NIFU SusValueWaste

Insight | NR. 12 – 2019

SusValueWaste Policy Brief nr. 3

Adding value to side-streams in the food and beverage industry: Lessons for the circular bioeconomy

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Executive summary

We present main challenges and opportunities for the valorisation of side-streams in the food and beverage industry, based on comparative case studies in Norway and in Denmark: on whey in the dairy industry, on animal by-products in the meat industry and on spent grain in the brewing industry. The case studies have shown that changes in regulations and political framework conditions can facilitate sustainable transition pathways by giving the right direction through a portfolio of policy instruments which need to be coordinated, both at international, national and regional level. The regional context is an important background for the possible valorisation options: geographical and logistic conditions vary quite a lot between Norway and Denmark and therefore policy cannot just be copied but must align with those conditions.

We have following policy recommendations:

- **More targeted policy instruments are needed to implement the national bioeconomy strategies.**
- **Companies must be encouraged to build up and maintain research and development expertise.**
- **Political instruments are needed that support the development of value chains that cross traditional sector boundaries.**

Circular bioeconomy

The circular bioeconomy cuts across many sectors and industries which traditionally operated more separately. The circular bioeconomy includes the production and processing of renewable biological resources, and the utilisation of side-streams and residues for high-value products.

In the European Union, agriculture and the industry sectors for the production of food, beverage and tobacco deliver 75% of the bioeconomy turnover and they stand for 80% of the employment in the EU bioeconomy.

To understand the challenges for a transition to a circular bioeconomy it is necessary to have a systemic perspective. We have to understand:

- The dynamics of the industry,
- Interdependencies between related industries,
- Changing vertical links in global value chains, and
- The role of institutions and changes of regulations.

The valorisation of side-streams requires a higher degree of coordination in value chains due to the properties of those: The amount or volume of side-streams and the timing of their production hinders its future utilisation and are characterised by the place of origin in the value chain. In 'normal' interactions the supply of a product is related to its demand, but the availability of side-streams does not follow market forces but the needs of the producers.

There are three solutions to this challenge:

- Improve the properties of the side-streams to allow storage and transport so that production volume and timing are less important,
- Process side-streams into new products to increase its value and the demand for these products achieves such an importance that the firm will coordinate the original main product and the new product, and
- Reorganise links between firms through change of management or ownership to downstream actors to assure constant flow of side-streams.

Corporate governance

There is a need for adapting corporate governance to the needs of the transition to a circular and sustainable bioeconomy. Firms need to realise that their employees develop and/or renew competencies and they have to change routines, business models and value chains within the boundaries of specific sectors. However, companies might have to open up for developing new value chains crossing the established sector boundaries.

Corporate social responsibility (CSR) can provide a competitive advantage to companies. To pursue a competitive advantage, companies must choose between product differentiation and low costs in terms of cost leadership. Most evident is the effect of CSR on reputation or branding. Branding and reputation are hard-to-get resources that cannot be imitated and thus serve as entry barriers to competitors. There is a positive association between companies' sustainability measures and their economic performance in terms of the cost of capital, operational performance and stock price. Despite such benefits, it has been observed that sustainability and broader CSR measures only rarely are placed at the core of a business's strategies.

With regard to valorisation of side-streams, the direction in which the companies go is dependent on the local/regional context, the properties of the resources, the existing regulations and the connections to other firms. However, the sustainable use of side-streams can contribute to a competitive advantage of the industry. Therefore, there exist a huge variety of possible directions to go.

In the dairy sector, CSR efforts address the usage of side-streams such as acid whey or sweet whey, as well as energy efficiency, animal health and packaging.

In the meat sector, CSR efforts focus on optimal differentiation and treatment of the different categories of animal by-products.

In the brewing industry, CSR efforts include the sustainable use of organic residues, reduced water consumption, waste water management, more efficient energy use and diminished CO_2 emissions, sustainable packaging and responsible drinking.

Sustainable business models address different ways in which firms can combine an improved customer value with societal, environmental and economic benefits They can target innovative value propositions, value creation and delivery, and ways to capture value.

Path-dependencies and lock-in mechanisms in transition processes

All economic activities are characterised by path dependencies. History matters. Certain lock-in mechanisms have reinforced particular development trajectories. Among such mechanisms are economies of scale, economies of scope or learning effects. Economies of scale means that an increased production volume can create benefits due to sunk costs of earlier investments. Economies of scope addresses the possibilities to differentiate the portfolio of products. Learning effects can be found when knowledge, skills and organisation routines increase with cumulative production.

