricity generation to meet the energy needs of the poultry farmers.

3.6.2 Initiation

The main driver of this innovative system was the necessity to find a sustainable and economic alternative for poultry producers to the previous practice of land spreading of poultry manure which is rich in nitrogen and phosphorus. The intensive nature of the poultry sector also presented challenges regarding the protection of waterways. In the late 1990's, land spreading, other than on suitable areas such as tillage land with prompt ploughing in, was no longer an option for Irish farmers due to environmental concerns and revised national/European legislative requirements. The latter set out required actions for farmers and other stakeholders to protect and improve water quality. The challenge was also to develop methodologies to improve bio-security for poultry production.

In the early 2000's, an initial pilot FBD unit on the poultry farm holding of Jack O'Connor, successfully demonstrated the feasibility of the waste to energy concept. This initial work turned out to be a win-win situation and set the foundation for the development of a technology to use the manure as a fuel for energy generation onsite. BHSL was set up in 2004 to build on and develop the potential of the successful early

pilot work. Through ongoing and enabling investment and development of strategic collaborations, the company now delivers and operates approved energy centres to poultry farmers around the world. Jack continues to leverage his extensive engineering expertise to drive new applications of the flagship technology as head of BHSL Research and Development, in Kantoher, Co. Limerick, Ireland.

3.6.3 Implementation

The challenge for BHSL was to produce a system that would be highly efficient in delivering sustainable energy and to meet poultry farmer's needs. For example, there was a need to leverage both knowledge and technology to ensure continuous and efficient combustion within the fluidised bed, and the process of fuel conversion to heat energy to be completed with a minimum of emissions.

The company collaborated with a range of stakeholders in order to move the project from initiation to implementation phase. Biomass experts in the University of Limerick provided valuable technical support to progress the developmental process. Limerick County Council, the Environmental Protection Agency and the Department of Agriculture provided support in terms of aligning system production with new environmental criteria. Local farmers also played their provided both insights, experience as well as sites that further validated the successful conversion from poultry manure to valuable energy.

As well as deriving significant heat energy from the poultry manure, the added benefit was that FBC technology displaced the need for costly LPG gas heating. Because margins are tight in farming, the opportunities for on-farm energy production, energy efficiency and enhanced sustainability and development of the circular economy are very important for farming.

Between 2004 and 2010, BHSL further deployed its technology on sites in Ireland. Research and development also continued in developing automated control technology, with the capacity for 24/7 remote monitoring and control capacity from its operations centre in Kantoher, Co. Limerick

Case Study

Nigel and Patrick Joice, Uphouse Farm, Norfolk (16 houses, 850,000 broilers)

As broiler producers, Nigel and Patrick built their first farm (of 8 houses in 1997) and added an additional farm in 2005. Then, they needed a solution for the use of poultry manure and having researched the market, chose BHSL FBC system and installed the FBD manure to energy plant in 2011. Historically, the farm used direct LPG combustion, typically 334,400 litres. In 2011, BHSL installed two FBC500 manure to energy heating

plants. In total these process up to 10 tonnes of manure a day and provide 950 kW of heat to the site in addition to an LPG backup boiler.

As part of a study with the UK Environment Agency the plant was commissioned on manure and operated to gather evidence for the safe use of manure as a fuel on poultry farms. This data were included in a comprehensive submission to the EU Departments of Animal & Food Safety (DG Sanco) and Environment (DG Enviro) in Brussels and as a result new rules became law in July 2014.

Manure has been used to replace 95% of the LPG user while doubling the amount of heat used.

The farm was the first poultry site in Europe to be given approval to use manure as a fuel under new rules. Nigel Joice was the Farmer Weekly Awards 2011 Poultry Farmer of the Year, and Nigel and Patrick were the British Farming Awards Renewables Innovator of the Year 2014.

The projected payback was less than 4 years.

Description of the Technology

The technology provides the basis for a sustainable circular economy. Following completion of a production cycle, poultry manure from the poultry rearing sheds is transferred to a bio-secure building which is completely sealed once the doors are closed. Over the period of the next flock, the stored manure is automatically transferred to the BHSL plant which converts the manure into heat or heat and electricity. The process is overseen by the BHSL Remote Operations Centre, and meets strict European emissions limits.

Poultry litter from one batch is combusted on the farm to provide clean, dry renewable heat to sustain the next batch. Surplus heat is available to produce renewable power for use on the farm or export to the grid. Major savings are made in the consumption of propane for heating. The next batch of chickens thrive in the warm, dry, optimally ventilated, low ammonia conditions of the poultry house, putting on more weight for each kilogramme of grain fed to them. The litter they produce is drier and less odorous. Rather than being transported elsewhere for disposal, with evergrowing environmental consequences, the litter is securely stored on the farm and then combusted on the farm to produce the heat and power for the next poultry batch. Thus the sustainable cycle is completed, heating costs are saved, bird welfare is ensured, the environment is respected and extra revenue is generated and margins improved.

An innovative bulk handling system called the BHSL Toploader is used to transfer litter from the storage area to the combustion plant. This low energy handling system is

automated, which minimises interaction with litter and farm staff. The system has been so successful, that BHSL offer this as a separate product suitable for a wide variety of applications and industries.

BHSL has developed a 24/7 smart management system for which allows for continued remote monitoring of units and automated, detailed reporting for international customers.

Benefits of the technology

There are a range of benefits with the BHSL system. The market and business model can be classified under the 3 P's, Poultry, Planet and Profit.

Poultry

In relation to poultry production, the system technology improves house conditions, improves feed conversion rations, allows optimal ventilation and facilitates improved biosecurity and enhances overall bird performance. It also facilities improved bird welfare and reduces the risk of avian diseases. There are important associated benefits of improved food safety and quality in poultry production systems.

Planet

From an environmental perspective, the technology represents a step change to sustainable poultry production and is at the forefront of regulatory compliance. The system provides for efficient storage and management of poultry manure. By providing an alternative to land spreading of poultry manure, the system reduces potential nutrient pressures on watercourses, while, at the same time, improving air and soil quality. The technology provides an alternative to reduce the use of fossil fuels while also reducing the carbon footprint and other greenhouse gas emissions from agriculture. The byproduct of the technology is an easily-transportable phosphorus and potassium fertilizer through a process of nutrient capture and removal.

The BHSL fluidised combustion unit is the only system designed specifically to meet the rigorous environment associated with using raw poultry litter as a fuel. It is also the only system licensed under new EU regulation that is allowed to use poultry litter on farm. BHSL's fully automated system does not depend on regular farm staff intervention, meets extensive safe emission standards and requires no additional feedstock, is technologically more sophisticated than competitors machines.

Profit

From a financial perspective, the manure to energy system provides low-cost, on-site electricity and heat generation, capable of delivering enhanced margins for the poultry producer. This is combined with fuel savings and improved yield and production efficiency. The technology eliminates manure disposal costs (and potential penalties) while being a vehicle that can attract green subsidies and low cost green finance, which all have a positive effect on profit margins for poultry producers.

