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EVALUATING SYSTEM DEVELOPMENT OPTIONS IN CIRCULAR ECONOMIES FOR THE MILK SECTOR - DEVELOPMENT OPTIONS FOR PRODUCTION SYSTEMS IN THE NETHERLANDS AND HUNGARY

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Abstract

The currently operating economic structures all follow the perspective of linear economies, which roughly translates to "produce - manufacture - discard". This, however, doesn't support the perspectives of the actual sustainability of natural resources, the operation of material circulation, or the planning of synergy between systems. In this research, we used a dairy farm in the Netherlands as an example to evaluate mainly the methods of moving from linear economic systems towards circular systems, for the sake of sustainability. Based on the analysis of three models from the Netherlands, we designed an analysis method that can help domestic entrepreneurships select strategies which help the actors of the dairy product sector move from linear economic systems towards circular ones. During the analyses, we mainly used the relevant data of LPT Ltd. (Livestock Performance Testing Ltd.) as the database. We requested professionals for consultations in order to receive the mandatory professional estimate. Furthermore, we cross-referenced the fundamental parameters of domestic systems using benchmarking. In order to create an understandable overview and actual strategy from all this, which can also be used in practice, we determined a division logic that's applicable to three-unit life cycle phases. We also designed the so-called CEV (Circular Economic Value), which can be used to strategically plan the process of reconfiguring milk production strategies (1. Low-input/low-output; 2. High-input/high-output; 3. Low-input/high-output) to be circular.

Keywords

Circular Economy, Dairy production, Circular Economic Value, Life cycle assessment

1. Introduction

Nowadays, sustainable and climate-friendly production gets a more and more important role in our daily lives. The need for methods aiding possible environmental, climate-related, social and economic problems that may appear related to manufactured and consumed products is also more important - due to them aiming to prevent negative influences these systems may have. The life cycle assessment and the circular economic model can be used together, which provides an opportunity to evaluate the criteria of long-term sustainability in our current economy, on multiple levels. The life cycle assessment process explores the environmental factors and potential environmental effects, which lets us analyse products and services 'from the cradle to the grave'. The life cycle assessment describes the entire lifespan of products and services. Among the areas to which the analysis is applicable, we can also find the usage of resources, and effects which are hazardous to human health and the balance of ecologies [1]. LCA models the life cycle of the product, for the entire product system. The product system has the fundamental attribute of being determined functionally, and not merely from the perspective of the end product. In the case of our current analysis, designing a B2B (business to business) -type life cycle system structure

became mandatory. This simplified life cycle system is used for procured base materials, which mainly consists of the following parts (Figure 1):

–input material manufacturing
–production process
–distribution process

Figure 1. B2B-type life cycle model

Both the climate change and the processes, which are increasingly hard to be sustained, place current politicians and decision makers into a tight spot. Nowadays, actually interpreting the problems of climate change also became a daily occurrence for average people, who start to feel the importance of handling them. Therefore – even for ordinary people - the need for taking the criteria of sustainability into consideration is steadily becoming more apparent, similarly to the initiative to deepen related knowledge. This can be achieved by using the life cycle assessment analyses together with the newest sustainability concept, named the "circular economy" model, for any relevant areas of daily life. 'Sustainability' and 'sustainable development' may be some of the most notable concepts in the XXI. Century. The Environment- and Development World Council of the UN issued the 'Our Common Future' report in 1987, and its contents reach more and more people nowadays. It says "Sustainable development is a kind of development which can assure that our current needs are satisfied, without endangering the opportunities of future generations by satisfying its own needs." [2]. If we want to form a deeper understanding of the definition, we have to interpret it in a complex fashion, since it encompasses multiple factors.

The most notable are the social, environmental and economic dimensions, the equilibrium of which can be called the basis of sustainability. These three dimensions are called the 'pillars of sustainability' (Figure 2).

Figure 2. Pillars of sustainability [3]

Sustainability is basically a state supported by these three pillars, and in case a change occurs in one of the factors, the other two will also experience change. The three-way optimisation between these pillars is important for establishing long-term sustainability [4].

Possibilities for transformation - the circular economy model

The currently operating economic structures follow the principles of the linear economy, which basically means 'procure – manufacture - consume – discard', or ' produce – manufacture – discard' in short. This, however, doesn't support the perspectives of the actual sustainability of resources, the operation of material circulation. Linear economy is based on linear processes, which prefer large mass products and cheap production costs. It mostly supports itself by procuring the necessary base materials for relatively low costs [5, 6].

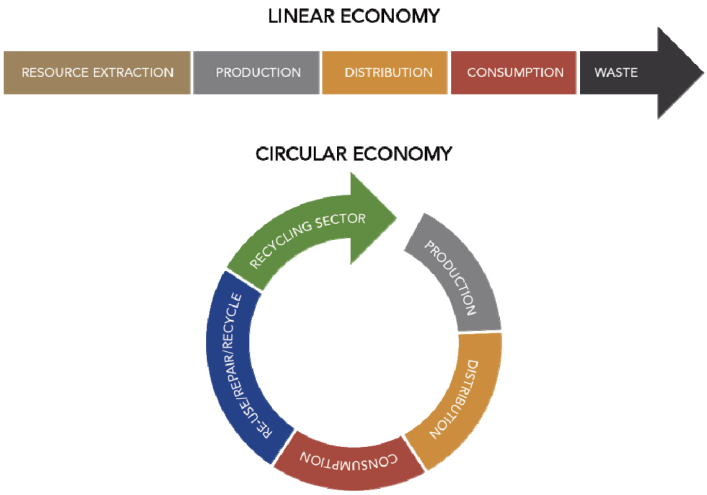

Figure 3. Basic structure comparison between linear and circular economic systems [7]

The circular economy can recycle manufactured products at the end of their life cycles, resulting in minimal, or no waste, using minimal, or no resources. The main processes of circular systems are the complete reduction, recycling, reuse, re-manufacture and improvement of waste. The circular economic model is basically an industrial system, where the 'end-of-life' concept is discarded in favour of repairing, and the usage of renewable energy sources is advised and promoted. It tries to eliminate waste by expert designing of materials, products, and systems – most notably business models [8, 9]. Circular systems introduce – and elevate – another aspect, which had its influence diminish gradually in western manufacture systems during the second half of the XX. Century, which is prevention.