In the beginning of a new economic development such lock-in mechanisms are necessary to reach some economically viable development: for firms it is necessary to achieve a predictable outcome and the lock-in mechanisms help to overcome uncertainties.

At later stages those lock-in mechanisms contribute to inflexibility and inefficiency. Firms cannot adapt to changed framework conditions and their development stagnates.

Here, we use the dairy sector, the meat sector and the brewery sector in Norway and Denmark as examples to show how companies adapt to changes in markets and regulation and can benefit from economies of scope, economies of scale and learning effects.

Meat processing and animal by-products

The meat industry in Denmark and Norway originates from a cooperative ownership model. In Denmark over the last 15-20 years, the sector has restructured and is now dominated by 4-5 large slaughterhouses with strong export orientation and international linkages, and ca. 100 smaller ones. Danish Crown is by far the largest company with some 25,000 employees, and still owned by Danish farmers. In Norway, the industry is more geographically dispersed, has smaller units, and is less internationalised. The largest meat and egg producer is Nortura, owned by Norwegian farmers, with more than 5000 employees and 30 production facilities.

Both countries have dedicated companies for handling animal by-products: In Denmark there are DAKA A/S (part of the German Group SARIA), BHJ A/S (part of LGI Group) and Farmfood A/S (owned by HKSCAN, DANPO and BHJ). In Norway there are Nortura's subsidiaries Norilla AS, Norsk Hundefor AS and Norsk Dyremat AS, and a few medium-sized companies such as Norsk Kylling AS, Fatland AS, Grilstad AS. There is also a rendering company – Norsk Protein AS – that receives by-products from slaughterhouses and meat processing companies, specified risk materials (SMR) and dead animals.

The main difference between the two countries is the size of the industry. Denmark's pig production is one of the largest in Europe. This gives better access to finances, export markets and raw materials, and hence economies of scale and scope. However, Denmark also face large challenges related to the sustainability of the highly industrialised meat production, including issues of animal welfare and usage of antibiotics.

Animal by-products (ABPs) are side-streams of animal origin that people do not consume. They come from slaughterhouses, food processing plants, dairies and as fallen stock from farms. They have rather diverse properties, such as gelatine, protein, enzymes, fatty tissues, collagen and phosphates, which offer varied possibilities for utilisation and conversion. This allows manifold possibilities for value-added products, such as pharmaceuticals, chemicals, food ingredients, enzymes, livestock feed, pet food, fertiliser and bioenergy.

The driving force for new valorisation pathways for ABPs has been changes in regulations. The meat industry had to respond to those, to make some organisational changes, to align to the changed conditions, and it tried to influence the regulatory framework as well.

How have the institutional framework conditions changed over time? The main argument for the changes in regulations of valorisation of animal by-products were severe health concerns for animals and for humans due to the observation of Transmissible spongiform encephalopathies (TSEs), first as a massive outbreak of 'mad cow disease' (BSE) in the United Kingdom in the mid-1980s, and later in 1996 the human variant, Creutzfeld-Jakob Disease (CJD). Regulatory changes addressed both inputs (types and volumes of animal by-products) and demand and market possibilities for the industry (trade barriers, bans, nutritional and health claims). The regulatory changes had four phases:

- 1990: EU ban on using ruminant meat and bone meal in feed for ruminants
- 2001: EU total ban on using any remains of all animals in feed for livestock (TSE Regulation)
- 2002 (changes in 2009 and 2011): EU regulation of three main categories of animal by-products
- 2006 (changes in 2008 and 2009): EFSA regulation on nutrition and health claims to be proven in clinical trials.

The rendering industry is specialized in handling ABPs and has lobbied for amendments of regulations.

Regulatory changes affect the types and volumes of inputs for the ABP industries. Temporary trade barriers impact market possibilities, demand and price formation for those industries.

Therefore, actors had to align with these conditions and tried to influence the regulations. An example of such successful lobbying is that EU lifted the export ban on processed animal proteins. Companies have become more innovative in the valorisation of the ABPs to gain from learning effects. Slaughterhouses have become much more active in valorising ABPs, but at the same time new, dedicated processors of ABPs have entered the stage, intensifying the competition for the raw material.

The fact that companies have to prove in clinical trials the nutrition and health claims for new products creates an advantage for larger companies, which have more economic capabilities to finance such trials.