Training and technical support

BHSL delivers a comprehensive solution for the Operation and Maintenance of its fluidised bed combustion (FBD) systems. Its Operation, Management and Maintenance programme ensures that the grower concentrates on the poultry whilst BHSL delivers consistent and reliable energy including total energy centre management.

- BHSL energy centres are securely connected to its operations centre. Its remote operations team track minute by minute data and manage remote interventions for optimum system performance.
- BHSL delivers Planned and Reactive maintenance to ensure the FBC systems operate efficiently and reliably. Its FBC units are designed specifically for poultry manure and its maintenance routines are tailored to ensure maximum operating effectiveness. Local technicians are trained and well placed for reactive calls if required.
- Like any mechanical system operating at high temperatures, certain components will wear out during the lifetime of the machine. BHSL has modelled the lifecycle pattern of all components of its system and ensures continued performance through timely replacements as a service

3.6.4 Dissemination/Diffusion

In 2010, BHSL's focus transferred to the UK, partly due to market potential and the attractiveness of the Renewable Heat Incentive (see the case below). The company has also been developing its range of products, overcoming the many and diverse difficulties in reliably processing variable moisture content, high ash products as a fuel.

These products include animal by-products such as poultry and hen manure, meat and bone meal, horse manure and sludges.

On the regulatory requirements around this concept, BHSL has also worked closely with the Department of Agriculture, Food and the Marine (DAFM) and the Environmental Protection Agency (EPA) and the EU to develop new rules governing the use of poultry manure as a fuel. This work led to the introduction of EU Regulation 592/2014 in 2014 setting out the guidelines on the use of poultry manure as a fuel on farm and later Regulation 2017/1262 and Regulation 2020/735 all on use of animal by-products and derived products as fuel in combustion plants.

BHSL has significant operations in the UK where supports for this type of technology are available to producers of larger volumes of animal by-products in a drive to divert the material from land spreading and lessen the dependency on imported fossil fuel. The most recent BHSL installation on Griffith's farm in Shropshire uses 75-tonne of hen manure daily to produce 5mWth of hot water for their hen laying and egg packing operation and generates 1mWe of electricity to be used on farm with excess electricity sold back to the grid.

This shows the range of BHSL's offering with FBC technology designed specifically for the site where it is located, particularly based on the volumes of feedstock available and the energy requirement on that site. Having initially started with 200KW units for smaller poultry operations, it now has up to twenty different plants operating in the UK varying in size from 500KW to 5MW. The technology is very compatible with on farm use in these hen and poultry operations which are already highly automated and remote management of the BHSL system allows 24/7 monitoring to ensure there are no disruptions to this new energy supply system.

BHSL has a dedicated R&D facility at its base at Kantoher, Limerick and links with universities, state agencies and EU partners in examining the potential of energy and nutrient recovery from multiple different feedstocks that have created so many issues due to no other outlet other than land spreading locally.

BHSL now delivers and operates approved energy centres to poultry farmers around the world. It has forged strategic alliances to enable further development, for example it has joined forces with Big Dutchman, a global leader in the egg and poultry sector. BHSL has also successfully expanded into water and wastewater management areas.

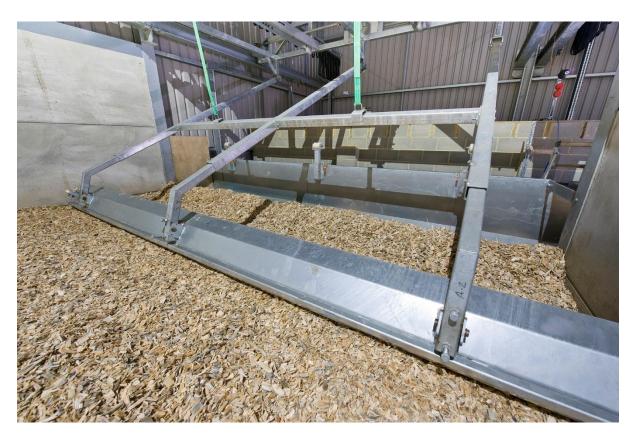


Figure 1: Toploading system which moves dried poultry manure from storage area towards a discharge edge and collection conveyer to combustion.



Figure 2; Conveyance to combustion area

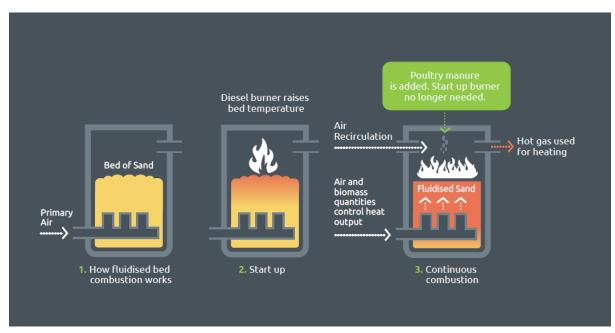


Figure 3: Fluidised bed combustion process maximises poultry manure combustion efficiency and minimises emissions



Figure 4: Combustion Chamber



Figure 5: Derived hot flue gas (at $> 850^{\circ}$ C) travels through a number of heat exchanger flue gas to hot water (or steam) tubes.

TIMELINE

- Late 1980's land spreading of poultry manure was no longer an option for farmers due to environmental concerns
- Early 2000's an initial pilot FBD unit on the farm of Jack O'Connor, who now heads up BHSL Research and Development, in Kantoher, Co. Limerick, Ireland, successfully demonstrated the feasibility of the waste to energy concept.
- 2004 Setup of BHSL Company to exploit potential of FBC concept
- 2004-2010 Successful deployment of technology in Ireland, continued R&D in remote monitoring and control system
- 2010 Focus on building capacity in UK market with attractive Renewable
 Heat Incentive in place
- 2011-2014 Data on the safe use of manure was included in a comprehensive submission to the EU Departments of Animal & Food Safety (DG Sanco) and Environment (DG Enviro) in Brussels and as a result new rules became law in July 2014.
- 2016 onwards focus on continued R&D and expansion to other countries.
 Development of strategic partnerships have facilitated forward expansion of the business. BHSL technology certified to meet Renewable Heat Incentive requirements.

3.7 Poland. GB Hybrid: hybrid subsoiler and strip-till combination

Contact details

• Name: Marcin Gryn

Organisation / Company: GB Agro

Case study author

Martyna Próchniak, LODR, <u>mprochniak@lodr.konskowola.pl</u>
Katarzyna Kozak

Links

Case study video: https://youtu.be/-ztlR4FHBzM

Social media:

Facebook: https://www.facebook.com/people/GB-agro/100070266183907/
 https://fb.watch/dIHYImbfXI/

o Instagram: instagram.com/gb_agro_sp.z_o.o

o Youtube: https://www.youtube.com/watch?v=ks5TNTx907M&t=123s

https://www.youtube.com/watch?v=7sIeUM03oBo https://www.youtube.com/watch?v=0H0n3JZyr7s

3.7.1 Initiation

Farmers in Poland have been struggling for many years with deteriorating soil structure, soil acidification, and increasingly unstable weather conditions. Progressive climate change is increasingly being felt in the form of snowless winters, prolonged periods of drought, hailstorms and torrential rains. Soil erosion is increasing, especially in areas of varying relief. These phenomena make rational production impossible and sometimes destroy the work and efforts of farmers. More and more people are starting to think about ways of preventing negative phenomena and introducing mitigation measures. Similar conclusions were reached by Marcin Gryn, who started working on the construction of an innovative machine at his farm a few years ago.