The logic of the new circular approach accepts that even though circulating waste within the system is inevitable, the solution it offers for the fundamental problem is at best, slightly effective. During the second half of the 1900s, a new branch of the linear economy approach was spread - this was the manufacturing of products with life cycles cut short. This basically meant shortening the usage lifetime of products artificially - during the production process [10]. The definition of 'planned obsolescence' can be attributed to the first few years of the 1930s. This is when an American economist first mentioned the possibility of its usage, which would offer a solution for the great economic depression of that time. Though it wasn't adapted widely at the time, 20 years later, it can be said that it was widespread practice within production systems [11]. This perspective still helps in sustaining the consumer society based on over-production to this day.

However, even decision makers managed to understand how the management of waste resulting from these processes cause an increased deadweight, which is more than their gains extracted from the economic growth, which happens due to the aforementioned processes. This is why the circular economy tries not only spreading the approach of reusing waste as a new form of capital, but also takes measures to lengthen the life cycle at the beginning of the process. This may be solved by modifying the warranty systems in a way that is applicable to a thought process tailored for long life cycle products. It further promotes designing business models (sharing economy, refurbishing, re-manufacturing, upcycling, etc.) which push actors taking part in manufacturing or distribution to make and promote products with as long lifespan as possible.

2. Method of Analysis

Due to the complexity of the topic, and the time constraints and variety in data at hand, which is applicable to the analysis, we chose the benchmarking method for conducting our evaluation. Benchmarking is a level-comparison method, which can be used to make a state for a set time and space comparable to another, by adhering to a set criteria system [12]. The benchmarking method can be used to compare even an entire sector for a set time and space, along the criteria system. We can use a mechanism with it, which assesses a future state based on the criteria system designed for the present condition. The reason for choosing the methodology is that benchmarking can be customised and specified for the analysis goals [13]. During the analysis, we used a simplified benchmarking to describe the milk production systems of the Netherlands, after which we designed a provisional framework system for evaluating domestic systems, in order to set a basis for future benchmarking analyses.

3. Results

The European Union abolished the 30-years old quota system for the milk market regulation in 2015. According to mid-term estimates, this increased the intensity of the competition for the milk market, which further caused a structural reconfiguration in the sector after a while. This process is assumed to cause a notable share of base material procurement to shift towards cost-effective manufacturing areas, which will in turn make the rationalisation of manufacturing base materials indispensable. Restructuring the domestic sector will be mandatory, which can be efficiently supported by an example already in effect in the Netherlands, based on the fundamentals of 'circular economy' - optimised for the domestic criteria system, of course. In our current analysis, we construct a guideline according to the example from the Netherlands, based on the circular economy model - in other words, the methodological solution blending the life cycle assessment and benchmarking methods. Our guideline can help achieving an optimal equilibrium in production systems via the 'Circular Economic Value', abbreviated CEV.

Analysis of models in the Netherlands

The basis of our analysis was the Dutch example modelling the transition towards a circular economy. We tried to apply this to our domestic criteria during the first steps as well. In the Dutch model, three types

of milk production systems were differentiated. These were applied to the criteria system and conditions of the circular economy.

Description of the Dutch practice's OPTIMISED (1) – EXTENSIVE (2) – INTENSIVE (3) graze farming and milk production:

1. *Optimised husbandry:* the technology aims at maximising production, matching biological goals to technological opportunities, thereby achieving circularity. This form of husbandry is the most widespread in Dutch milk production, but it has a significant development requirement in order to reach circularity.
2. *Extensive husbandry:* based on ecological or bio-farming, strictly prefers the soil- , plant- and animal-cycles, and local production. This system is closest to reaching total circularity, but it requires controlling and regulatory interventions. A financial return model has to be designed for it. It's not sustainable without subsidies from the State.
3. *Intensive high-tech husbandry:* in this solution, we can find both the basic principles of circular economy, and modern technological solutions. The system is already circular for the key areas, and also has advantages for productivity and circularity. However, from the perspectives of adaptation and social acceptance, it still poses significant risks. Due to the large volume of output, linear systems have a notable role in operating it.

Operations of linear economic systems in milk production

In the case of the linear systems still in operation in the Dutch economy, production inputs are often used in a way that offers maximum income. Based on the law of diminishing returns, in the case of these production strategies, the increase in return by unit of production decreases, whereas the volume of environmental load related to excess production increases exponentially. The costs of neutralising appearing environmental externalities also increase. In practice, this results in negative effects related to the milk cycle appearing en masse, while we can observe nutrients getting washed out of the soil or leaking out, the emission of greenhouse gases (NO_x, CH_4, CO_2) increasing, and the water bodies being over-polluted and overused. In the case of linear systems, market connections usually aren't based on cooperation, which causes global market exposition, hectic changes in prices, and fundamentally erratic changes in conditions related to manufacturing and consuming safe products (changes in feed prices, diseases, epidemics, climate effects). General income security is also under constant duress. In the case of linear production systems, milk yields may be excessively high, but will also cause the pollution and emission related to production (by-products, waste, GHGs, nitrogen and nutrient washout) to skyrocket (Figure 4).

