BRANCHES

BOOSTING RURAL BIOECONOMY NETWORKS FOLLOWING MULTI-ACTOR APPROACHES

CASE STUDY

Qvidja farm – Solutions for climate smart food production

The Qvidja organic farm is an experimental farm that demonstrates and implements regenerative farming practices for food and renewable energy production that take into account both nutrient recycling and carbon sequestration while increasing biodiversity. The regenerative farming practices applied at Qvidja farm provide measures to decrease carbon emissions from agriculture as well as increase the soil organic matter and soil fertility. Such practices include, e.g., lighter tillage, continuous plant cover, rotational grazing, agroforestry, increased biodiversity and cover cropping (Heimsch et al 2021).

In Qvidja farm, all fields (180 hectares in total) are farmed as grassland, which aims to improve the structure of the land. The farm is gradually switching into a crop rotation with the emphasis on native species and nitrogen-binding plants. The effectivity of carbon sequestration in farms is affected by the assortment of carbon-storing plants present on the farm. For example, both, deep-rooted grasses and leguminous plants are excellent at absorbing and storing of carbon.

In addition to the assortment of plants, the method of harvesting has also an impact on the amount of stored carbon. For instance, higher remaining grass after a cut allows the plants to continue photosynthesis and enables a faster root recovery. In the fields of Qvidja, the height of the grass is left at 15 cm above ground instead of the previous 10 cm. The carbon sequestration of perennial grass is based on the high number of growth cycles, continuous vegetation cover and on deep and wide root system that bind carbon to the soil. Carbon is also transferred from roots to soil microbes and is retained in the soil once the microbes die. This improves the humus content of the soil.

KEY WORDS

Biomethane, carbon neutral agriculture technological innovations

COUNTRY

Finland

AUTHORS

Saija Rasi (Luke)
saija.rasi@luke.fi
Kirsikka Kiviranta (VTT)
kirsikka.kiviranta@vtt.fi
Kirsi Korpijärvi (VTT)
kirsi.korpijarvi@vtt.fi

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The carbon dioxide exchange between the atmosphere and a managed forage grassland was studied at Qvidja farm in 2018 and 2020. According to Heimsch et al. (2021)," the Qvidja field acted as an annual net carbon sink and had the potential to contribute to the short-term climate change mitigation".

Figure 1. The soil before (left) and after (right) experiments where different organic soil amendments were added to soil to improve the structure of clay soil. Photos: Saija Rasi.

Grazing is also an effective method to improve the effectiveness of carbon sequestration of grass and plants. In Qvidja, cows, sheep and horses graze utilizing a hastened pasture cycle, where a large herd graze in a single grazing area only for a short time and then move to another grazing area. This cycling allows the plants to regrow while also keeping the farm animals fed until the cycle is repeated.

Figure 2. Cows and horses grazing at Qvidja farm. Photos: Saija Rasi

Agroforestry, a farming method where trees and bushes are cultivated alongside crops, is also an effective method of carbon sequestration. The broader biodiversity of plants in these farmlands also improves the balance of microbes and fungi that are beneficial for carbon sequestration.

Over 700 ha of forest grow at the Qvidja farm, utilizing the continuous cover forestry method, where the trees are allowed to regenerate naturally. There are also agroforests in the area containing various tree species of different size and age and thus retain their biodiverse ecosystem better than typical cultivated forests.

Figure 3. Forest of different age (up) and natural wetlands in the areas that are kept to increase biodiversity (down).

The conventional agriculture is heavily relying on fossil energy. At Qvidja farm, this dependency on fossil fuels is decreased by several renewable energy production technologies (Figure 5). All the systems are built in form of experimental facilities to provide information on farm-scale renewable energy production. The utilised energy production options at Qvidja farm are biogas production, biological methanation, wood gasification, wood chip fuelled heating plant, and solar PV.

Figure 5. Qvidja farm provides a research and development environment for various renewable energy technologies. Photo: from video The farmer isn't the problem, they are the solution (2022): https://www.youtube.com/watch?v=B6eAbiFlxTM).

Biogas, containing methane and carbon dioxide, is produced when organic matter is degrading under anaerobic conditions. The agricultural residues are good raw materials for biogas production. Treating manure via biogas process can remarkably decrease greenhouse gas emissions as for example methane emissions from open manure storages are prevented by capturing the methane in biogas process and used in energy production. However, manure might need a co-substrate to improve the profitability of the processing.

After the digestion process, the nutrient-rich digestate can be used as organic fertilizer in the farm fields. The digestate has good fertilising value and it also helps to maintain or even increase soil organic matter. In Qvidja farm, grass and manure from the farm are used as a feed for the biogas plant. Energy from the biogas unit is utilized in electricity and heat production. In addition, part of the produced biogas is upgraded, after which biomethane can be used as a vehicle fuel.