The soil in the region where Marcin Gryn's farm is located is quite heavy and waterlogged. The terrain is hilly and therefore periodic surface runoff was often observed - water erosion destroyed the crops but above all leached nutrients and

degraded the soil. The owner, who had been involved with the small 5 ha. farm since he was a child, started to take an interest in no-till methods from around 2012, observed farmers who were already using these methods and also followed industry websites.

His own experience in vegetable seedling production, and the failures of other farmers in long-term no-till farming, led Mr. Marcin to draw a concrete conclusion: to maintain yield stability in no-till farming, and to make the plants more resilient to the negative effects of drought, deep fertilisation is necessary.

3.7.2 Implementation

In 2012, the farmer decided to sow wheat in a no-till system for the first time; at that time, a disc harrow was used for cultivation, sowing was done with a cultivating and seeding unit. However, the tillage turned out to be shallow and further cultivation could lead to excessive compaction of the soil. It was necessary to purchase a grubber - a two-pronged ploughshare - that would be able to cultivate the soil to a depth of 25-30 cm and mix harvest residues with the soil, loosen the soil and thus replace the plough. While observing other farmers, he noticed that no-till had problems with plant rooting and a lack of nutrients in the deeper layers of the soil which generated problems with water uptake and a decrease in productivity. He thus decided to make modifications to his machine. In 2014-2015, together with his father, he constructed a fertiliser reseeder on his farm: a fertiliser box was placed on the grubber, fertiliser was applied deep into the ground (fed behind the feet/working element of the machine), to a depth of 25-30 cm, during cultivation.

Then the first prototype of a two-stage strip-till system for cauliflower and broccoli was developed. Cultivation was only carried out in strips and fertiliser was applied deep. The first on-farm experiments with strip-till were set up with satisfactory results. The plough was no longer necessary. From 2015, only the strip-till unit was used. The owner came to the conclusion that if it worked in vegetable cultivation, it should also work in oilseed rape.

In 2017, Mr Marcin Gryn and his father built the first rape strip-till unit - at that time the farm already covered an area of around 20ha. The effects were satisfactory, the machine performed very well. There was also an idea to introduce it on the market, but the financial possibilities were limited. In the same year, the farmer also started studying agriculture at the Warsaw University of Life Sciences.

The constructed rape unit was used on the farm until 2020, but as the farm expanded its efficiency decreased. There were also problems with the durability of the equipment. It was necessary to design a larger machine with greater durability.

In 2019, Mateusz Bender- an engineer and machine designer- was brought into the project. Work started in 2020. The first prototype was based on his own idea, the second prototype was constructed on the basis of a design in a computer programme that visualised and optimised parameters, hence it was possible to achieve replicability and to easily reproduce the components (parts were easy to copy in the case of series production of the machine), and thus to reduce the consumption of materials, which had meanwhile started to become more expensive. It turned out that if a machine needed to be more robust; then, twice as much material was needed. The resulting equipment also had a much broader application than that used previously on the farm, and many technical improvements were made.

Meanwhile, in 2019, Marcin Gryn qualified for the Young Farmers Exchange organised by the Polish Grain Growers Association, and travelled to Texas, USA. He ended up on the farm of Terry Hlavinka, the largest Case dealer in the state of Texas, who also has his own 10,000ha farm. He saw a series of Case machines that are not available on our market. There he also saw that the machines are built with a high strength reserve, but are also built simply so that as few components as possible may break down. Additionally, the machine should be as cheap as possible. Many of the solutions he observed were able to be transferred to his design. He also gained a lot of experience from discussions with farmers in the USA, which confirmed the role of deep loosening on heavy soils.

During the construction of the prototype design, there were problems with making the components - it was difficult to get satisfactory results based on the local market. There was a shortage of suitable specialists and the parts received often did not meet the design requirements. Construction dragged on. There were also inevitable construction errors; these were gradually eliminated by means of tests on the farm.

Eventually, the constructors reached the point where further work was impossible without external funding. Mateusz Bender initiated a meeting with familiar entrepreneurs from Zamość who manufacture and distribute machinery: Tomasz Szewczyk and Grzegorz Czyż. After presenting the project to them, the dealers decided to invest in the idea and started working on serial production of machines.

The participation of the investors allowed for the professional construction of the first unit. They have a production hall, professional steel processing machines, professional staff and access to materials. They also have extensive experience in machine construction. In 2021, the company GB Agro was established. In 2020-2021 the first copy of the hybrid- subsoiler and strip-till machine with pneumatic fertilizer reseeding was built.

3.7.3 Dissemination/Diffusion

Two copies of the GB Hybrid were produced in the summer of 2021. They were additionally tested in sowing oilseed rape on their own fields. They are available for sale from autumn 2021. The production capacity is 2 machines per month. The start of sales coincided with a number of adverse events - the COVID-19 pandemic and the unstable situation in agriculture which significantly slowed down investments in Polish farms. Materials also became more expensive and labour costs increased. However, the constructors did not cease their promotional activities; the machine was presented at agricultural events, open-air events, meetings with farmers organised by ODR and the media. Furthermore, testing the machine continued. Marcin Gryn stresses that it is a machine based on his experience and it works - the proof is that his farm grew from 5 to 100 ha in a short period of time. He is still looking for improvements and tries to incorporate the comments he receives.

The shareholders want to expand the range of machines and develop the company. The design of the machine is versatile - the construction is simple, it allows to diversify and add new elements so that it can be used in other crops. It does not require opening a new production line, but simply retrofitting specific parts. A current order is for planters for strawberries and tomatoes using depth fertilisation based on basic components.

Contacts at the university have also made further cooperation possible - in a consortium with the Warsaw University of Life Sciences, potato cultivation in the notill system with subsoiling will be tested. A consultancy was also involved. This year the first plantings were made.

Many years of experience have shown the benefits of no-till and the use of the machine: saving and retaining water in the soil, increasing biological life. The structure of the soil is improved, the soil is loosened, which translates into savings of fertilisers and fuel - the soil has less resistance, which reduces the energy consumption of cultivation. Time is saved, the number of operations is reduced and emissions are reduced. No-tillage helps to prevent wind and water erosion - especially in farm conditions. However, it is a demanding system, as Marcin stresses: it requires consistency, effort and knowledge, but above all it does not forgive mistakes.