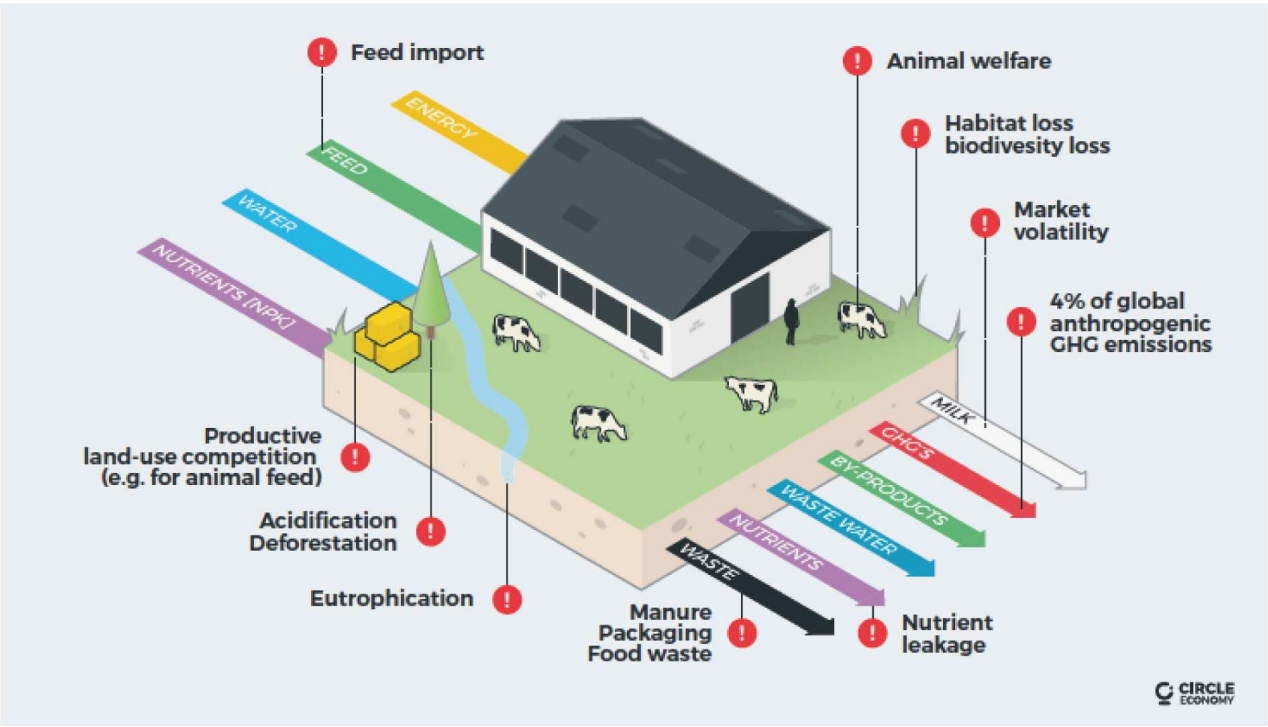

Figure 4. Linear milk production system based on the Dutch example [14]

Transforming linear systems to circular systems in practice in the Netherlands

Circular milk production systems concentrate on realising closing cycles, which mean new challenges mainly during the operation and the usage of natural resources (Figure 5). By decreasing environmentally problematic effects, they wish to achieve positive effects from the perspective of regenerating rural areas and ecosystems [14].

In the Netherlands, greenhouse gas emission rates, realising nutrient cycles and increasing bio-diversity are the areas which can be considered key factors for improving the conditions of sustainability. We can safely state that thanks to the general environmental awareness of the farmers, neither soil- or rural conservation, nor the questions of water and waste management pose a problem.

As for the Dutch production systems, the transition towards a circular economy poses significantly less demands than f. e. the milk production systems of post-socialist countries, including Hungary. Dutch farms' soil nutrient supply, waste management, water usage and sewage treatment, soil quality conservation, and general quality conservation technological solutions are already widespread in practice, on a professional level. In the case of animal feeds and fertilisers, they successfully achieved a state where usage of different materials effects on water and air quality are as insignificant as possible, while soil quality is kept maximised to the greatest possible extent.

The quantity of waste from milk producing dairy farms can be called nearly non-existent, or absolute minimal in current practice (Figure 5).