Figure 6. Biogas plant (left) and grass silos (right). Photos: Saija Rasi.

In addition to the biogas plant, the QPower's biological methanation pilot plant is located at the Qvidja farm. In biological methanation, microbes are utilized to produce methane from carbon dioxide and hydrogen. Process is based on exothermic Sabatier process:

$$4H_2 + CO_2 = CH_4 + 2\ H_2O$$

Hydrogen for the pilot plant is obtained from electrolysis and from the wood gasification unit. As a carbon source, the plant can utilise carbon dioxide from biogas process or carbon dioxide and carbon monoxide from wood gasification unit. The plant's efficiency is 82%. The process operates under temperate conditions; the temperature is 60 – 85 ×C and the pressure near ambient pressure.

Figure 7. Biological methanation unit at Qvidja farm. Photo: Saija Rasi.

Wood obtained from forest thinning is used locally at Qvidja farm in a wood gasification unit and in conventional wood chip -powered heat generation unit. The processes provide electricity and heat for the farm.

In the wood gasification unit, wood material from forest thinning is converted into synthesis gas. Gasification is a thermochemical conversion of organic material to product gas at high temperatures with a reduced amount of oxygen (less than in stoichiometric combustion). Product gas consists mainly of water vapour, carbon monoxide, carbon dioxide, hydrogen, and nitrogen, but it also contains impurities such as tar, fine particles, and sulphur compounds. The impurities need to be removed from the gas before end-use. The gas composition depends on the type and construction of a gasifier, fuel used, and process parameters (Sansiwal et al. 2017). In general, gasification is considered as an attractive process to exploit the energy from certain biomass materials for various end products such as heat, electricity, and transportation fuels due to the good conversion efficiency of the process.

Unlike typical wood gasification units, the gasification unit at Qvidja farm is a unique oxygen-enriched gasifier that produces pure and tar-free synthesis gas that can be fed to a methanation unit, or it can be directly used as a fuel in gas engines. High operation temperature (<1000 ×C) also ensures an efficient decomposition of other harmful substances (QPower, 2022a). The nominal power of the oxygen gasifier unit at Qvidja is 250 kW and it consumes approximately 250 litres of wood chips per hour (QPower, 2022b).

Figure 8. Gasification unit at Qvidja farm. Photo: Saija Rasi.

Solar photovoltaic (PV) system is one option to increase energy self-sufficiency at a farm. Qvidja farm has invested on a solar PV system with 95kWp capacity. Solar PV panels convert sunlight into electrical energy. Although Finland is a Nordic country, the solar irradiation levels are similar to the irradiation levels in Poland and Germany. The optimal solar PV system size is farm- and site specific and hence, when sizing a PV system, the power consumption profile of the farm needs to be taken into account. A challenge in Finland is the intermittency of the available solar energy (summer-winter cycles). Therefore, under Finnish conditions, the farm needs to have a relatively high power consumption also during summer time, as the amount of substituted purchased electricity is a key factor for the profitability of the PV system. The solar PV system is well-dimensioned when most of the generated electricity is used directly at the farm, resulting in avoided costs on purchased electricity.

The renewable energy technologies used at Qvidja farm are presented below in Figure 9.