TIMELINE

- 2012 Interest in no-till and first sowing on the farm
- 2013 purchase of a two-beam power harrow
- 2014-2015 construction of the unit with fertiliser reseder, first on-farm experience with strip-till
- 2017 construction of the first combine for strip-tillage of rape
- 2017 beginning of studies at the Warsaw University of Life Sciences
- 2018 formal takeover of the farm by Marcin Gryn
- 2019 first discussions with Mateusz Bender about professional machine design
- 2019 trip to USA
- 2020-2021 prototype hybrid- subsoiler and strip-till machine
- 2021- Establishment of cooperation with investors: Tomasz Szewczyk and Grzegorz Czyż, establishment of the company GB Agro. Commencement of serial production of strip-till machine with pneumatic reseeding of fertilizers hybrid of subsoiler and strip-till.
- 2021 summer production of the first machines
- 2021- presentation of the machine at the Green Agro-picnic for Young Farmers in Końskowola
- 2021 autumn official start of sales
- 2021-2022 presentations and tests of the machine
- 2021-2022 cooperation with the Warsaw University of Life Sciences (SGGW) in the framework of no-till potato cultivation with deep fertilization







Figures 1,2,3: GB Hybrid, hybrid subsoiler and strip-till combination

3.8 Italy. TENUTA DI BAGNOLI

Contact details

- Name: Musini Giovanni, CEO, TENUTA DI BAGNOLI SRL
- Email: INFO@TENUTADIBAGNOLI.IT
- Organisation / Company: TENUTA DI BAGNOLI SRL TENUTA DI BAGNOLI SRL SOCIETA' AGRICOLA
 VIA G. GARIBALDI 83 35023 BAGNOLI DI SOPRA (PD)

TEL. <u>+39 049 538 0100</u>,

P.IVA 05085750288 REA PD-441833 CAP.SOC. 40.000€ I.V.

Website: https://agronotizie.imagelinenetwork.com/aziende/tenuta-di-bagnoli-di-giovanni-musini/32844

Case study author

Elisa Tomassi, Confagricoltura, elisa.tomassi@enapra.it

Links

Case study video: https://www.youtube.com/watch?v=eqzAWF2MXFU

3.8.1 Introduction

Biogas is one of the most useful alternative energy sources for the transition to renewable energy and a circular economy. Obtained from the degradation of organic substances such as manure, sludge and biomass, biogas is often reproached by environmental groups who probably do not know how this can also be "done well", especially when it gives the opportunity to utilize what otherwise would be expensive to disposed of, as waste. Biogas plants were born over thirty years ago as advanced systems for the recovery of organic waste, such as livestock sewage, manure, organic fraction of waste collection (household food waste), waste from fruit and vegetable markets, purification sludge of the waters.

Similarly to what happened in the photovoltaic sector, in the last 15 years legislation has encouraged the use of electricity produced with biogas plants so as to promote their development and achieve the production targets from renewable sources as defined by the European Union in the context of the struggle against climate change. Currently this incentive cycle is running out, as Italy has substantially achieved these objectives, the so-called "Burden share", but the plants will continue to operate for

their main purpose, namely the recovery of these large quantities of waste, using the energy produced for self-consumption or in any case in non-incentivized contexts.

In the coming years, the system of incentives for the production of electricity will therefore gradually run out, replaced by the production no longer of biogas, but of bio-methane intended to replace polluting fuels such as diesel for diesel engines in the road transport sector, in the larger new EU goal of sustainable mobility for goods and people. Unlikely to the past, the incentives for this new energy era will no longer weigh on citizens' bills and therefore on general taxation but will be supported exclusively by large fossil energy producers, who through this new system will be even more incentivized towards a transition of energy production based on renewable sources; a further concrete step in the fight against climate change.

3.8.2 Initiation.

In Tenuta di Bagnoli, a combined approach to optimize the workflow and reduce environmental impact as much as possible is utilized. The main issues faced, in order to proceed, were operator's safety, reductions of energy consumption, and facilitation in the exploitation of natural resources.

For example in Azienda Tenuta di Bagnoli (Bagnoli di Sopra, Padova) energy production has been matched with beef pasture/grazing. Nevertheless, there are only few examples in Italy bringing together Agrovoltaics and grazing as, for example, at Sant'Alberto, Ferrara, where the Azienda agrozootecnica Caseificio Buon Pastore manage a herd of 600 sheeps, grazing under 70 hectares of photovoltaic plants (https://www.caseificiobuonpastore.it/).



Figure 1: Sheeps at Caseificio Buon Pastore (Source: Caseificio Buon Pastore)

Following the relevant investment to be made by Tenuta di Bagnoli's President, Mr Marco Di Stefano in Pontinia (Latina Province – Latium Region) with sun-dynamic oriented photovoltaic plant in 106 hectares) is presented.

The opportunity to study these issues and their implementation in practice, in the company, was given by the advisors of Confagricoltura.

In that year, 2007, the financial maneuvers of the Italian government made available funds for the "green" conversion of farms, in compliance with the commitments made in Europe on environmental and agricultural issues (from fossil to renewable energies such as photovoltaic and biogas plants – FESR/POI Energie Rinnovabili e Risparmio Energetico 2007/2013 co-financed 1887 projects mainly in the south of Italy with 1,071 billions of euro defined by the National Strategical Framework – Quadro Strategico Nazionale QSN). That gave Tenuta di Bagnoli the impulse to invest in renewable energy and switch from traditional agriculture to agrienergy.

After the initial struggle, the economy of the farm changed and gave the company the opportunity to start a global plan of innovation. Environmental awareness was the main reason for change, but benefits were also gained in terms of the improvement of work conditions and, of course, the reduction of the use of chemicals and water. The overall advantage is most evident in high-quality and large farms such as the one

examined here (prosecco wine production (19 hectares), agritourism, grain (47 hectares) and beef & pig (2 stables 190 units and 360 units x 18 hectares). The company already had a valuable income, and could afford change. Smaller farms are often stuck and find it difficult to change

3.8.3 Implementation

Planning

The planning of the development of the innovation was made by the advisory services of Confagricoltura 2, input suppliers (manufacturers), university/researchers; the company started to plan the investment (plants) in 2007.

As farmers, the company lacked the knowledge and the perspective to integrate what is just a series of technologies and make it work in reality. Therefore, they decided to ask their advisors in Confagricoltura: these advisors have the necessary training to overcome this gap between what's ideal and the concrete technologies available and most suitable for our combination of needs. Through these advisors, Tenuta di Bagnoli has been supported by agronomists, engineers, and experts on funding and policies.

A very primitive cost-benefit analysis was carried out with a Return on Investment (ROI) of 7-9 years and an amortment period of 20 years. After a first overview of what was needed and was feasible, the company asked local manufacturers to help them out. They had already seen some applications of renewable energy systems and storage systems on German farms, so they knew what to ask for. The manufacturer helped them planning the plants and provided them with workers trained for light duty maintenance.

The most difficult part in that phase was to gather the right information about regulations and the documents to produce, then define what to do and which technology would have been best for them. So they asked "energy advisors" to help them to interpret the regulations and elaborate possibilities. Of course, they had to rely solely on trustworthy professionals, because they lacked the basic knowledge to move on, only by themselves.