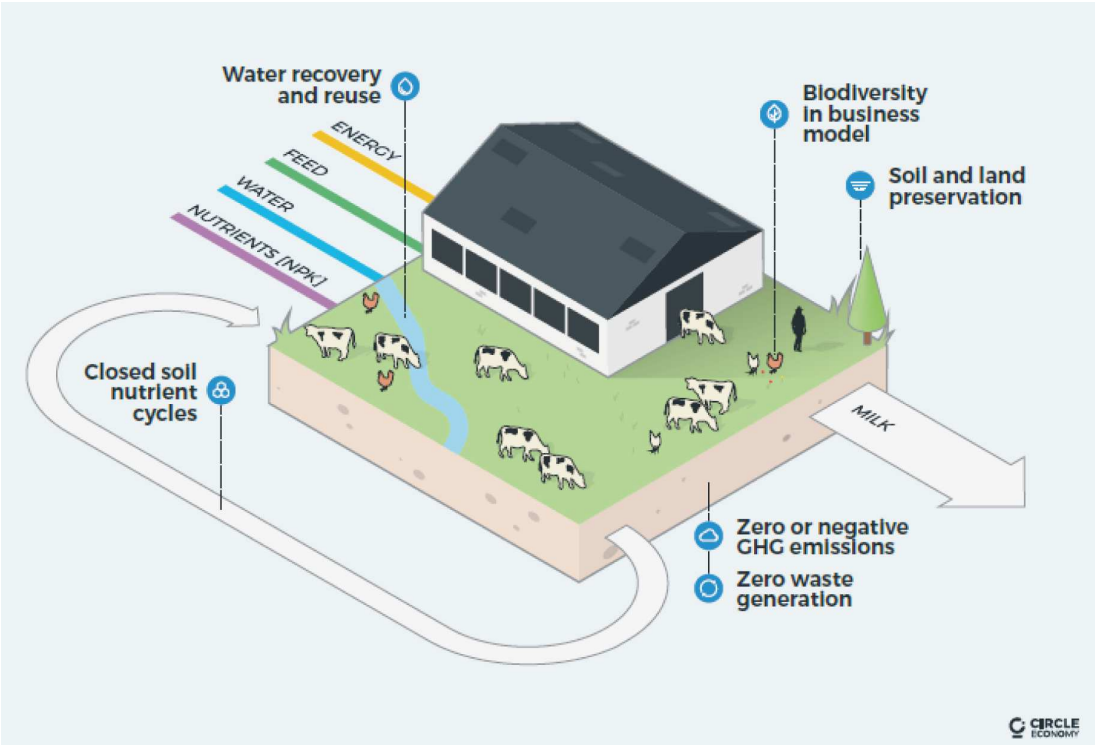

Figure 5. Circular milk production system based on Dutch example [14]

The current Dutch practice was categorised into the three previously mentioned categories (extensive, intensive, optimised) by experts. The practice of Dutch milk production is clearly following technological systems related to grazing husbandry (Figure 6). This can be considered quite unique for the European practice. In the case of the categorised milk production husbandry technological solutions, Dutch experts determined tasks which may assist the transition towards a circular economy within the various categories [14].

In the case of the 'optimised' production method, maximising yields is the goal, but this can only be done if the system's biological and technological circulations are both completely assured, and remains assured even in the future. The most notable tasks to conduct are to mitigate the risks related to procuring inputs or import inputs, and to increase the level of biodiversity for optimised technological systems (Figure 6).

The usage of the 'extensive' technology is the closest to achieving the optimum state of circular

economy's system attributes, as it generates no negative externalities during its operations. However, it's often observed that it generates excess positive externalities, by which the system is also categorised with those that produce unsustainable system attributes en masse. The technology of extensive grazing isn't sustainable in the Netherlands either, meaning it shouldn't be continued with circular economy's system developments as a business model.

In the case of 'intensive' grazing technological system, we can mainly say that it can be operated using very expensive technological solutions, which is why a reasonable return timeframe can only be achieved with a significant income. Making sure that feed circulates, in other words, closing the cycle, is impossible with such a high material flow rate. This intensive process poses a huge challenge of both GHG emission, both water circulation to achieving a circular system.