The dairy and ingredients industry

The dairy sector in Denmark and Norway also originates in cooperatives. In both countries, a strong structural development has restructured the industry from many small dairies to a few, large and highly efficient ones. Yet dairy production in the two countries differ

in two central ways: the orientation towards international trade and the exploitation of side-streams – both are achieved by the Danish dairy industry but not by the Norwegian.

Norway is outside the EU and has a negative trade balance for agri-food products in general with the EU – 4,496 million € in imports against only 579 million € in exports, and for fresh milk, cream, buttermilk and yoghurt 17 million € vs. 3 million € (numbers for 2018, source: EU Agri-food trade statistical factsheet European Union-Norway, 2019). Denmark is part of the European Single Market and Danish dairies export for 1.8 billion € and EU gets the largest part of it. This is about 20% of all Danish agricultural exports.

The other difference is related to the valorisation of side-streams, particularly whey, which is a by-product of cheese and yoghurt production.

Arla Foods in Denmark benefits from economies of scale, from economies of scope and from learning effects in whey valorisation and has established a subsidiary company for this purpose - Arla Foods Ingredients (AFI). AFI processes 6-7 million tons of sweet whey every year on its Danish facility and has facilities in Germany and Argentina. The products that include a wide range of food ingredients - proteins, permeates and lactose - are sold in more than 90 countries. The revenues are higher than from Arla's cheese production.

Norway's TINE focuses on the quality of its end products, on health, packaging and on animal health, but not on valorisation of side-streams. The high specialisation of TINE's dairies has led to large volumes of side-streams, such as acid whey due to the increased production of cottage cheese and Greek yoghurt. These large volumes do not allow for using old methods of handling whey (feed for pigs, biogas production or fertiliser). Hence, TINE has become a supplier of intermediate whey products to Arla Foods Ingredients.

The special properties of acid whey make it difficult to valorise. AFI has developed Nutrilac, which can be added to *acid whey* and then the product can be used for yoghurts, beverages, soups etc. This innovation was enabled by large investments and a global network of suppliers and joint ventures, and an own R&D division. Therefore, it can be said that Arla Foods managed to create economies of scale and scope and learning effects, while TINE is somehow stuck in a chosen path for valorisation of its traditional products while trying to address challenges related to animal health and the quality of primary products.

The brewing industry and spent grain

The beer brewing industry has long been considered somewhat bio-circular since the major part of its organic side-stream, spent grain, returns to the biological system in the form of animal feed. In many places, spent grain has historically been given away free to farmers as livestock feed, especially for cattle.

In terms of environmental sustainability, this can be a good management choice for the bioeconomy, placing it between 'recycle' and 'reuse' in the waste pyramid. However, the fast deterioration of untreated spent grain requires the presence of local farmers as well as good transport infrastructure.

Yet, according to Statistics Norway and Statistics Denmark since the 1980s, the number of farms has declined by 60% in Norway and Denmark, making the disposal of spent grain potentially more expensive and complicated. In addition, giving spent grain to farmers brings little or no revenues to breweries and prevents further valorisation of this resource.

Globally, brewers produce about 38.6 million tons of spent grain a year. Therefore, a change in spent grain management could have significant environmental and economic impacts.

The large quantities of spent grain, along with an increasing interest in the circular bioeconomy, have spurred interest in developing new valorisation pathways as an alternative to the traditional use of spent grain as animal feed. Spent grain has a high protein content and other nutritional assets, and research has shown that it can be used as a feedstock in various industries, including livestock feed, food and nutrition, chemicals, pharmaceuticals and biofuels. Yet, despite this technical potential, scholars have identified few examples of advanced uses of spent grain on an industrial scale, suggesting low levels of the deployment of research results.

Three main factors explain why breweries do not invest in alternative options for valorising their spent grain: costs, location and CSR.

Breweries avoid *extra costs* due to exceeded storage capacity for spent grain and costs for waste disposal. Since spent grain deteriorates very fast, the large number of smaller breweries tend to get rid of the spent grain as fast as possible. Alternative techno-logies require cold storage or pressing and drying equipment, an extra economic burden and production activity that those small breweries cannot handle. In cases where the breweries are not located near farms, alternatives have to be looked for, such as bioenergy.

