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BOOSTING RURAL BIOECONOMY NETWORKS

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Editor: Kirsikka Kiviranta (VTT)

Creators: Raffaele Spinelli (CNR), Raphael Tremmel (DBFZ), Laura García (DBFZ), Andrzej Galiński, Piotr Kaleta (BIOGAL Sp. z o.o.)

Contributions: Enzo Gramigni, Natascia Magagnotti, Matteo Monni, Antonio Orlandini, Lamberto Santini, Fuse Composite, Agnieszka Pyzel, Anna Subocz

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Case Study

Microchips: from forest residues to a new versatile product

Creator: Raffaele Spinelli

Contributions: Enzo Gramigni, Natascia Magagnotti, Matteo Monni, Antonio Orlandini, Lamberto Santini, Raffaele Spinelli

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Content

CASE STUDY Microchips: from forest residues a new versatile product	
Creator	Raffaele Spinelli
Contributors	Enzo Gramigni, Natascia Magagnotti, Matteo Monni, Antonio Orlandini, Lamberto Santini, Raffaele Spinelli
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1 Introduction

The BRANCHES project aims at increasing the implementation of new cost-efficient technologies, mobilizes more biomass and creates innovative business opportunities in rural areas by improving and strengthening connections among practice and science of bio-based economy. Valuable knowledge produced by research and development should always be shared well beyond the scientific community.

BRANCHES will integrate selected knowledge on forest and agricultural biomass supply chains with available innovative technologies and best-practice cases for bioeconomy solutions with bioenergy conversion systems in a wider bioeconomy context. Across EU countries, existing policies and best available technologies will be presented in easily understandable formats (Practice Abstracts and factsheets) through National Thematic Networks launched by this Project.

In Italy, the CNR and ITABIA team produced two Practice Abstracts on the subject of microchips, which are an emerging product with multiple applications. In fact, the two practice abstract exemplify the two main applications of microchips: a local surrogate to imported pellets and an ecological substitute to toxic herbicides. While the two value chains are quite different, they both share the following main characteristics: a) they turn a low-value residue into a high-value product, due to its capacity to replace expensive raw materials, and b) they replace industrial imports with local products, thus accruing large benefits in terms of rural development and carbon balance.

This study combines the two Practice Abstracts into a single integrated case, thus reinforcing the main message otherwise conveyed by each Practice Abstract in isolation. Discussions with practitioners further highlighted the fundamental similarity and the crucial differences between the value chains presented as separate Practice Abstracts (n° 2 and n° 55). Since they show how the same success factors can be developed in different ways, it makes much sense to combine and present the two separate value chains as a single study.

2 Case description

The term "Microchips" describes a very small (7 mm length) homogeneous wood chip product. Compared to other wood chip grades, microchips have the peculiar characteristic of a very small and even size. That confers many qualities to microchips, and especially a much better flowability compared to standard chips that are larger and much more variable in size. Such better flowability brings about dynamic and static benefits, and respectively a) easier automatic feeding (dynamic benefit) and b) homogeneous coverage when layered (static benefit). In turn, each of those two sides of the same quality reflects a specific innovative product, namely: pellet surrogate and mulch. The two value chains gathered under this case study exemplify those two products.

Pellet surrogate

Microchips cannot match the quality of pellets in terms of high energy density, extremely low moisture content and even piece size: however, if properly dried, microchips have a low enough moisture content and

a good enough flowability for feeding stoves that were originally designed for pellet fuel, and that are much cheaper to purchase compared with a classic chip boiler.

Figure 1 – *A classic example of microchips, produced here as a pellet surrogate to feed small-scale pellet stoves for residential use. This product must be very small (≤ 7 mm), very even and very dry (≤ 13% on a wet weight basis). Otherwise, the stove may malfunction…*

Today, many different entrepreneurs have endeavored into the production of fuel microchips, and several of them have gathered in a dedicated association, the Consorzio Forestale dei Produttori di Cippatino e delle Biomasse di Qualità (https://consorziocippatino.com/) based in northwestern Tuscany. However, the undisputed pioneer of microchips is Travaglini Bros., a family-owned farm business in the Chianti hills. As part of their thriving agroforestry business, Travaglini Bros. log their forests, grow agricultural crops and raise cattle - and this activity is successful enough to support the families of the three Travaglini brothers (now in their 70s) and of their sons - who live in the farm. Travaglini Bros. were among the first ones to acquire a chipper and install a chip-fed boiler, for heating the whole farm building complex. They also got into micro-chipping already 12 years ago, supplying a number of residential users in the surroundings. Eventually, Travaglini Bros. got into modifying commercial boilers and selling them to customers together with a guarantee of good functioning and fuel supply at an agreed price, competitive with that of conventional pellets.

Over the years, the process has evolved quite a bit, and today Travaglini have organized micro-chip production as follows:

1 - Storage and air drying of low-quality chestnut logs. These are the by-product of post and fencing assortment processing, which is done directly at the landing in the own forests. These logs are crooked, undersized or - most often - affected by ring-shake, all of which makes them unusable for the manufacturing and more valuable assortments. Reject wood is left piled at the landing or moved to the new satellite yard, where it sits for approximately one year, during which tannin is washed away and moisture is lost. Initial mean moisture content is 42%-w, and that will drop to 27% -w after one year-long storage in a ventilated position. Most of the wood they use for microchip production is their own, and it is difficult to calculate a price - but if they were to sell that wood on the market they would obtain a price of 30 € t^{-1} at the initial 42%-w moisture content.