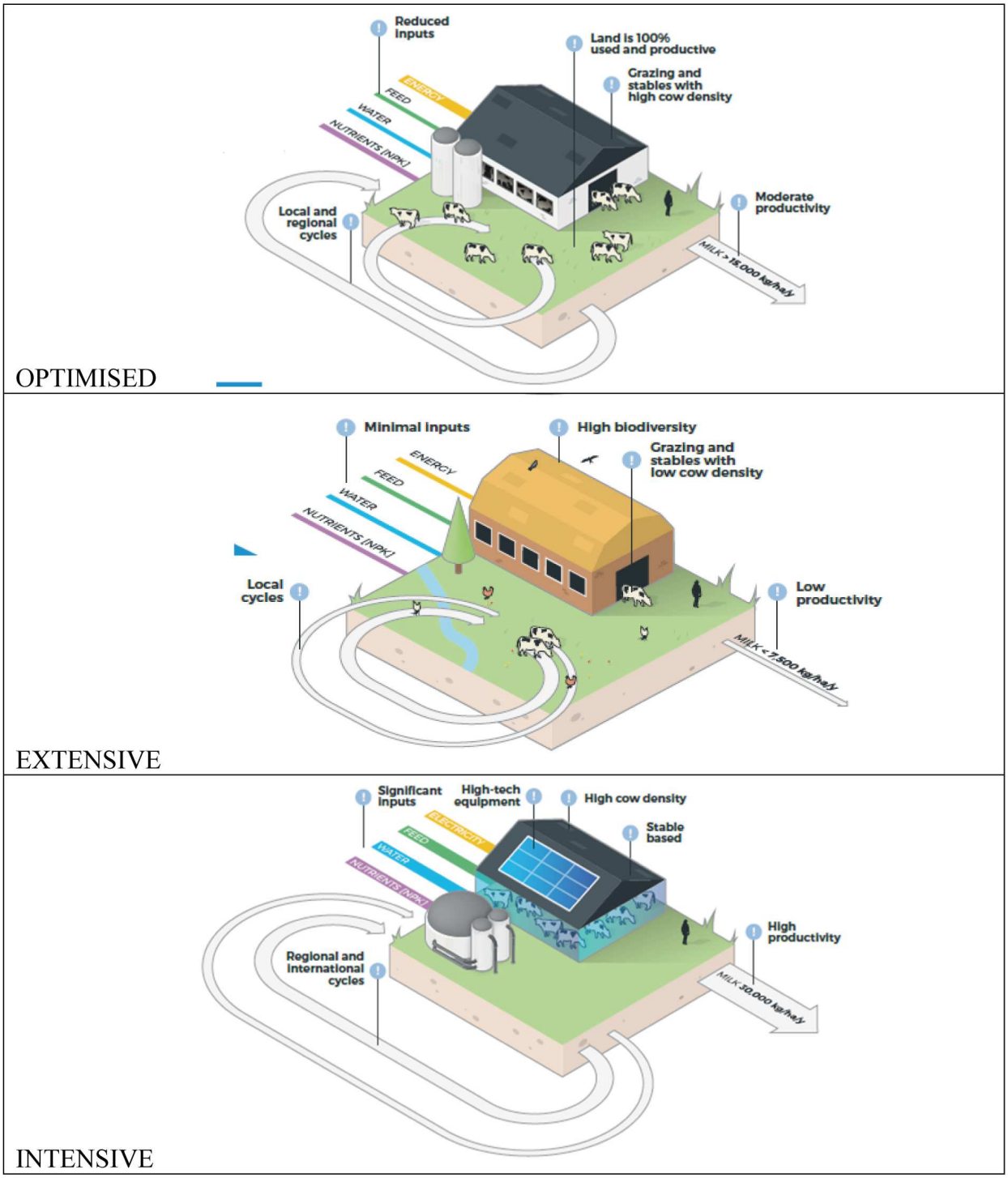

Figure 6. Husbandry methods currently in use in Dutch practice [14]

Circularity of linear milk production systems in Hungarian practice

The main goal of our research was to categorise the domestic milk production technological solutions, based on Dutch examples. We also tried to pave a way for domestic dairy farms towards circular economic developments based on the categories. Based on the statistical data on hand, we weren't able to determine similar economic categories calculated for the Dutch system's indicators. The reason is that these can only be categorised with incomes that come from a wide spectrum, based on available statistical data, and are ill-suited for being the basis of universal structural attributes. Based on prior analyses, we understood that we often couldn't describe production plants related to the various categories, because the comparison conducted by using statistical data at hand didn't result in acceptable significance values. In practice, this meant that f. e. their size, or technological solutions used may have suggested prior the analysis that the dairy farms are similar, yet their income efficiency or yield indicators were completely different. This means that there was no chance of handling them as elements of the same group, or interpreting them as similar existences. The subsidy systems of domestic husbandry, and related development obligations (f. e. manure management) are varied. Feeding traditions are old, and adhering to the EU's regulations is mandatory. These factors determine an entirely different development route for the domestic sector, compared to the Dutch practice. In the following part, we show the Hungarian production models, which are based on the milking house production structure, and are capable of being landmarks for a strategic development taking circularity into consideration, which can be followed by other dairy farms.

Introduction of Hungarian base models

1. Low input – low output (extensive): This economic model is ecological from its holistic perspective, aims to reach long-term sustainability, but differs from the Dutch system because of the special forage production based on arable lands (due to the herd size). In Hungary, the average farm size is 380 milking cows/farm [15]. The soil-plant-animal-manure-soil is the model closest to complete circularity. Its basis is the production of own forage and protein on arable lands (home-grown protein), and the feeding model based on min. 70% forage ratio (based on dry matter) in the top lactation period. The quality of the home-grown forage can be medium (Net Energy for lactation (NEl) 5,5 MJ/kg dry matter). The production volume in this economic model is min. 8,000 kg milk/cow (for 305 days). Sustainability (including economic sustainability) is based on the cow producing close to 32,000 kg milk during its lifetime [16], meaning one of the most notable attributes of the 'low-output' model is the long productive life [17]. This is due to the cow reaching its production peak by the time of the third-fourth lactation period [18]. The feeding based on forage makes it possible to achieve 4 closed lactations on average [19]. Currently, the average lactation (productive life) is 2.2 in Hungary [15], which shows a similar value in the USA (2,63) [20]. Therefore, the returns achievable from the 'low output' system are long-term, since the long lifespan (return can be expected by reaching the potential peak production in the 3rd lactation, and the cost-optimised calf /heifer growing). By minimising purchased products, it's cost-efficient, but produces limited output. It's eligible for subsidisation from an animal welfare and animal health perspective, requires small investment to realise as an economic model, and is sustainable long-term. The risks related to inputs and import inputs are the lowest in this system, operations are only slightly dependent on market changes. Main indicators are: imported input feed and total feeding costs aren't above 25%; average productive life is at least 4 closed lactations; lifetime milk production is min. 32,000 kg milk for each cow.