Development

² www.confagricoltura.it

³ Confagricoltura employees.60 Technicians, agronomists, engineers trained by Enapra (Confagricoltura's private owned agency). The energy advisors have been trained by Engineers and Technicians, work in the local Unions serving their associates (260,000 farmers plus 2,500 employees in 140 offices all over Italy. Source: Confagricoltura).

In 2008 the company started to search the most suitable technology with respect to their needs. During this time, they traveled a lot to visit relevant already existing experiences. They finally found the best choice with a German biogas plant company which had already decided to establish an Italian office right in the vicinity of the farm.

The development phase started in 2009. After gathering the information and putting together the necessary documents (planning phase), it was time to focus on the various parts that compose the farm. Most care was given to the biogas plants (that had to be built in a way that would not conflict with the facilities in which they host their guests - visitors of the farmhouse).



Figure 2: Bagnoli Farm with Biogas plants and the photovoltaic surface

The photovoltaic arrays were originally built on the floor, as that was the common pway at the time. The company recently decided to improve and enlarge their grasslands, so as to integrate the benefit of some additional space to put solar panels without wasting the land.

The help they had in each stage was provided by advisors, agronomists, veterinary, contractors, manufacturers, our agricultural workers, suppliers.



In Tenuta di Bagnoli, the production of prosecco is the primary source of income. Being already in contact with a local, well rooted private bank, they decided to get a loan to support their investments, offering the assets of the family as a guarantee. The main difficulty in this phase was the formalization of the necessary actions such as bank contracts or the authorization for the construction and management of plants. It was extremely difficult for the officials in charge to interpret legislation that, at that time, was still imperfect.

Many factors delayed some phases of the development: the lack of knowledge, combined with the doubts and worries about such an investment, made them re-think and often reduce the amount of innovations that they wanted to carry out. Therefore, sometimes they had to scrap some opportunities; for example, they decided to postpone the renewal of the tractors in favor of more environmentally friendly ones – investment that they are still not able to fulfill 100%.

It took them two years to finally achieve the core of what they wanted. They were able to overcome their doubts with the help of their advisors, their general contractors and their manufacturer, and make the whole system efficient in 2010.

Realization (final product)

In 2010 the farm was completely done and running. The technologies they currently used are:

- PV arrays mounted on the floor;
- Agrivoltaics (PV panels on a higher level) on the grassland;
- Biogas plants mainly with own beef and pigs manure;
- Heat pumps for the stables and the facilities;

- Led lighting on the whole farm.

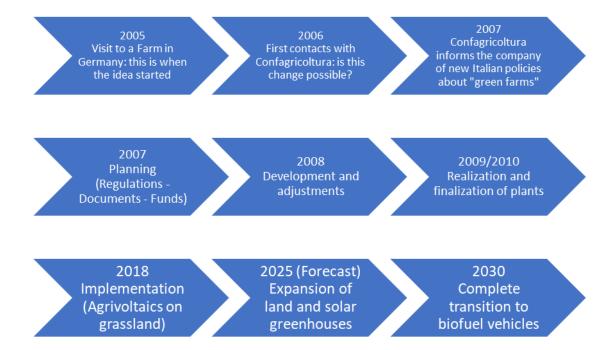
The company uses crops and manure from beef and pig stables to produce electricity which is used to climatize the stables and make the plant function. The remaining energy is sold to a local provider who distributes the energy to the surrounding farms/activities/houses. Currently they strive to improve their tractors (biofuels), and find investors as well as to buy some land and build some greenhouses.

3.8.4 Dissemination/Diffusion

In Tenuta di Bagnoli they are very proud of the progress they made both in terms of their approach implying a different way of farming, and in terms of the condition of their land and the satisfaction of their employees. The innovations they introduced not only make farming easier, but, they additionally change the rural landscape around the farm. After introducing such changes in their farm, many other farmers have started to learn about them and become integrated in this virtuous path. Furthermore, the company promotes this approach to farming to all their guests in the farmhouse and to their neighboring farmers through the organization of many events they have on site. Their contractor and their dealers can now present the Tenuta di Bagnoli case to newcomers, hoping that they'll be less doubtful and more determined in pursuing the change.

The company continues to refer to professionals for maintenance or when they need to re-arrange some equipment, so now new professions arise. Moreover, with the start of the PNRR in Italy – the RECOVERY PLAN 2021–2026, and hopefully of new ways to get access to funding, as green farming will be considered more and more beneficiary, it will be easier to intertwine relations and the exchange of knowledge, power and competences with their fellow, neighboring farmers.

TIMELINE



3.9 REScoop. Landschapsenergie cv, Belgium/Bocholt

Contact details

- Name: Fientje Verbruggen
- Email: fientje.verbruggen@boerennatuur.be
- Organisation / Company: Boer en Natuur & Landschapsenergie cv
- Website: https://www.landschapsenergiecvba.be/

Case study author

Dirk Vansintjan, REScoop President, dirk.vansintjan@rescoop.eu

Links

Case study video: https://www.youtube.com/watch?v=SxPoTizpXgl
Social media:

- o https://www.facebook.com/BoerennatuurVL
- o https://twitter.com/boerennatuurVL
- o https://www.youtube.com/channel/UCvjbexaLGeME JxAC 3gDxQ

3.9.1 Introduction

Bocholt is a small municipality (13.000 inhabitants) in the North-east of Flanders, Belgium. Local farmers harvest the wood in the wooded sides of their meadows and fields with adapted machines according to a jointly drawn up plan. This harvesting is done according to the coppice principle: relatively thin trunks are cut above the ground, after which branches grow again from the remaining stumps, which can be harvested again about 15 years later.

The harvested wood is processed by the farmers into high-quality wood chips (chip size, moisture content, dust content, etc.) so that it can be used in medium-sized wood chip heating installations (+/- 250 kW). The chips are sold to the 'Landscape Energy cooperative'. The 'Landscape Energy cooperative' operates a heating installation that produces heat for the schools of the PVL-Biotechnicum school campus.

In addition to producing wood chips, this coppice management is also a form of maintenance of the wooded edges along the roads and also a measure with positive effects on biodiversity. The method of harvesting is therefore geared to this.

3.9.2 Initiation

Before World War II, the Flemish landscape was characterised by many hedgerows and small coppice stands delimiting fields and meadows. These hedges were cyclically chopped for firewood, construction timber and tool making. With the advent of cheap fossil fuels after World War II, this use of hedges lost its profitability. As a result, many hedged disappeared to make space for larger fields, or their management was neglected. This allowed the hedges to grow into tall, mostly unstable trees, without much lower growth. Due to neglected management, much specific biodiversity disappeared. Refuges for small meadow birds such as shrubs and bushes became rarer, and the landscape became more monotonous due to the neglect of cyclical, phased landscape management of the hedgerows. This is the situation to this day, and farmers complain about large trees blocking the way for their machinery and casting shade on their fields. For these reasons, they would prefer to see the hedgerows strictly managed again, while environmental organisations fear losing them. Moreover, municipalities are starting to have problems with unstable trees that are dangerous for people using municipal roads.