Figure 2 – *Reject chestnut logs in the open-air storage. One can clearly see the central log as being affected by ring shake, which rules out its conversion into a high-value fencing product.*

2 - Chipping and screening. Logs are chipped by Travaglini, using their own Farmi 260 CH powered by a small 85 kW tractor. The tractor is fed with a loader mounted on a second farm tractor. The chipper is set to a cut length of 7 mm, and productivity is substantially reduced compared with the productivity obtain with the standard 20 mm cut length setting (3 t h^{-1} instead of 5 t h^{-1}). Chips are blown directly into a bin trailer that is fitted with a self-constructed oscillating (reciprocating) screen. Basically, the screen consists of an iron wire net installed on 4 spring supports and shaken by a cam that is powered by a small hydraulic motor through the tractor's own circuit. Normally, 80% of the particle weight is micro-chip, 20% premium boiler chips.

3 - Drying. Chips are dumped on a new solar drier just built on the satellite yard and consisting in a walled concrete pad sited on well-ventilated position for air drying. In summer, moisture content is reduced to 18% within 3 days, after stirring the chips with a front-end loader twice per day. The pad can process about twenty 30-t batches in a 2-month long hot and dry season. That limits production capacity to 600 t $year^{-1}$, but this figure is much below current production, so there is much room for further growth.

4 - Bagging. A bagging line for the microchips has been installed and fills standard 15 kg plastic bags, with thermo-sealing. The system is manual and requires that an operator attends to it. The investment cost for the bagging plant was 8000 €. Screen rejects are sold to local heating plants at 90 € t^{-1}. Both stove-worthy microchips and boiler chips are sold directly to the final users, not to retailers: this way the intermediation cost is avoided. All microchip bags are stored under a roof until delivery, and can stay there for few months, because the process is completed within the end of the summer (early September) in order to obtain accelerated chip drying on the pad, while consumption occurs from October to March.

Like other forest entrepreneurs, Travaglini Bros. endeavoured into microchip production in order to find an outlet for their unutilized wood and to counter dwindling firewood demand. Among the main success factors, the most important is the ability to reach the final user, without intermediaries. Other significant success factors are the use of unutilized labour resources at marginal cost, control of the raw material supply, capture of opportunity wood and reduced investment cost. In fact, the cost for setting up this microchip operation was 38 000 € and represents about less than half that of setting up a comparable pellet-manufacturing

operation. For Travaglini bros. this is a relatively small operation, with an estimated output of slightly over 100 t per year, but it is a very profitable one and it is strategic for optimizing the use of internal resources and for reaching new customers.

Ecological mulch

This alternative value chain was documented in the Pistoia mountains, in Western Tuscany. The landscape is more rugged than in the Chianti hills, and forestry dominates over agriculture. Again, microchips are produced mostly from chestnut residue. There are two main reasons why chestnut is specifically targeted for microchip mulch: first, chestnut firewood is the least valuable on the market. Therefore, turning residues into firewood is a tempting option when dealing with beech or oak, but not with chestnut. Second, chestnut wood is the richest in tannin, which makes the chip mulch especially durable – and that is definitely a desirable quality. In our example, chestnut-dominated coppice stands are harvested according to traditional uneven-aged coppice system in order to obtain several different products, and namely: chestnut timber (used for roofing), chestnut poles and fencing assortments, oak firewood and chestnut chips. The harvesting is performed by local small-scale logging companies, such as Santini Timber or Orlandini Agricola Forestale. Both are pioneers of cable yarding and normally resort to whole-tree harvesting.

Figure 3 – *One of the cable yarding operations common on the Pistoia mountains. A light tower yarder is used to bring whole trees to the roadside, where they are processed and loaded on trucks for subsequent transportation to the end user or to a centralized sort yard.*

Santini also runs a small-scale processor, in order to speed up production and alleviate the burden on the chaser. After careful study, Santini selected the most suitable machine for the wood size and type available in the area. Their light Arbro stroke processor is mounted on a small, tracked excavator and can easily deal with the most branchy wood, while still being light and cheap enough to be within reach for most small-scale loggers. Its small size and light construction are not a synonym for poor durability, since the same machine has now been in operation for about a decade without suffering any major issues.

Figure 4 – *The light stroke processor used by Santini Timber. The processor is installed on a mini-excavator and the whole machine is compact and light enough for easy relocation and trouble-free maneuvering even in constrained-space work sites. The machine is also cheap and reliable. It is now 10-years old, and it still runs smoothly. Professional handling and careful maintenance is all it takes to guarantee a long service life.*

Such an affordable machine allows a small company to spare enough capital to purchase additional equipment and increase its task-versatility. Besides his tower yarder and processor, Santini also owns forwarding trailers, spare tractors, and a mobile chipper, for reaching those constrained landings that are outside the reach of a heavy industrial machine or completing those urgent jobs, when an industrial chipping contractor is not available.

The harvesting operation includes the following work steps:

1. Motor-manual felling by chainsaw
2. Dragging to the skyline corridor and extracting to the landing with a light tower yarder
3. Mechanized processing with a light excavator-based processor (or by a loader and a chainsaw assistant, in the case of Orlandini)

When the site is accessible by truck, logs are loaded directly at the yarder pad and taken to the mill. Otherwise, a farm tractor equipped with a forwarding trailer will move them from the yarder pad to a proper roadside landing. Below a simple graphical description of this system.