CSR has motivated current spent grain management for some small breweries. For example, one brewery making certified biodynamic beer composted the spent grain and applied it to its own barley field to comply with the Demeter standard. Combatting climate change is a central part of the CSR policy of a large brewery, and the company carries out CO_2 accounting across all its plants; however, spent grain management is not a main issue in its CSR policy.

The sustainability of new valorisation pathways has to be assessed through life cycle assessments, which can include the social value of the existing practice of giving the spent grain to local farmers. In cases where the spent grain not is available for free anymore, the farmers have to find other feed sources, some even from abroad.

Policy implications

Valorisation of side-streams requires both technological and institutional innovation. Valorisation pathways are the trajectories through which such values are created and distributed by and among actors from industry, farmers, policy, research, civil society and households. These pathways depend on the market and political framework conditions but are also conditioned by the regional and local context. And they are the result of past strategies and choices of industrial actors operating in these environments.

Changes in political framework conditions can facilitate sustainable transition pathways by giving the right direction through a portfolio of policy instruments and regulations. This would include support to research, development and demonstration, but also instruments, which can stimulate the demand for more sustainable products, such as public procurement. Or they can support new pathways or punish old ones through financial incentives such as tax relieves or higher taxes.

To be successful those policy instruments need to be coordinated, both at the national and regional level. They are influenced also by international regulations. And they have to be updated and aligned with newest developments to avoid support for mature technologies and to address new challenges, such as new health risks.

The case studies have shown that the regional context is an important background for the possible valorisation options: geographical and logistic conditions cannot just be copied, and this also applies to policy. Long distances and the physical properties of the side-streams make transport expensive and require more local and distributed solutions.

The size of firms and farms also has an impact on the possibilities to handle side-streams in a different way. New specialisation patterns contribute to high volumes of side-streams, which earlier – with lower volumes – could be valorised or disposed of locally without hampering health or environment. Here we must develop new valorisation pathways, often as part of global value chains.

Firms acquire new capabilities and get access to new market segments through participation in specific value chains, which might be outside their traditional sector boundaries. A central upgrading mechanism for firms is to learn from downstream firms - their buyers.

Through governance of global value chains, the lead firms organise activities to achieve a functional division of labour within the value chain. This allows them to:

- Set prices,
- Set compliance with technical, environmental and legal standards,
- Re-allocate value-added activities, and
- Distribute costs and benefits.

Building the circular bioeconomy requires developing new value chains for the food and beverage industry, which allows better valorisation of side streams. Central actors here may well be non-food firms, such as biotech firms, feed producers, or waste handling companies, implying the creation of new inter-sectoral linkages. But it also depends on new products and production processes that enable waste prevention in all segments of the food chain, to recycle packaging and unavoidable food waste.

Corporate social responsibility must ensure that the sustainable valorisation of organic side-streams becomes a core element of food companies' business models rather than just add-ons easy to forget. To balance environmental and social sustainability with economy, the industry must collaborate with civil society organisations, such as consumer organisations and environmental NGOs to achieve such goals.

However, the crossing of traditional sector boundaries to produce completely new products out of side-streams requires also interaction with other industry sectors to make the business opportunities offered by these resources known and to achieve interaction in new value chains.

The sustainability of the chosen valorisation pathway for organic side-streams has to be a primary goal of industry and policy, combining environmental sustainability, economic sustainability and social sustainability.

We have following policy recommendations:

More targeted policy instruments are needed to implement the national bioeconomy strategies.
While there is a set of instruments to support the development of renewable energy and sustainable transport, there is a lack of such a range of instruments for the bioeconomy that can be adapted to the different regional conditions. We propose low thresholds for small and medium-sized businesses to be developed to test new products and processes. The authorities' health requirements for new food products create clear barriers for these small and medium-sized companies. We also propose that companies can receive support for demonstration facilities to minimize the financial risk associated with the commercialization of new technology.

Companies must be encouraged to build up and maintain research and development expertise.
There is a tendency that most companies reduce their research and development capacity and that they are depend on collaboration with the supplier industry or research institutions to develop new products and processes. Public support for competence building in companies should be developed.

Political instruments are needed that support the development of value chains that cross traditional sector boundaries.
Value creation based on side-streams is currently most often limited to the value chains that have been developed in the respective sectors, and the sector crossing value chains are very rare. Through require¬ments for public procurement, market opportunities can be created for products that are the result of such innovations. More regional cooperation is needed to support industrial symbiosis, but also completely new relationships with companies with different types of expertise.

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