To address these problems, the Interreg-funded 'Twecom' project ran from 2013 to 2015. The aim was to bring these hedges back into management, alleviate most of the problems of municipalities and farmers, and find ways to valorise the harvested biomass so that the hedges would survive at the same time.

The perfect conditions to start such a project were present in Bocholt at that time. Part of the school campus was under construction, so the heating network could easily be incorporated during the construction works. Moreover, a new heating system was needed in the town hall. At the same time, the municipal administration was very interested in this project because they had (and still have) a climate and energy commitment (the covenant of mayors) to reduce their greenhouse gas emissions. For them too, the combination of neglected landscape management with reduction of greenhouse gas emissions and possibly even cheaper heating would be an absolute win-win.

3.9.3 Implementation

To ensure a good cooperation, a partnership charter was signed by all stakeholders, in which landscape management forms the first pillar and the heat network and heating the second.

All partners of this partnership with their respective responsibilities are listed below:

1. Regionaal Landschap Lage Kempen (RLLK)

- Their mission is to safeguard and manage the typical landscapes of the region, of which hedgerows are an example. Their concern for the preservation and management of these age-old landscape elements was the most important reason for them becoming the lead partner.
- Takes care of the management plans for the hedgerows in and around Bocholt
 in consultation with all the other partners and relevant stakeholders such as
 environmental organisations and farmers. They make an inventory of the
 hedgerows and decide which ones are going to be coppiced when. Using DIPLA
 (see www.profisi.eu/www.diplalogin.eu), an innovative online tool for
 organising landscape management, this becomes much easier and clearer for
 the workers to execute.
- Applies for permits (e.g. to cut trees).
- 2. Agrobeheercentrum Eco²
 - Takes care of good communication with farmers and Workers and coordinates the local group of farmers (agro-management group) and the execution of the management operations
 - Helps building support across all stakeholders, for example concerning the management plans of the hedgerows
- 3. The municipality of Bocholt
 - Owner of most of the hedgerows which are coppiced for woodchips
 - Partly pays for the execution of the management works (1€/m hedgerow)
- 4. Workers (with local farmers of the local agro-management group)
 - Possesses the machines
 - Executes the coppicing, chipping, storage and drying, sieving and delivery to the wood chip burner
- 5. Landschapsenergie cvba

The latter is a cooperative, which is different from but forms part of this partnership, founded in 2014. With subsidies of the province of Limburg, Interreg, an 'ecology grant' from the Flemish government and an additional loan, this cooperative bought and constructed the biomass heating system in the practice hall, storage bunker for wood chips of 100 m³ and heat network. It is therefore responsible for the second pillar, including the maintenance of the burner and heat network.

It consists of:

- Schools (kindergarten, primary school, secondary school (biotechnicum), practice hall)
- Agricultural test centre (PVL)
- Community hall

- Municipality
- Workers

Landschapsenergie buys wood chips from Workers and sells heat to the schools, PVL and community hall. It brings producers of wood chips (Workers) together with users (schools etc.) and others to guarantee a continued, broad support across all stakeholders. The main advantage that the cooperative offers to the community is a local and sustainable product with a very low price, especially now when prices of gas, fuel oil and electricity are skyrocketing. This allows the cooperative to offer heat to public buildings at an affordable rate.

Dit gebouw wordt verwarmd met biomassa uit Bocholtse houtkanten, geoogst door plaatselijke landbouwers.



Figure 1 Overview of the different partners involved in the project © Landschapsenergie

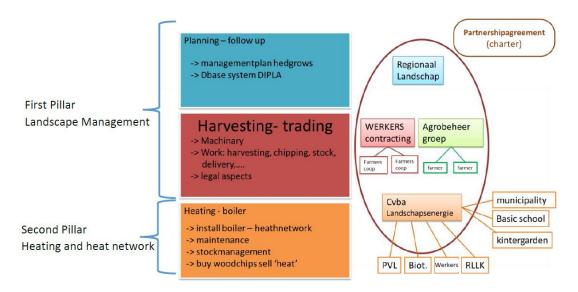


Figure 2 Partnership in flowchart © ECCO – interreg North-West Europe

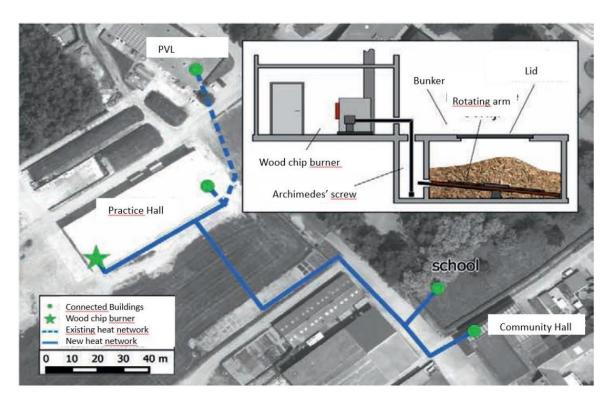


Figure 3 Site map Bocholt ©ECCO – interreg North-West Europe

Overview of the process

- 1) Building support across all stakeholders: farmers, municipality, environmental organisations, citizens
- 2) Developing generic management plan with all relevant stakeholders
- 3) Finding out who owns what (property rights)

- 4) More detailed inventory of the hedgerows
- 5) Fighting invasive species
- 6) Compiling management plan
- 7) Coordination and execution of the management operations
 - a. Cutting
 - b. Chipping
 - c. Storing
 - d. Drying (open air)
 - e. Sieving
 - f. Transport to bunker of wood chip burner
 - g. Planting extra seedlings if gaps of more than 4m without seedlings in the hedgerow
 - h. Additional maintenance (of big trees, pruning, watering, ...)

Every year, a piece of the hedgerow in Bocholt is cut, not more than 100 meters at a time. Then the farmers move a few meters and cut another piece. Before hedgerow management was implemented, the trees were all growing upright, without any bushes in between. One could look from one field to the other but now, because the hedgerows are managed, s/he can see a dense structure emerging. The trees that are cut down grow from the bottom, in several stumps, which gives you that dense bush structure.

After the trees have been cut, they almost immediately go to the woodchipper and are turned into wood chips. Afterwards, the chips are transported to the cogeneration installation owned by Landschapsenergie. Through the heating network, Landschapsenergie provides heat to the local nursery school, the primary school, the secondary school, the Biotechnicum, the PVL and the parish house. All of this is done with the wood chips that are taken from the hedgerows.

There are several benefits that come with the project. It's good for biodiversity, while the much denser structure allows animals to hide much better; birds make nests and find food.

When people pass by and see the hedgerows, they will immediately feel it. Because of the dense structure, they get much more shade alongside the road. Especially during the hot days in summer, one clearly feels the difference in temperature.

For agriculture, the hedgerow has advantages too. They create a natural buffer against fierce winds which can harm the crops. Additionally, there was a lot of drifting sand in the North of Limburg last summer. An observer could actually see that the top layer of the fields was blown away; hedgerows can act as a buffer and protect against fierce winds.