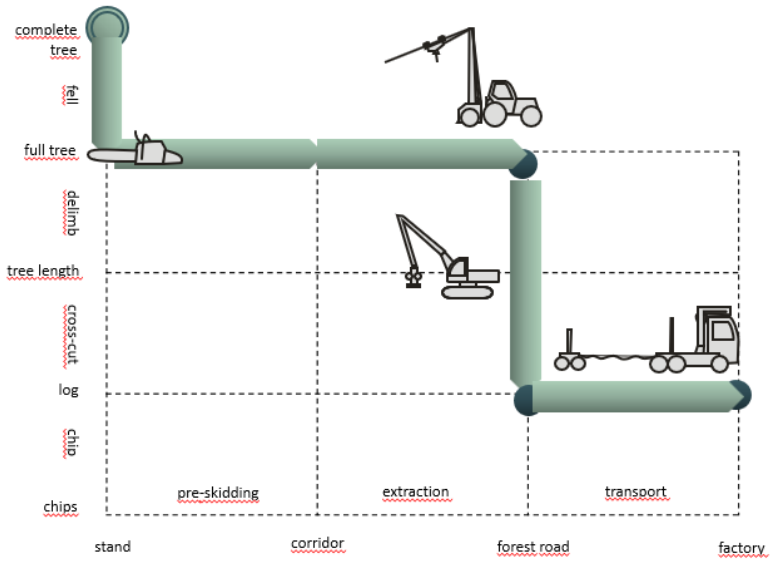

Figure 5 – *Schematic description of the whole-tree yarding system common in the Pistoia mountains.*

Yarding operations as those run by Orlandini or Santini are typical of the Tuscan mountain, where a dozen other yarding operators are also active. Those operations are quite different from the operations found in the Alps, because extraction distances are generally shorter, but tree size and removals are smaller, and the species are entirely different – being generally hardwood or young softwoods – not the large and valuable spruce trees one is yarding further North.

Operators have adapted and they have found the right equipment and methods for matching their own wood basket. Orlandini and Santini are leaders in this sector, as they pioneered yarders and processors, respectively. More contractors are following their example, to the benefit of increased financial, social, and environmental sustainability in forest operations.

Logs are taken to the sortyard owned and managed by Orlandini Agricola Forestale. This company was among the first to resort to whole-tree chipping, which has now grown into a very common business model all around Tuscany. As competition became fiercer, Orlandini realized that once again you have to start a new game if you want to stay ahead and changed its fuel chip business into an innovative microchip business, geared to offer a new product: ecological mulch. Being the first to offer such a product, Orlandini acquired the leading customer in the Province – Vannucci Piante - and they are once again showing the way ahead!

In Pontepetri is the largest of Orlandini's sort yards. While tops and branches are too bulky for efficient transportation and they are chipped at the forest landing whenever possible, logs are moved to the sort yard and chipped after air drying. Orlandini separates different log sorts by size and species, and they have their special recipes for mixing those woody ingredients to obtain the ideal product specifically suited to each individual user. By introducing chestnut in the mix, they increase the proportion of tannin in order to obtain better durability for their chip mulch. Conversely, they can reduce (or entirely remove) chestnut from the mix if the goal is obtaining hot-burning fuel chips.

The great thing about chip mulch is, that the only specification set by the customer is that of a durable even-sized chip, with a length below 2 cm. There is no strict moisture content specification, and therefore mulch chips can be produced simply by adjusting chipper cut length to the minimum setting and by installing a 3x3 cm or 3x2 cm mesh screen. There is no need for screening the chips after chipping nor for drying them to a very low moisture content (<20%), as is the case when producing microchips for use with pellet stoves.

All the microchip mulch produced by Orlandini Agricola Forestale goes to one single custmore: Vannucci Piante. Established in 1938 by Vannino Vannucci Sr. on a plot that measured less than a hectare, this nursery has become a global company that produces over 3000 plant varieties, for a total surface of 590 ha. Now in the capable hands of Vannino Vannucci Jr., the company remains a family-owned business, but its customers are spread over three continents, and range from the quality-minded home-owners purchasing a few ornamental plants for their gardens, to the Royal Gardeners of Buckingham Palace or of the Jordan Royal Residence.

Figure 6 – *Microchip mulch freshly layered on garden plant pots at the Vannucci Piante nursery*

From the humblest to the loftiest, such clientele has a distinctive outlook on environmental and social sustainability. In order to resolve any concerns, Vannucci Piante operates under a double environmental and ethics certification scheme. That is quite important for nurseries, which are intensive operations and use significant amounts of water and chemicals. In fact, Vannucci Piante has endeavored into a very ambitious project: the Vannucci Zero project. The project was launched in 2021 on a pilot site measuring 15 ha, located at La Ferruccia, just outside Pistoia. The innovation is radical: even if the new nursery is designed for potted-plant production, its surface has received minimum treatment to maximize water infiltration rate during rain events. Pots are lined on bands of permeable geotextile fabric, which only cover the area right under the potted-plant lines. Access and service roads are only metaled on the two 40 cm-wide strips corresponding to the vehicle wheel tracks. These measures maintain full soil permeability to the point where no surge ponds are necessary. Furthermore, all plant supports are made of locally sourced chestnut posts, which receive no preservative treatment, given the high natural durability of untreated chestnut wood. Finally, all herbicide has been replaced with ecological mulch, supplied by Orlandini. Rather than spraying toxic chemicals, Vannucci Piante now applies a thick layer of microchips to the top of each pot, which constitutes a durable and effective mechanical barrier to weed growth. With that measure alone, herbicide use has been cut by over 50%, while creating a new market for local forest companies,

such as Orlandini, who operates just few kilometers uphill. Vannucci Piante currently uses 8000 m^3 of microchips per year, but that amount is rapidly expanding, as the new weed control technique becomes generalized: microchip is far superior in environmental, social, and financial terms.