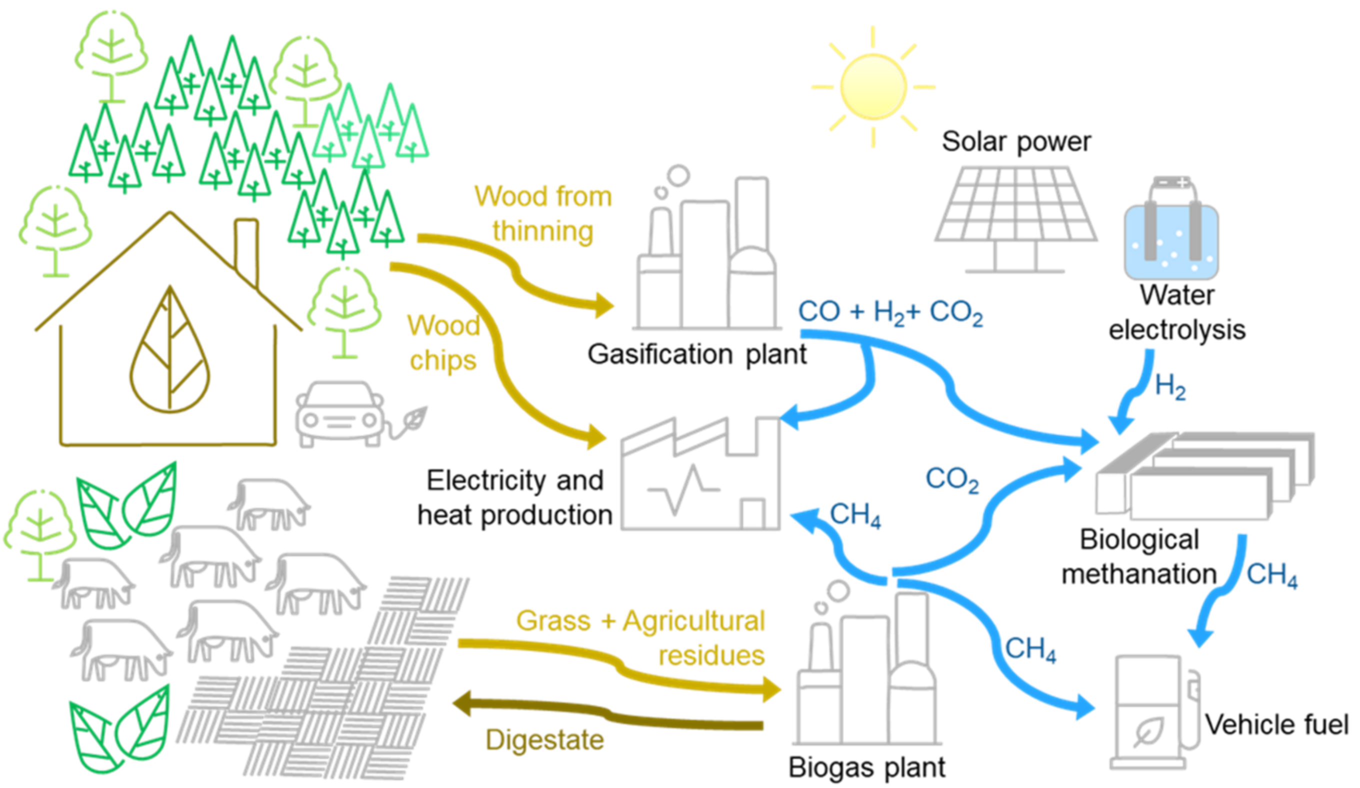

Figure 9. Illustration of energy production at Qvidja farm. It describes the linkages between the main unit operations at the farm.

Motivation for development

Climate change has direct and indirect effects on agriculture. On the other hand, agriculture contributes to greenhouse gas emissions. Key motivations at Qvidja farm are to experiment farming practices for food and energy production that simultaneously mitigate climate change, increase biodiversity and minimize nutrient leaching to the Baltic Sea. These targets are reflected in all practices and techniques piloted at the farm.

The methods and technologies piloted at Qvidja farm, described in detail in Chapter 2, aim to decrease carbon emissions from agriculture while taking into account nutrient recycling and carbon sequestration. The carbon sequestration is directly reflected in growth conditions and the security of crop supply. The methods applied at Qvidja also improve the tolerance of the arable land against the extreme weather conditions caused by climate change.

Economic-, energy- and environmental perspectives

Improving biodiversity is in the focus of all actions done at the Qvidja farm. The technologies and methods piloted and used at the Qvidja farm enable the farm to improve its soil structure, minimize nutrient leaching, increase carbon sequestration and improve energy self-sufficiency. In this chapter, the energy-related trade-offs of bio-based alternatives for conventional energy production in rural regions, especially from an agricultural farm perspective, are discussed.

From the energy perspective, agricultural production generates a variety of bio-based residues and side streams with energy recovery potential. Harnessing suitable technologies to recover the value of these streams provides several benefits for the farm itself, but also for the local and regional bioeconomy. The bio based residues and side-streams with valorisation potential can include for instance livestock manure, straw, grass, and logging residues. For example, the energy production potential for biogas from local agricultural and livestock residues is large compared to what is currently being exploited in Finland. Many of the above mentioned residues and side-streams are already exploited at the Qvidja farm, either via technologies that are already mature (biogas plant, wood gasification) or that are still on a piloting phase or close to commercialization (biomethanation).

The premises at Qvidja farm provide a versatile research and development environment for renewable energy technologies that can be used in agriculture to valorise bio-based feedstock. The technologies applied in Qvidja present different solutions that a farm, or a rural entity, can deploy to replace conventional fossil-based fuels.

Generating energy from local bio-based sources improves the energy self-sufficiency at a farm-level and even at a national level. By generating energy from bio-based residues and side-streams, a farm can obtain direct savings from avoided costs related to purchased electricity and fossil fuels. This can improve the overall economic feasibility of the farm. In terms of security of supply, by generating energy, the operations at the farm are less dependent and vulnerable for the price changes in purchased electricity or imported fuels. In addition, in some cases, the excess energy produced can be sold in the form of electricity, heat or transportation fuel. This provides a new source of income for the farmer.