Results

- Without the sieving and the transport, around 12.5 liters of fuel on average are used to harvest and process a ton of wood chips.
- Using values of 36,783 MJ/liter for the fuel and 12,324 MJ/kg for the wood chips (FOD Economy, Belgium), this means that for each unit of energy that is used, 27 units are harvested.
- Or for every liters of fuel used, 27 liters are produced.
- Comparison: processing of crude oil has a ratio of about 1:20 to about 1:4 (and dropping, because it becomes increasingly difficult to access the remaining oil reserves, thus requiring more energy).

3.9.4 Dissemination/Diffusion

Information boards on site (both on the side of the hedgerows and the woodchip burner) transparently explain the story about this unique collaboration and show the technology used and the processes implemented.



Figure 4 The information boards on the wood boiler site ©REScoop.eu

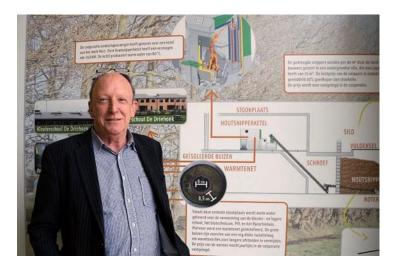


Figure 5 member of the cooperative and technical manager © innovatiesteunpunt

Moreover, Landschapsenergie is referred to in different publications (for example in the magazine of the Boerenbond, the Flemish famers association).



Figure 6 article in Boerenbond magazine

Moreover, an "ecco" video has been produced to showcase this project and inspire other pilots in Europe: https://youtu.be/u7Png9Nfeyo

The Agro Fossil Free project features this project, highlighting the collaboration between farmers and energy cooperatives: https://youtu.be/XFZTWKQMSnM

The students of the school that is heated by the cooperative district heating network are also closely connected to the project. The Biotechnicum school shows the students

how the cogeneration directly heats the local school. The children tell this to their parents and explain to them that the school uses energy from local and sustainable sources. The school definitely sets an example. Schools from all over the country that are looking for ways to improve the overall efficiency of their school buildings, come to visit Landschapsenergie in Bocholt. They want to see how they do it over here and whether they can apply it in their own schools too.

Two pupils from primary school De Driehoek in Bocholt made a video about the hedgerow management and woodchip heating in their community: https://www.youtube.com/watch?v=mu4HDU608II

TIMELINE

- Before WOII: hedgerows in Flanders are cyclically coppiced for firewood, construction timber and tool-making
- **After WOII:** cheap fossil fuels, the economic use of hedgerows lost its profitability.
- 2013-2015: Interreg funded Project Twecom: renewed interest in hedgerow management. Objective was to finding ways of valorising the harvested biomass.
- 2013: Inventory of hedgerows Bocholt
- 2013: construction works in the school campus in Bocholt
- 2014: foundation of the energy cooperative Landschapsenergie
- 2014: start hedgerow management in Bocholt
- **2015:** heat network in operation
- **2017**: price of dry wood chips drops from 100 €/ton (2015) to 84€/ton (2017)
- **2018:** Interreg funded project ECCO: exchange with other pilot projects in Europe, further expansion of hedgerow management and heating network
- 2021: Community hall connected to the district heating network
- **2022:** final event of ECCO study visit in Bocholt, interreg project officer visits the district heating

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5. Annexes

Annex 1

The AFF proto framework for a brief characterization of innovation cases⁴

Please propose at least 2 cases for innovations

Ideally we are looking for innovation processes where the first idea (or problem or opportunity) come from farmers. Nevertheless, the first idea can come from other actors (agronomists/advisors, research, etc.) as well. In all cases the actor(s) who have 'the first idea' have to cooperate with other actor(s) in (some of) the next steps of the innovation process/building.

our 'AFF partner' name:
lame and E-Mail address of person
n charge for this case:

Categories	Short description
1) Acronym and/or short name of the	
innovation case and Country/ location	
2) What is it all about?	

⁴ Adapted from AgriSpin.

Please give a short description of the case in 3 – 5 sentences	
3) Multi-actor at some stage (please describe actors such as researchers, policy makers, advisors, farmers (small, medium, big), manufacturers/dealers (local, regional, national, international), etc.) If possible, give a rough number of how many actors are involved in the innovation process	
 4) How widely is it used? In terms of geographical scale In terms of frequency of application In terms of numbers of adopters Type of farmers (e.g. small, medium, big) who use it 	
5) To what (which need) is the innovation responding? Or What was the main driver of the innovation?	

Cases are to be excluded, if

- 1. they do not portray or have a multi-actor approach/component (< 2 different actors), with at least one farmer/ farmer organisation
- 2. they do not have a minimum history and no implementation by the time of exploration

Annex 2

Questionnaire Agrofossilfree Innovation case studies

INTRODUCTION

Contact details

Interviewee Name:

Organisation/Company:

Position in organization:

Date:

1. INITIATION

- 1. What was the trigger/motivation for the initiation of innovation? What was the problem? (environmental concerns, policy driven innovation, production problems, spray efficacy, difficult topographies, suitability for small farms, affordability, ease of use, operators' safety, other)?
- 2. Who came up with the idea? Was there demand from the farmers or any other actor?
- 3. Who was involved in the discussion/ development of **the idea** (company, farmers, advisory services, input suppliers, university/research, users, local or other authorities, EU/national/regional/local funded project)? Was there a (formal or informal) group/network formed to discuss the idea?
- 4. When did the idea come up?
- 5. What is the benefit?
- 6. Who benefits? (small, medium, large farms; production branch; local area/region/national/international; etc.)

2.IMPLEMENTATION

A.Planning

- 7. Who was involved in the planning of the development of the innovation (company, farmers, advisory services, input suppliers, university/research, users, local or other authorities, EU/national/regional/local funded project)?
- 8. When?
- 9. Did you get funding for planning? By whom?
- 10. Difficulties at **planning stage** (financial, not the right people at the right time, access to information/knowledge, etc.)

B.Development (experimentation with the innovation)

- 11. What was the first step in the development of the innovation?
- 12. When?
- 13. How was the innovation developed? Which stages can be recognized? When did each stage happen?
- 14. Involved actors (company, farmers, advisory services, input suppliers, university/research, users, local or other authorities, EU/national/regional/local funded project) in each stage
- 15. Who did what and when, on which field which actor was involved in each stage?
- 16. Which actors/networks were (the most) important for this innovation process and why?
- 17. Funding: who paid for it: investors/company, stakeholders) Did you get funding? By whom in each stage?
- 18. Difficulties (financial, not the right people at the right time, access to information/knowledge, etc.)
- 19. Limitations (policy, legislation, societal demands, research knowledge gaps, competitors).
- 20. Did you face problems (re: difficulties, limitations or other e.g. technical, etc.) during the procedure which resulted in stopping/ delays of the development of the innovation? What was the cause? How were they solved (who did what to overcome this problem(s))?
- 21. (How many times) did you have to go back το previous stages in this procedure (for example re-planning, re-design, etc.) and why? Or, did you have to go back in this procedure and why?
- 22. Support (technical, emotional, organizational, financial, etc.) in facing these problems. Supported by whom? When? In **which stage** you needed most the support?
- 23. What external factors (wider environment policy, legislation, societal demands, economic, etc.) were helpful?