Figure 7 – *The Vannucci Zero project. Pots are placed on a permeable pavement (grass pad and geotextile cover) and the support structure for both the plants and the irrigation pipes is made by untreated chestnut wood poles.*

3 Practitioners' feedback & motivation for development

The reasons for implementation of both microchip solutions are multiple, and they all concur to their success. Those are:

1) Large availability of unused forest residue that cannot find a viable market. Alternative users offer a very low price that barely compensate production cost and is only accepted if the residue must be disposed of and cannot be left in the forest (e.g. fire prevention, amenity etc.);

2) Very high price of the surrogated industrial product. Pellet is sold at >5 € per 15 kg bag (>300 €/t) and herbicide is even more expensive. Furthermore, pellet availability and price are quite erratic: they may change abruptly with any disruption of the main supply channels, as it happened with the recent Ukrainian crisis, which caused an acute shortage of pellets with the resulting price spike (tripled within a week);

3) Regulations that are limiting or even banning the use of certain herbicides, as is the case for Glyphosate in Tuscany. Regional legislators placed a ban on the toxic herbicide few years ago, and that ban has impacted both food and non-food production, as in the case of ornamental nurseries;

Additional feedback received from the public attending the demonstrations concerned the following subjects:

- Several stakeholders found it very interesting to see such a large nursery (and the other nurseries around), which is a very important local employer and economy driver. They appreciated the direct connection between horticulture and forestry, which may help broadening one's mindset.

- Another subject of interest was the use of a yarder with relatively small trees, on a slope that could have been harvested with ground-based systems – although with some difficulty. The capacity to apply cable yarding to borderline conditions (for tree size and slope gradient) is crucial in minimizing site impacts.

- Some delegates also reported that microchips are occasionally used as mulch in their countries, but not on the industrial scale that was witnessed during the showcase day.

- Most appreciated the professional management of all the operations visited on occasion of the Showcase Day, as well as the strong experience of the operators. The use of low-cost machinery was also noted and favorably assessed, and so was the ability to maintain profitability when dealing with small sales and light removal, both of which represent severe challenges to financial sustainability.

4 Trade-offs between economic, energy and environmental effects

Both operations – PA #2 and PA # 55 – demonstrate successful value chains that are innovative, effective, and adapted to the local needs and potential. Starting from the same general conditions, they show two different ways to generate revenue from the same resource with the same level of affordable low-investment technology.

Due to their reliance on local raw materials, both value chains are resilient to global perturbations and can help mitigate their impacts. That was clearly the case of the pellet supply shortages derived from the Russo-Ukrainian conflict.

Furthermore, developing a local microchip business can boost the revenues obtained from low-value forest resources and support active forest management where it is most needed. Replacing imported industrial products with locally sourced domestic goods is also likely to increase energy efficiency, as well as GHG emission mitigation efficiency, due to the shorter transportation distance and the fewer processing steps. That is true for both imported pellet and herbicide – the former needing active drying and long-distance transportation, the latter requiring industrial processing and use of noxious chemicals.

Finally, evolving from firewood-production into microchip-production offers significant benefits for both producers and users. For producers, that means changing from labour-intensive and potentially hazardous semi-mechanized firewood processing to safer fully mechanized chipping; for users that means phasing out their old, inefficient and polluting firewood stoves and adopting newer, more comfortable and cleaner pellet stoves. In fact, firewood can be produced and used in modern and efficient ways, but the cost of converting an old firewood business (or firewood stove) into a modern and efficient firewood business (or firewood stove) is often higher than that of shifting to an entirely new product, such as microchips.

Figure 8 – *Traditional semi-mechanized firewood processing is labour-intensive, costly and hazardous*

5 Knowledge transfer potential to other regions

The main driver for establishing the microchip value chains described in this case study is the large availability of unutilized forest resources, which cannot find a viable market. Designing a new product is shown here as a successful solution, especially if such new product can replace another high-value product at competitive conditions. That is what PA #2 and PA #55 exemplify, as they show how forest residue can be processed into a competitive surrogate of expensive imported pellets or herbicide. Of course, the new product must be reliable, effective and consistent, and matching those specifications requires considerable skill and professionalism.

On the other hand, there is no need to commit large capitals into expensive and sophisticated machinery, nor to incur into large energy or material consumption, as when installing a small-scale pellet plant. The equipment required is that normally used for logging, which one expects to be already available to a professional logging enterprise. Only minor adaptations and/or additions are required.

The main barrier to a further development of microchips as a surrogate for pellets is legislation, or the lack thereof. At present there are no official quality standards defining microchips, although when microchips are quality certified, the certificate generally makes reference to chip quality Class A1+, according to standard UNI EN ISO 17225-1: 2015. However, most pellet stoves are only certified for use with pellets, not chips – regardless of quality. The result is that any malfunctions or non-compliance events eventually occurred when feeding those stoves with microchips are not covered by a manufacturer's warranty. In fact, a few manufacturers have now launched dedicated models that are certified for use with microchips, and they extend all their warranty conditions to that fuel, too. However, current public funding schemes do not include microchip stoves into the subsidized stove categories, and therefore a microchip stove may not benefit from the tax credit or subsidy granted by the regional legislator. Apparently, no such limitations are incurred by microchip mulch.

Concerning replication, installing a value chain for pellet surrogate requires that pellet is in large demand by residential users and that local production is limited. Such conditions are best met in relatively warm climates, where the utilization of heating plants is not extensive enough to justify the larger investment of a more efficient chip boiler. For the same power output, pellet stoves are simpler, cheaper and smaller than chip-fed boilers, while more convenient than firewood installations that cannot be automated. It is not by chance that Italy is the largest global consumer of pellets in residential heating applications, with an annual demand estimated at 1.4 million tons. This large demand is matched only in part by national production, quantified at 0.8 million t and largely supplemented by imports. Similar conditions are likely encountered in other Mediterranean and Southern European Countries, even if microchips could also be produced and used further north. The question is just about how competitive they can be against local industrial pellet and/or an intently used chip boiler, if heating requirements are large enough to justify its larger capital cost.