In the case of biogas production, besides energy, the farm can also increase its self-sufficiency on fertilizers as well. Recycled fertilizers from biogas production are used as a fertilizer at the Qvidja farm. During the biogas production process, the nitrogen present in the feedstock is transferred into more soluble form in comparison to ordinary substrate. By using the recycled nutrients as fertilizers on the fields, the demand of purchased chemical fertilizers reduces. In addition, the operation of the farm is less affected by fluctuating market prices of the chemical fertilizers.

Naturally, replacing conventional energy sources with bio-based alternatives, fossil emissions are reduced. The QPower's biological methanation pilot plant at the Qvidja farm takes this one step further, as during the biological methanation process, bio-based carbon dioxide emissions are also mitigated. During the methanation process, carbon dioxide is converted to biomethane with hydrogen from electrolysis and/or from the wood gasification unit. Therefore, the carbon dioxide present in biogas, previously vented to the atmosphere during the combustion of biogas (for heat and/or electricity) or during the upgrading process of biogas into biomethane (used as a transportation fuel) is avoided through the applied technologies.

On the contrary, an important barrier for farms to replace conventional energy production with renewable alternatives are the high capital investment costs for bioenergy production units at a farm-scale, e.g., in the case of a small-, or medium-scale biogas plants. Furthermore, investment costs have significantly increased recently as consequence of inflation and global supply challenges. However, the increased energy prices can reduce the payback time of the investments. In the Finnish case, investment subsidies from Finnish authorities are often needed to make agricultural renewable energy investments financially feasible at a farm-scale.

The on-going research and development work on the biological methanation process at the Qvidja farm is an example of an action to improve the feasibility of bioenergy production. By converting the carbon dioxide from biogas to biomethane, a more valuable product can be generated from the same amount of feedstock while generating value for the previous side-stream.

Knowledge transfer potential to other regions

Qvidja farm pilots and demonstrates methods for regenerative and holistic farm management and bioenergy technologies, which have the potential for knowledge transfer and replicability in other regions as well. On the fields, Qvidja aims for carbon-sequestering and biological cultivation. The fields are on grassland, artificial fertilizers are avoided, and crop rotation method, native-species as well as nitrogen-binding plants are used. In the forests, biodiversity is promoted by applying continuous cover forestry, where the trees are allowed to regenerate naturally. As the forests have trees with uneven ages, the forests are more diverse. From a renewable energy production perspective, the renewable energy technologies in Qvidja cover biogas production, biological methanation, wood gasification, wood chip-fuelled energy production, and solar PV.

All the activities, farm management methods and bioenergy technologies, aim to improve the sustainability and feasibility of primary food production while also improving the state of the environment. The methods and technologies can be applied in rural regions where primary agricultural production takes place.

The replicability potential of the technologies and methods piloted at the Qvidja farm depend on the characteristics of a farm where the addressed solutions could be implemented. The characteristics can include, among other aspects, the availability of fields and forests, the size of the farm, the availability and quality of residual biomasses, the amount of energy utilization at farm as well as the location of the farm. A farm aiming for carbon-sequestering and biological cultivation or targeting a reduction of fossil fuels does not need to incorporate all ideas demonstrated at Qvidja farm, but the primary producers could choose technologies or methods most suitable for the characteristics of the farm in question.

Summary

To conclude, Qvidja farm provides several examples of methods and technologies on how farmers and foresters can promote climate smart food production. Qvidja farm demonstrates methods for regenerative and holistic farm management to improve soil structure, minimize nutrient leaching and to increase carbon sequestration in primary food production. In addition, the farm uses and pilots several renewable energy technologies that can be used in agricultural farms to improve energy self-sufficiency. All work done at Qvidja is done in favor of the climate and the Baltic Sea, biodiversity being the foundation for all actions.

ABOUT BRANCHES

BRANCHES is a H2020 "Coordination Support Action" project, that brings together 12 partners from 5 different countries. The overall objective of **BRANCHES** is to foster knowledge transfer and innovation in rural areas (agriculture and forestry), enhancing the viability and competitiveness of biomass supply chains and promoting innovative technologies, rural bioeconomy solutions and sustainable agricultural and forest management.

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THE PARTNERSHIP

Luke LUONNONVARAKESKUS · National Research Council of Italy Institute of BioEconomy Department of Biology, Agriculture and Food Science · VTT · University of Warmia and Mazury in Olsztyn · DBFZ · circe Research Centre for Energy Resources and Consumption · ITABIA Italian Biomass Association · MTK · aveBiom Spanish Biomass Association · UFZ · W-M ODR · BioEconomy Cluster