C.Realisation (final product)

- 24. When was the innovation finalized?
- 25. How did the final version look like in comparison to initial design? Why the changes?
- 26. Is the product patented?

3.DISSEMINATION/ DIFUSION

- 27. How/when was it introduced to the public (market)?
- 28. What is the strategy to disseminate the innovation?
- 29. Were there any difficulties after the product was in the market?
- 30. How did you deal with such problems (redesign for improvements, etc.)
- 31. Currently, how many users? Who are the users (small, medium, large farms; production branch; local area/region/national/international; etc.)
- 32. How do farmers react? (Farmers' feedback/reflection, if any).
- 33. Has the innovation started to be considered as 'normal' by the farmers

Annex 3

Basic Instructions for preparation of multimedia material

Media

Video Content

- Video to describe innovation process (co-creation) and steps
- Voiceover/subtitles
- Photos
- Interviews
- Need for video script first (see below)
- See some INNOSETA examples:

SPAIN - WAATIC + DOSAVIÑA

https://www.youtube.com/watch?v=eUSWtS5_JJw

GREECE - AGROHALC

https://www.youtube.com/watch?v=t9UUSHjg37M&list=PLHkPRU_MtI5RLxjQcyLBVJvQPmjj07Gwq&index=2

FRANCE - Performance Pulvé

https://www.youtube.com/watch?v=iLQWfqNtHLQ

NETHERLANDS - Wingssprayer

https://www.youtube.com/watch?v=iSNoIo5A4Nc

TIMELINE

The description of case studies is recommended to be divided in 3 sections (following the Case Study Questionnaire Structure):



STEPS:

- -follow the timeline as identified during the case interviews
- -describe how the innovation developed with some basic details, dates (when possible), steps and actor involvement, etc.

Below you can find the basic structure of media material for each Phase.

1. Initiation phase (step by step)

 Problem/Motivation: What is the problem(description), who observed it/whose demand was it.

- Actors involved/Cooperation: Who came up with the idea?
- When?
- Back ground/previous experience of pioneers. Previous experience with agricultural
- Other actors involved/partners' experience.
- Any previous ideas/trials in the past that didn't come to a success?
- Expected benefits of the innovation.
- What kind of farmers/farms (target group) does the innovation aim to? (for example what kind of cropping system, big small/farms, size of farm income, etc.)
- Stages that can be recognized in the development of the concept.

2. Implementation phase (step by step)

Planning and Development

Which stages can be recognized? (Planning , draft versions and trials to a market-ready product.

- First step/first draft of the innovation and/or the innovation development plan.
- When did each stage happen and which actors were involved (farmers, companies, universities, research institutes etc.)?
- What kind of difficulties where encountered during the development procedures and/or in each stage? (any kind for example technical, legislation, policy, knowledge gaps etc)
- Funding: where did it come from? Did you have difficulties with it? In which stage funding was crucial to exist?
- Principles of technology in use.

3. Diffusion phase

- Launching of new/innovative product: When and how?
- Persuasion of first farmers to use it, how?
- Farmer target groups the (final) innovative product aims to (cropping system, farm size, farm income, young/old farmers, familiarization with technology, etc.)
- Further stages of diffusion. When did they happen? (for example, participation in demonstrations, agricultural fairs, collaboration with more resellers/dealers, etc.)
- Number of current users and prospects.
- Factors in favor of its adoption (for example, ease of use, visible results, operator comfort, cheap, availability of technical support, etc.)
- Advantages that this innovation offers? Old days (first idea) vs. now (finished product in the market)?

There can be used at the end or throughout the timeline:

Photos or video other material/documentation provided by the manufacturer.

▶ Demonstration of the innovation in use/Demonstration under real circumstances.

Farmers' (users') interviews should also be included. Please make sure that we also refer under which conditions farmers use it:

- ✓ Crop system
- √ Farm size
- ✓ Compatibility of the innovation with other farm technologies/suitability(or difficulties) for the farm
- ✓ Difficulties in getting familiar with the product (for example due to complexity of use) and availability of training/ technical support
- ✓ Cost of purchasing and maintenance?
- ✓ Perceived advantages by the use of the product?

RECOMMENDATIONS

It is recommended that first you make a plan of what you wish to show (re: interview schedule and abovementioned instructions) and then you record or shoot (interviews and events).

In the first place one must have in mind that we address **mixed audiences**.

It is also useful to start with a **prewriting** or **outline**, i.e. put together ideas on **the goal** or to tell someone "why they should watch this video" in one sentence (in our cases, more or less, the goal is to show the co-creation of innovations, that is, the cooperation of actors to co-produce a technical innovation); **the values** (cooperation/networking for interactive innovation in which each actor brings its own resources – knowledge(s), experiences, financial, technical, etc.); the available **sources of information** (interviews, documents, websites and social media, marketing videos, etc.); and the **roles** (1-2 central characters as, for example, the manufacture(s) and a farmer or advisor/researcher). Then one has, of course, to see what is feasible given the available resources.

Then it is suggested to divide a page in two columns and write the corresponding pieces of the audio and the visual (see table below) so that you will not have, for example, to say (or to have someone saying) something on a topic but you miss relevant pictures or shooting.

Visual	Audio
What to show	What the presenter or the interviewee says
What to show	What the presenter or the interviewee says
What to show	What the presenter or the interviewee says

Remember that the keys to success with the type of videos we want to make are **brevity and visuals/pictures/video**. On the one hand, concise information is easier to remember; keep your video short and break it up into blocks/chunks of information to help viewers retain the information. On the other hand, relevant visuals show the viewer what you're explaining and that will increase retention even more. Moreover, note that most people want to see more than a static talking head; a video that shows nothing but a person speaking for several minutes gets soon boring. Plus, many people are **visual learners**. Without some form of images or graphics to accompany the speakers, the video content will not be as effective as we would like it to be!

It is also suggested that in the very beginning (i.e. first few seconds) you use 'something' like an interesting story, a different perspective or a surprising statement/question (related, of course, to the topic of innovation co-creation) to **hook the viewers** and give them a reason to watch it. Then one should focus on the **main message**, i.e. try not to confuse the audience by trying to put too much in. Additionally, viewers require **context** to understand how the story relates to the real world.

Finally, the ending should point out what you want your viewer **to do or walk away with** (for example, share the video with others/colleagues, join the project, read the Practice Abstracts, download a report/deliverable, etc.).

Before you release it watch it carefully **as you were a viewer** (and, if possible, ask few people from the target-audience to watch it with you); look for relevance of content, language and images - and improve or even cut unnecessary parts, jargon, long words or sentences, extraneous information.