Figure 9 – *Group photo from the Showcase Day devoted to the microchip mulch value chain (20/09/2023)*

6 Summary

Low-value wood products and forest residues can be effectively converted into microchips, which are an emerging product with multiple applications. Among them, the two applications explored in the case study are: 1) a local surrogate to imported pellets and 2) an ecological substitute to toxic herbicides. Both applications rely on the excellent flowability of very small and even chips, which facilitates trouble-free automatic feeding (dynamic benefit) when used to replace industrial pellets in pellet stoves and guarantees homogeneous coverage when layered (static benefit), when used as a mulch to replace herbicide.

Microchips can be produced with a minimum of dedicated equipment (if any) and do not require revolutionizing one's production system. Most logging enterprises can adapt their operations to a collateral production of microchips with little modifications.

Microchip production has a very large potential for expansion and very few hurdles in its way. In turn, it replaces imported, carbon-inefficient and even toxic and polluting products with a locally produced, clean and ecological raw material. Microchips offer a clear improvement in terms of environmental, social, and financial sustainability.

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Case Study

From hemp to composite material

Creators: Raphael Tremmel, Laura García

Contributors: Fuse Composite

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Content

CASE STUDY From hemp to composite material	
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1 Introduction

The European Union's Horizon 2020 funded project BRANCHES, has as aim to promote the introduction of new technologies and innovative practices in the collection, processing, conversion and utilization of biomass for energy biomass for energy production and other value-added applications such as biomaterials and bioproducts. The project runs from January 2021 to December 2023, carried out in parallel in 5 countries: Spain, Italy, Germany, Poland and Finland with the coordination of the Natural Resources Institute Finland (Luke). For this, BRANCHES aims to strengthen the links between practitioners, users and innovation promoters as well as to facilitate the exchange of information, meetings and collaboration between bioeconomy stakeholders. In this way, innovations are brought closer to potential users, promoting the introduction of new and innovative business opportunities in rural areas. This will encourage an efficient and sustainable use of biomass and promote a more resilient and decarbonized society.

For the identification of innovative practices in Germany, the focus lies on practices with high-added value utilising agriculture and forestry resources, and in particular the valorisation of residues. It was also decided, considering the interest of the German national thematic network (NTN), to focalise on circular practices that represent a more sustainable use of resources as well as to include social innovation and innovative modes of cooperation or of working towards reaching innovative products.

This case study reports more in detail an innovative practice, identified as a best example of regional cooperation and innovative utilisation of hemp plant and its fibres. It describes the fine tuning of working between innovators of a material process hand in hand with regional farmers, both delivering their expertise to the project and working together to revitalise the use of hemp plantation in Saxony, Germany. Also, it depicts novelty hemp-based materials to establish into the national and international market, with the environmental benefits and regional integration. The selection of this case study took place within the management team of the NTN, as it presents a viable, innovative production process and final composite product that already is open for commercialisation. It was initially identified thanks to the second year “best innovative practice contest- 2023”, and although it was not the final winner practice in that year, its concept, process, and exclusively regional focus called onto our attention to explore further this example and present is uniqueness to our NTN members.

2 Case description

FUSE™-Tape, a product in the "Natural Fibers In USE" (FUSE) brand of SachsenLeinen GmbH, is a sustainable alternative for conventional Unidirectional (UD)-Tapes as it is based on natural fibres. The idea of this innovation was born in the expert panel Sachsen-Leinen e.V. With the goal to substitute conventional fibres used in composite materials, SachsenLeinen GmbH developed a technique that creates fibre-tapes made out of hemp. This resource has the potential to reduce CO_2-emissions and the accumulation of non-recyclable fibre waste. Hemp has a lower density than comparable materials while providing ideal technical performance. SachsenLeinen GmbH is located in Markkleeberg in the south of Leipzig and works together with regional farmers (field in Mausitz, Zwenkau), to keep a shorter value chain and thus to shorten transportation. Additionally, this cooperation with regional farmers facilitated the cultivation of a type of hemp that is suitable for their process and reactivated the hemp fields and its uses in Saxony, Germany. The whole supply chain is transparent to ensure quality and sustainability. The FUSE™ UD tape can be used for technically demanding composite products and passes the needed endurance tests for extension and flexure. This analysis was performed with a composite of 50 % FUSE™ UD tape and 50 % thermoset resin. The tested properties can be provided with product weights of 100 to 250 g/m^2 which offers various possibilities for composite elements. A comparison with other natural fibre tapes shows that with its available length of up to 500 m per roll and direct surface formation it is more efficient in application than other products, based on natural fibres, on the market. The current available width is up to 20 cm, with a future prospect of up to 50 cm. The production process allows the use of various natural fibres besides hemp, for instance flax, sheep wool or pineapple, and also combinations of different fibres. The product has a technology readiness level (TRL) of 6 still in the development phase, although FUSE™ already offers an efficient alternative for mineral based fibre and has proved its performance as reinforcement material in ski and snowboards.

Photo 1: Hemp-based UD tape product from FUSE Composites (Source: https://en.fuse-composite.com/).

The production costs are very low and consist of sourcing and storage, running costs, marketing and low personnel expenses because of economical campaign production. Revenue comes from direct marketing of the UD tape, development services for specific client requirements and licensing. So far, the natural fibre supply chain consists of only few suppliers, but prospective the sourcing needs to be diversified. For the FUSE™ production, it is very important to ensure homogenous and reliable feedstock quality. Current plans pursue a regional supply chain from crop to refinement in the south of Leipzig. The future prospect is to obtain resources mainly from central Germany to support the regional development of the bioeconomy. A parallel increase in production will enable the company to accept larger orders, for example from the automobile industry. Other potential applications are in interior designs, packaging, and sporting equipment. Design based on natural fibre are functional and resource efficient while being durable and recyclable. Packaging made with FUSE™ is lightweight, durable and safe during handling. A composition of sporting equipment with natural origin addresses the connection to nature and creates a more appealing product. Another possible application is the use of natural UD tape in wind turbines where huge amounts of fibre are needed. While conventional glass fibre cannot be properly recycled, rotor blades made with hemp as the fibre composite can be put in thermal recycling. Clipping accumulating in the production of the rotor blades can even be composted.