2. High input – high output (intensive): as for its theoretic basis, this economic model is the most popular one in Hungary. In the current state of the economy (many bank loans due to recent farm reconstructions), the goal is to maximise the output. From the perspective of circularity, it's not an optimal model where increasing biodiversity is concerned. This is due to the limited opportunities to decrease the import input side, but on the whole, it's still a sustainable economic system. The model's exposure is significant, and can be instable due to social acceptance as well. Due to the huge volume of production, linearity plays an active role in maintaining the system. We have to add, though, that its theoretical basis makes this system the most widespread in Hungary, yet, where yield volume (output) is limited, Hungary's reality lags behind the goals we want to reach. This is mainly caused by management reasons. The basis of the high input model is feeding based on max. 50% concentrate in the peak lactation period (min. 50% forage ratio

based on dry matter), with an average forage quality. The production volume in this economic model needs to be at least 11,000 kg milk/cow (for 305 days) in the future. They reach this level of production via maximising the concentrate ratio. By improving forage quality, the concentrate ratio can be decreased of course, but the level of production makes it impossible to reach a forage ratio above 60%. This is the reason why this production system is a special type among the others. We can make it more sustainable, or more circulatory, if at least 50% of the concentrate costs will be produced by the dairy farm - adhering to the home-grown example. In the current practice, purchased grain- and supplements are 70-80% of total concentrate costs on average, and at least 45% of total feed costs. By trying to achieve a goal of 33,000 kg milk as lifetime performance for each cow, the system can become sustainable, if the productive life reaches 3 closed lactations using this feeding system. Reaching this indicator value requires long-term development work, well-executed implementation, and perfect dairy farm management. However, designating it as a goal is a must, since nearly all economic models' minimum requirements are to make the producing cow to reach the potential peak lactation and to cover the costs of both raising and production during its productive life. Main indicators are: imported input feed in total feed costs aren't above 40%; average productive life is at least 3 closed lactations; lifetime performance is min. 33,000 kg milk for each cow. It's important to note that in this farm system, the animal health treatment costs may be high, just as the costs related to early culling and animal deaths.

3. Low input - high output (optimised): In this economic model, the goal is to maximise output incomes, in a way that the system's biological and technological circularity is also sustained as best as possible. The basis of the low-input soil-plant-animal-manure-soil circularity model is the home-made 'excellent' forage based on plant production on arable lands (at least 6 MJ/kg DM net energy content for lactation, and min. 60% fibre digestibility), the high ratio of home-grown protein, and the feeding model based on min. 60% forage ratio (based on dry matter) in the peak lactation period. The production volume in this economic model is min. 9,500 kg milk/cow (for 305 days). This production level can be achieved in case if the (non-maize based) forage average net energy content reaches an average of 6 MJ/kg DM NEl value, the dairy farm produces top quality forages, and the TMR (total mixed ration) NDF-digestibility is close to 60%. If they reach for the goal of 33,250 kg/cow as lifetime performance, it's realistic to require the productive life to reach up to 3.5 closed lactations with this feeding system. Main indicators are: imported input feed in total feeding costs aren't above 30%; average productive life is at least 3.5 closed lactations; lifetime performance is min. 33,250 kg milk for each cow.

The data seen in the economic models are our own calculations, which are based on the national database of the Lifestock Performance Testing Ltd [15].

The main characteristics of the three milk production systems were summarised in Table 1. We have to mention that during the description of the models, we didn't aim to introduce all production or farming types. Instead, we wished to introduce systems which fundamentally determine domestic milk production's (mainly entrepreneurships dealing in milking house production) development possibilities, to offer a way to reach a sustainable dairy farm. One significant difference is that the method of producing eco- or bio-milk in Hungarian and Dutch practices is different. In the Netherlands, bio-products are exclusive to grazing sources, whereas in Hungary, these products are also mainly sold to customers by sources producing based on farming plant-based feeds.

Using the life cycle assessment and the benchmarking methods together to analyse circularity

In order to determine some kind of road towards the circular economy of the Dutch practice for the domestic production, we realised that including the specifics of resource usage, market, and social indicators that are characteristic of the given economic unit into the analysis. These factors are also applicable to the toolsets usable to intensify circulation level.

Due to the novel, holistic approach, the parameters of circularity can be determined for either the given product or the system in its entirety, and excavating the system insufficiencies causing non-sustainability becomes possible. Therefore, to describe milk production processes, we designed a theoretical model, which analyses the entire life cycle, but remains able to handle various phases based on their homogeneity (Figure 7).

Table 1. Analysis of the three technologies as Hungarian models

INDICATOR		LOW INPUT – LOW OUTPUT (EXTENSIVE)	HIGH INPUT – HIGH OUTPUT (INTENSIVE)	LOW INPUT – HIGH OUTPUT (OPTIMISED)
ASPECTS OF CIRCULARITY	Circulation of nutrients (✓-lowest)	✓✓✓	✓	✓✓
	GHG emission/kg milk (for in-stomach processes, ✓- lowest)	✓✓✓	✓	✓✓
	Bio-diversity (✓-lowest) for farmland plant production	✓✓✓	✓	✓✓
	Culling rate, mortality (✓-lowest)	✓	✓✓✓	✓✓
	Transportation of material flows, input-output ratio (efficiency of material usage) (✓-lowest)	✓✓	✓	✓✓✓
SOCIAL ACCEPTANCE	Acceptance (✓-lowest)	✓✓✓	✓	✓✓
PRODUCTION	Milk production (for 305 days)	min. 8000 kg/cow	min. 11.000 kg/ cow	min. 9000 kg/ cow
	Milking average	min. 25 kg/day/ cow	min. 35 kg/ day/ cow	min. 30 kg/ day/ cow
	Productive life (average number of closed lactations)	min. 4	min. 3	min. 3.5
	Lifetime performance (milk kg/cow)	min. 32,000 kg/ cow	min. 33,000 kg/ cow	min. 33,250kg/ cow
	TMR: forage ratio in the period of peak production	min. 70%	min. 50%	min. 60%
	Forage quality	average	average	exceptional (6 MJ/kg DM. NEl) and min. 60% TMR NDFd
	Home grown feed / all feed	min. 80 %	min. 50%	min. 60 %
	Import input feed costs	max. 25%	max. 40%	max. 30%