Photo 2: Potential uses of FUSE™ UD Tape product (Source: https://en.fuse-composite.com/).

In the development of the FUSE™ UD tape several challenges arose. As the existing supply chain of natural fibres was concentrating on the textile industry, it was necessary to establish direct distributions from farmers to the production plant. To compete with conventional fibres, the hemp tape needed to be at least as homogeneous and resilient as their precursor. This could be achieved with close cooperation with applied research, namely the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing (PAZ) in Schkopau, Saxony-Anhalt, leading to an innovative production process. The process consists of first arranging the fibres in a unidirectional manner, starting on the harvest. The harvest machinery, which is not available in many EU countries, and rounds several European areas in the harvesting season (Late July – Late August) to carry out the harvest, is already designed to cut the long stems of the hemp plant in two to three sections and place them in the field in a unidirectional manner.

Photo 3: Harvesting process (Source: Laura García).

This is important to also facilitate the retting process, which builds up the fibre development in the plant, and consists in leaving the cut hemp stems in the field to receive rain, sun and, more importantly, to be enhanced by the soil microorganisms. This allows the cellular tissues and pectins surrounding bast-fibre bundles to rot, facilitating the separation of the fibre from the stem. During this process, another machine is utilised to turn the sub-partitioned sections of the plant along their longitudinal axes every now and then. After the stems are retted and dried, they are taken to the plant, where a mechanical process takes place to assure finalize the separation of the fibre from the stems and assure a similar thickness among fibres. This is then followed by the weaving of the fibres with polymers for the construction of the composite UD tapes.

By concentrating on the production of a UD tape for fibre composites instead of more complex textiles, several steps could be eliminated to make the process more efficient and the product more homogeneous. Due to small output and well-established synthetic competition, the production needed scaling through campaign production and, cooperative marketing and development.

3 Practitioners' feedback & motivation for development

A wide range of products depends on reinforcement with synthetic fibres. As we face a changing climate because of the use of fossil resources and an alerting accumulation of non-recyclable waste, there is a need to substitute unsustainable materials like glass and carbon fibre. Many sectors are already trying to achieve that goal and most of the times the obvious solution is to use natural feedstock as alternative. The challenge of natural material is to achieve the necessary properties needed to compete with conventional products. For companies to accept the more sustainable alternative, it needs to be reliable and homogeneous for industrial production. In the case of FUSE, they created an efficient substitute that meets the technical requirements. Additionally, because there is no need for energy demanding artificial fabrication of synthetic fibres and transportation from oversea production is replaced with local cultivation and efficient refinement, it is less energy consuming. Broad implementation of FUSE UD tape could lead to drastic decrease of CO_2-Emissions

by the production of composite materials. To use natural materials in composites even removes carbon from the carbon-cycle.

Value added remains in a regional supply chain, while establishing a strong cooperation with the agriculture cooperative, given that the plant is very weather resistance, with low care needs that reduces the cost of production. When licensing the technological process from FUSE, it is easy to use and to manage for the other potential users, allowing a production of simplified steps towards a highly applicable and diversifiable product of tested quality.

4 Trade-offs between economic, energy and environmental effects

As FUSE™ UD tape is made from regional, natural resources it has lower production costs, but also lower environmental costs than conventional UD tapes. The innovative production process reduced the number of production steps. Thus, the shorter supply and production chain leads to more efficiency and the current campaign production reduces labour costs. The regional production and feedstock supply reduce the environmental impact of transportation, and it supports the local economy, so there is a social benefit as well. The environment benefits from the decrease in mineral fibre, too. The negative effects of glass fibre or carbon fibre, that cannot be properly recycled, on humans and the natural system are decreased. While the production of natural fibres is mostly based on the cultivation process and the energy need of further processing is relatively small, synthetic fibres origin from fossil resources and are about ten times more energy demanding. Hence, production of natural fibre composites produces less carbon emissions. Additionally, because of the natural origin, the fibre is biodegradable. A composite made of this fibre has similar properties, depends on the used binding material. As natural fibres are less dense compared to synthetic fibres, composites can be more lightweight, which is advantageous for the automotive sector and for transportation.

The setup of a regional supply structure with cultivation, refinement and production strengthens the local economy, attracts new producers and promotes the development of new innovative approaches. FUSE™ acts as provider of the fibre but also as partner in the innovation process of possible natural fibre-based products that have individual requirements.

5 Knowledge transfer potential to other regions

As it is increasingly important to find alternatives for fossil resources, the implementation of natural feedstock in industrial systems is crucial. Because there is a high demand for composite materials based on fibre, the pioneer technology of FUSE™ has the potential to reduce the use of non-renewable resources in several sectors. If the structural demands for the composite use are met, the fibre-base can always be from a natural origin.

One possible limitation of natural grown materials is the prioritized use of arable land for food production. Agricultural used land is decreasing constantly due to unsustainable management. A potential risk of scaling up the use of hemp for material production at industrial scale is to potentially put food systems under pressure. A possible solution is the secondary use of crops. For example, the straw of hemp or flax, grown mostly for linseed oil, can be used as source for natural fibres, as these plants are already grown in huge amounts and the residue is accumulating as a waste product.

Other aspects to consider for practitioners are the “try and error” nature of this practice and technological process. Although, the technological process can be calibrated and specifications can be made, this is not the same with the hemp plantation, when applied in other regions where it has not been widely produced, such as is the case in Sachsen in the last decades. Trying different hemp varieties and testing their productivity in the given environment is to be expected.

6 Summary

This case study presented the innovative process designed by the start-up FUSE™ Composites from Leipzig, for the utilization of hemp to produce composite unidirectional (UD)-Tapes for their utilization in diverse other sectors, such as the sports, automotive, housing, among others. In the case study, the process, technologies utilized, cooperation models between the farmers and processing company, as well as the advantages and disadvantages of this innovation have been detailed. In summary, the production of a hemp-based UD tape allows to substitute conventional fibres made of glass and therefore contributes to a more sustainable product that has demand in diverse end-product sectors, such as the sport, furniture, housing, among others.

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BRANCHES

BOOSTING RURAL BIOECONOMY NETWORKS

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Boosting RurAl bioeconomy Networks following multi-actors approaCHES

Case Study

Biogal – The green biogas plant in Boleszyn

Creators: Andrzej Galiński, Piotr Kaleta (BIOGAL Sp. z o.o.)

Contributors: Agnieszka Pyzel, Anna Subocz (WMODR)

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BOOSTING RURAL BIOECONOMY NETWORKS

Content

CASE STUDY Biogal – The green biogas plant in Boleszyn	
Creators	Andrzej Galiński, Piotr Kaleta (BIOGAL Sp. z o.o.)
Contributors	Agnieszka Pyzel, Anna Subocz (WMODR)
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1 Introduction

BRANCHES project aims to implement the implementation of new cost-effective technologies; mobilize more biomass and create innovative business opportunities in rural areas by improving and strengthening the links between bioeconomy practice and science. The project will ensure communication through the two-way flow of information for the transfer of ideas and technologies between scientists and professionals from agriculture and forestry in rural areas. The valuable knowledge produced by research and development should always be shared far beyond the scientific community.

BRANCHES will integrate selected knowledge on forest and agricultural biomass supply chains with available innovative technologies and best practice cases for bioeconomy solutions with bioenergy conversion systems in a wider bioeconomy context. In all EU countries, existing strategies and best available technologies will be presented in easily understandable formats through the national thematic networks launched by BRANCHES. The results of cooperation between national thematic networks are expected to have a widespread impact on professionals in European rural settings.

2 Case description

Biogal is an ecological biogas plant located in Boleszyn – a village in Warmińsko-Mazurskie Voivodeship, Poland. It was founded in 2012 and currently employs over 40 people. The company obtains raw materials such as manure and self-grown corn from its own pig farm and from other local farmers to produce biogas. In addition, Biogal also processes agrifood industry waste products such as residues from brewing, fruits and vegetables production and overdue food.

Figure 1. Biogal plant from the air. Source: BIOGAL

Figure 2. Cogeneration block at Biogal. Source: BIOGAL

Figure 3. Study visit to the company. Source: WMODR

Biogal's activity is beneficial especially for the pig producers who do not have enough agricultural area to meet the Nitrates Directive, i.e. due to cooperation with Biogal they are able to deal with production of manure and slurry exceeding 170 kg per 1 ha per year. Biogal deals with energy production from a combination of renewable sources, waste food products processing, organic fertilizer production (productized under the Naturgal brand) as well as obtaining wind and solar energy. The company is currently implementing several wind energy investments in local villages and towns in Warmia and Mazury.

The ecological granulated digestate fertilizer Naturgal is produced in the mesophilic natural manure methane fermentation process, and it is recommended for vegetable crops, ornamental plants, fruit trees, shrubs as well as field crops. This fertilizer enhances the natural development and high quality of crops. Obtained electricity and heat constitute an effective element of infrastructure development, allowing electricity supply for Biogal's own needs, for other local farmers, residents and for public sector institutions. Heat is provided for 2 local factories, 3 schools, 2 churches and 350 single-family houses – the company supplies energy to 4 nearby villages and built a 27 km long heat pipeline in the area surrounding the plant in Boleszyn. The constructed heating network is routed to a construction and housing elements manufacturing plant and serves for precast concrete products drying.

Facts of the Biogal plant:

- Electricity generating installation's value is 11.5 million euro (52 million PLN)
- Total installation's value, including heat, energy transmission and fertilizer production is 15 mil. euro (70 million PLN)
- Direct operating costs per MW of generated electricity is 70 euro (320 PLN)
- Indirect operating costs per MW of generated electricity is 26 euro (120 PLN)
- Installed electricity capacity is 3.6 MW
- Technology readiness level (TRL) is 9 which means it is a ready solution