Source: self-made, based on the database of Lifestock Performance Testing Ltd. [15]

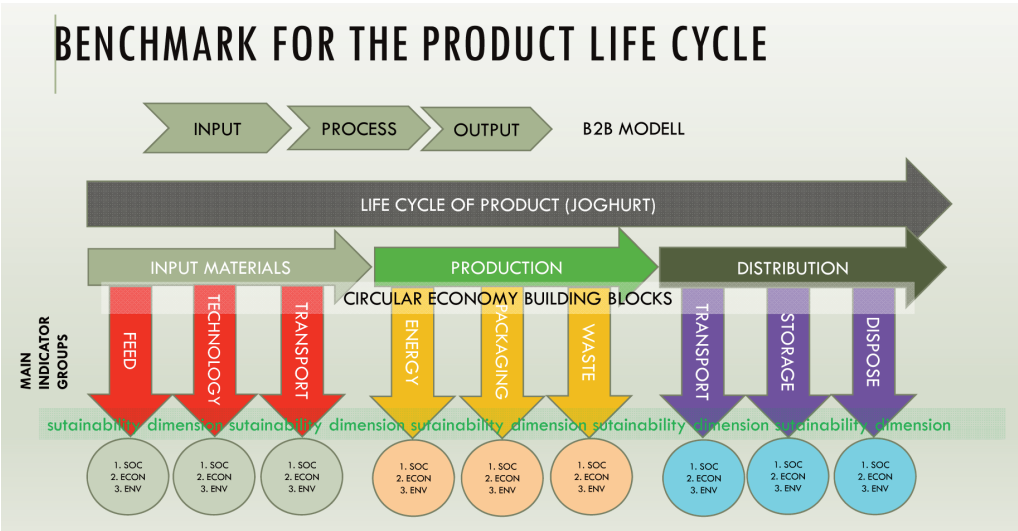

Figure 7. Possible life cycle of foodstuffs related to milk production

Life cycle assessment can be used well for milk production systems, and can also be applied to milk production practice safely. The level of adherence to circular systems can be assessed based on the LCA phases (Base materials - production - distribution), and by using the main- and sub-group indicators of the various phases (Figure 7). Determining the main indicators was done based on experts' decisions, and was arranged around three main production elements. Furthermore, the main indicators can be categorised into three sets of sub-indicators, where we determine technological, economic and environmental

indicators. We can conduct the LCA analyses assisted by benchmarks, during which the starting condition and goal condition of the system are determined. The difference between the two states will become the framework of the road towards making the system achieve a circular economic state. Filling the designed model with data, and evaluating its operations only include the orientation assessment of producing base materials in the current phase of the analysis. However, using this, the systems of Hungary become applicable to a comparison with the Netherlands' systems, albeit only in their basic attributes (Figure 8).

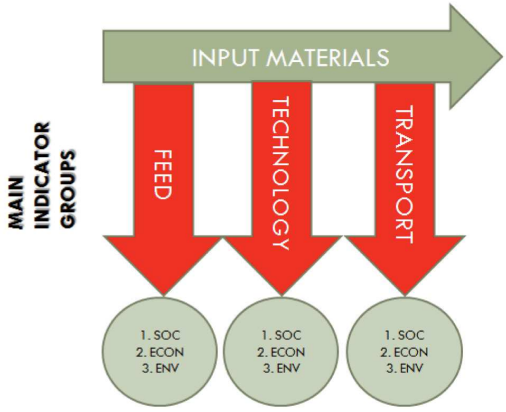

Figure 8. First phase of milk products' life cycle

In the case of base material production, the indicators evaluated can be summarised by analysing the social/economic/environmental aspects of transport needs related to feed production, sustainability of technological solution used, and operation of the system. After cross-referencing the results of the analyses, we defined the Circular Economy Value percentage value, which is defined by the optimal (CEV = 100%) technological solution according to the Dutch circular economy definition (Figure 5). Table 2 summarises the overall data of the analysis, according to technological solutions used. As for the working conditions of domestic extensive (LILO), intensive (HIHO), and optimised (LIHO) systems, we have to note that if we compare them to Dutch categories, the average yield index value of Hungarian systems - 8.000-11.000 kg/cow/lactation - isn't significantly higher than the output value of the Dutch extensive model. Therefore, comparing the Dutch and Hungarian system elements is rather difficult, as the input side's characteristics is entirely different, and we can also come to a multitude of incorrect conclusions when comparing the output dimensions.

Table 2. Systems evaluated, and their related CEV% values

TECHNOLOGY	INDICATORS ANALYSED	CEV VALUE %
LOW INPUT –LOW OUTPUT (LILO) (EXTENSIVE)	Feed production	68.00 %
	Technology usage	76.00 %
	Transport total	74.00 %
	ΣCEV_{LILO}	**72.60 %**
HIGH-INPUT –HIGH OUTPUT (HIHO) (INTENSIVE)	Feed production	58.00 %
	Technology usage	66.00 %
	Transport total	60.00 %
	ΣCEV_{HIHO}	**61.30 %**
LOW-INPUT –HIGH OUTPUT (LIHO) (OPTIMISED)	Feed production	71.00 %
	Technology usage	74.00 %
	Transport total	74.00 %
	ΣCEV_{LIHO}	**73.00 %**
CEV VALUE OF BASE MATERIAL PRODUCTION:		BETWEEN 61.3 % and 73 %