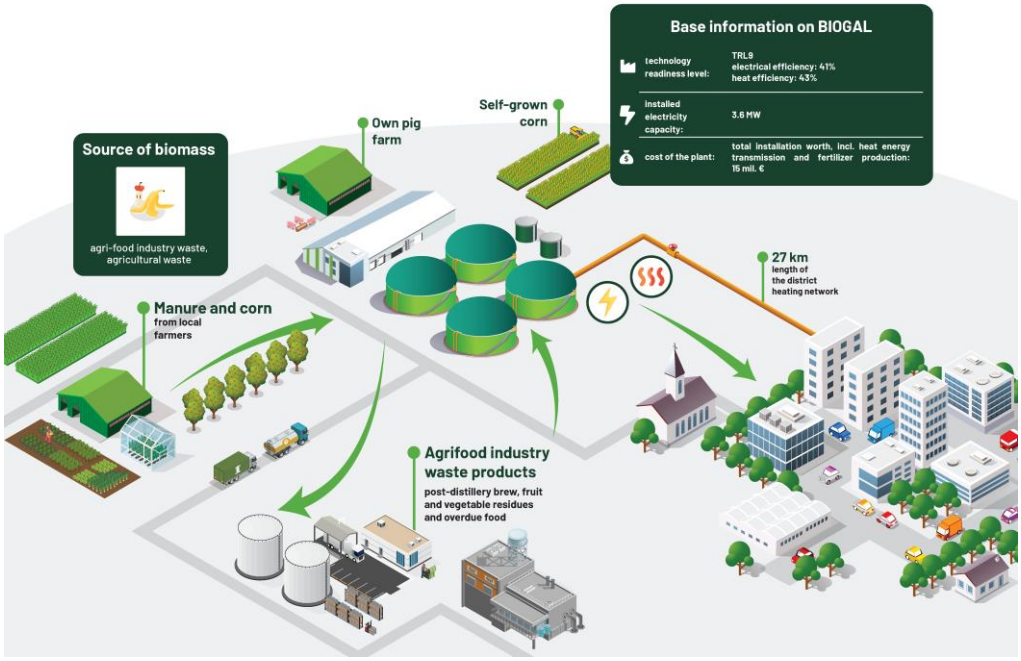

Figure. 4 Biogas plant layout. Source: UWM

The company was very aware that pig production imposes a burden on the environment and they employed solutions already existing in Western European countries, i.e. a biogas plant construction and thus disposal of swine slurry. And that is how the idea was born, as Biogal produced quite large numbers of pigs and those in turn generate large amounts of slurry.

It was one of the first biogas plants in Poland, based primarily on solutions typical for Germany, i.e., the Navarro System where the substrates, i.e., corn silage and slurry were coming directly from the farm. Later, this idea was modernized and changed development direction due to the fact that the conditions for this type of installations in Poland began to be unfavorable and they were facing bankruptcy. Therefore, completely different, low-cost substrates needed to be used for methane-based biogas production, i.e. waste products. Also, the market itself forced the expansion – demand for electricity and heat power.

Introduction of the blue certificate serving to diminish the risk of investments in new generation sources was a milestone in the development of the existing biogas installations. In July 2016, the new authorities introduced new Property Rights for the production of electricity from agricultural biogas called PMOZE-BIO. Later, Feed-in tariff (FIT)/Feed-in Premium (FIP) system was introduced – yet another RES Act amendment.

3 Practitioners' feedback & motivation for development

At the beginning, the farm specialized in pig production. The owner was aware that it was burdensome for the environment, so technological solutions existing in Western Europe were used. Because the farm produced large amounts of slurry, a biogas plant with a capacity of 1.2 MW was built. It was one of the first biogas plants in Poland. The resulting facility was initially based on German technological solutions. The Navarro System was introduced, which involves using substrates coming directly from the farm for biogas production, i.e. in the case of Biogal, from slurry and corn silage. Over the years, the facility was modernized. The substrates used so far have been significantly reduced and a low-cost feedstock, i.e. organic waste, has been introduced. Currently, the installation has a capacity of 3.6 MW and is constantly being developed.

The added value of the investment, apart from the production of biogas, is a by-product in the form of ecological granulated digestate fertilizer Naturgal, which has a very beneficial effect on the soil, and also contains an admixture of corn, which, thanks to its large amount of fiber, limits the effects of drought in the soil.

Biogal is constantly investing in expansion, first of all to the waste suppliers network. This way costs of providing heat for residents are reduced considerably, taking into consideration high prices of gas and hard coal – waste heat prices are simply more stable and lower.

4 Trade-offs between economic, energy and environmental effects

The electricity and heat generation processes are a result of methane fermentation in agricultural biogas plants, take place in an environmentally sound manner and constitute an innovative form of modern agriculture. However, due to difficult situation in the pork market (i.e. swine fever) the way ahead will not be challenging.

Obtained electricity and heat constitute an effective element of infrastructure development, allowing for electricity supply for Biogal's own needs, for other local farmers, residents and for public sector institutions. However – there still remains a considerable public reluctance due to the odours.

The company obtains raw materials such as manure and self-grown corn from its own pig farm and from other local farmers to produce biogas. In addition, Biogal also processes agri-food industry waste products such as residues from brewing, fruits and vegetables production and overdue food.

In terms of economic aspects – biogas plants allow for energy independence and profit from electricity sales, especially facing high energy costs. However, there are relatively high investment costs combined with still insufficient legal regulations concerning RES.

In terms of ecological aspects – biogas plants provide groundwater protection, help contribute to reduction of animal production odours spread to concentrated locations, ensure cleaner air and reduced eutrophication of local waters and soils e.g. by improving organic matter content and decrease the carbon footprint of slurry management and biomethane production thus contributing to lower greenhouse gas emissions.

In terms of socio-cultural aspects – biogas plants are more environmentally-friendly than companies using fossil fuels – especially combined with the still not fully exploited huge potential of biogas production in Poland. However, there still occurs some dose of inhabitants' resistance due to generated odours.

In terms of technological aspects – biogas plants take advantage of waste heat which is transferred to the municipal heating network. Furthermore, they store biogas and thus balance the power system operations.

5 Knowledge transfer potential to other regions

Biogal promotes eco-friendly activities related to on-farm utilization of generated waste. They are also an integral part of mitigating emission effects. The company closes the organic matter circulation at a farm level and is an excellent example of an agricultural biogas plant with a good replication potential. They utilise waste products generated not only on-site but also by other businesses which could lead to forming new partnerships in the future. Emphasising Biogal's openness to visitations and eagerness to share their practical perspective on each investment process stage and employed technology, there is a huge potential of knowledge transfer, including the NTN contribution.

A direct transfer of the know-how and the entire technology proposed above to any region in Poland or in any other European country is possible. Obviously, the exact costs and benefits from using the technology will depend on the factors mentioned above and local economic factors as well as the logistics used in each case.

6 Summary

The Biogal agricultural biogas plant in Boleszyn, Poland deals with energy production from a combination of renewable sources, waste food products processing, organic fertilizer production (productized under the Naturgal brand) as well as obtaining of wind and solar energy. The company is currently implementing several wind energy investments for local villages and towns.

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Showcase video: *https://youtu.be/dQUf762p2LY*