4. Conclusion

Based on the circular models of the Netherlands, we were able to determine that guiding the linear production models into a sustainable circular system can be defined well in production systems, which have clear demand and supply relations, and the frequent intervention processes don't have an impact

on the usage of various resources. Based on the Dutch example, we can also see that the fundamentals of circularity can help coordinate competitiveness and sustainability. This is due to how circular economy can help separate economic growth from the limitless consumption of resources, by which the mentioned resources' renewable attribute can achieve a net positive effect. During the evaluation of the Dutch analyses, it became apparent how neither a high concentration of negative externalities, nor that of positive externalities can be found in circular production systems. Too many positive externalities impair the financial sustainability, as we could see in the extensive Dutch model, whereas too many negative externalities (basically import content) may mean a cheaper product on the market, but isn't acceptable from society's perspective. We couldn't satisfactorily categorise domestic milk production systems - mainly due to differences in technology - using the Dutch indicators. Therefore, we made three generic production categories or models (extensive, intensive and optimised) in the production size dimensions, which have at least 200 cattle, and conduct activities in milking houses. This production context covers approximately 90% of Hungary's milk production, uses manure management also applicable to the EU practice, has a milking house and stables of sufficient technological level, and may aim to reach sustainable or circular system changes during its choice of strategy.

By rendering parameters to the indicators used for the various production models, and determining the Circular Economic Values, we were able to assess the Hungarian milk productions' technological solutions' sustainability level. The detailed analysis chart in Annex 1 clearly shows that the intensive (HIHO) production systems have multiple linear production components, which guide the system applications away from the closed cycle development of various processes. The 63.10% CEV value may mean a significant need for correction in the future for economic actors, who choose this system for their dairy farms. However, in the cases of the extensive (LILO) and optimised (LIHO) system models, we can see that they're significantly more closed, and follow the circular solutions with much more discipline (CEV = 73%). Based on theoretical correlations, we could assume that the extensive (LILO) model has better performance during the calculation of CEV values, yet, we saw that we got a higher CEV value at the end of our analysis for the optimised model operating with low input and high output. This relationship also clearly shows that systems which weigh the process with the least amount of (positive and negative) externalities are preferred for either sustainability, or circular system descriptions. Also, these systems are able to avoid these external effects in the long-term. In this relation, the Dutch and Hungarian milk production analysis results were identical.

In the case of Hungarian models, it's advised to set the general goal of reducing the culling rate (by 10-80%) – in order to achieve a transition towards circular economic practice – which may bring fundamental changes in the sector's environmental emissions (energy, water and waste management together). In the case of extensive (LILO) systems, the goal may be to reduce GHG emission for feeding practice, whereby the economic indicators can also be improved. The sustainability or circularity of intensive (HIHO) systems should be intensified, which may be achieved most notably by reducing the input content of feed, by which it's also possible to increase the positive effects the system that has on biodiversity, and import market risks may be avoided. For intensive systems, drastic reduction in culling rate may cause a significant change in both waste management and efficient animal performance. As for the optimised (LIHO) model, a significant improvement may be achieved by increasing the ratio of home-grown protein in the feeding practice, which brings them closer to circular systems. Also, the goal-specific increase of forage ratio which takes GHG emission aspects and lactation periods into consideration is also advised.

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Annex 1: Summarizing chart relating to the calculation of Circular Economic Value (CEV) (evaluated by using data calculated with the Livestock Performance Testing Ltd. database, and expert estimations)

INDICATOR FEED	$FEED_{LILO}$	$FEED_{HIHO}$	$FEED_{LIHO}$
Nutrient circulation	0.70	0.50	0.65
Social acceptance and assistance	0.75	0.50	0.60
Mass feed quotient	0.70	0.50	0.60
Mass feed quality	0.65	0.65	0.95
GHG emission (from digestion)	0.60	0.75	0.75
CEV VALUE %	**68%**	**58%**	**71%**

INDICATOR TECHNOLOGY	$TECH_{LILO}$	$TECH_{HIHO}$	$TECH_{LIHO}$
Import feed costs and its effect on circularity	0.75	0.60	0.70
Improving biodiversity	0.85	0.50	0.75
Lactation production	0.70	0.85	0,80
Milking average	0.65	0.85	0.75
Average number of lactations	0.80	0.50	0.70
CEV VALUE %	**76%**	**66%**	**74%**

INDICATOR TRANSPORT	TRA_{LILO}	TRA_{HIHO}	TRA_{LIHO}
Home grown protein feed usage	0.80	0.50	0.60
Import input feed (cost), and its effect on decreasing transport costs	0.75	0.60	0.75
Area of milk processing (less advantageous value means higher export ratio and transport)	0.60	0.80	0.70
Avoiding dairy product and waste transportation (waste processing costs)	0.85	0.50	0.85
Transporting material flows, input-output ratio (efficiency of material usage)	0.70	0.60	0.80
CEV VALUE %	**74%**	**60%**	**74%**

SUM CEV %	**72,6%**	**61,3 %**	**73 %**

Affects circularity:
Strongly supports circularity:

CEV%: defines how the analysed system or system element performs on average at the time of the analysis, compared to the system realising perfect circulation, meaning the optimal system (determining the maximum values of the circular framework - 100% - was done based on the Dutch example). See Figure 5!

Abbreviations:

$FEED_{LILO,HIHO,LIHO}$ = Indicator values related to feed production for the various technological solution variants

$TECH_{LIHO,HIHO,LIHO}$= Indicator values related to technological solutions used for the various technological solution variants

$TRA_{LIHO,HIHO,LIHO}$= Indicator values related to transport needs used for the various technological solution variants